2021-2251, 2021-2291

UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

REALTIME DATA LLC, dba IXO,
Plaintiff-Appellant

v.

ARRAY NETWORKS INC., NIMBUS DATA, INC.,
Defendants

FORTINET, INC., REDUXIO SYSTEMS, INC.,
QUEST SOFTWARE, INC., CTERA NETWORKS, LTD.,
ARYAKA NETWORKS, INC., OPEN TEXT, INC.,
MONGODB INC., EGNYTE, INC., PANZURA, INC.,
Defendants-Appellees

Appeal from the United States District Court for the District of Delaware in Case No. 1:17-cv-00800-CFC, Judge Colm F. Connolly

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REALTIME DATA LLC, dba IXO,
Plaintiff-Appellant

v.

SPECTRA LOGIC CORPORATION,
Defendant-Appellee

Appeal from the United States District Court for the District of Delaware in Case No. 1:17-cv-00925-CFC, Judge Colm F. Connolly

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APPELLANT REALTIME DATA LLC'S PRINCIPAL BRIEF

(CORRECTED)

Dated: December 7, 2021

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CERTIFICATE OF INTEREST

Pursuant to Federal Circuit Rule 47.4 and Federal Rule of Appellate Procedure 26.1, counsel for Plaintiff-Appellant Realtime Data LLC certifies the following:

1. The full names of all entities represented by undersigned counsel in this case:

   - Realtime Data LLC

2. The full names of all real parties in interest for the entities:

   - None/not applicable

3. The full names of all parent corporations for the entities and all publicly held companies that own 10 percent or more stock in the entities:

   - None/not applicable.

4. All law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities:

   - Reza Mirzaie, Marc A. Fenster, Brian D. Ledahl, Paul A. Kroeger, Shani Williams, and Philip X. Wang of Russ August & Kabat
   - C. Jay Chung and Stanley S. Thompson, formerly of Russ August & Kabat
   - Stephen B. Brauerman and Ronald Golden of Bayard LLP
   - Sara Bussiere, formerly of Bayard, LLP

5. The case titles and numbers of any case known to be pending in this court or any other court or agency that will directly affect or be directly affected by this court's decision in the pending appeal:

- *Realtime Data, LLC v. Spectra Logic Corporation*, CAFC No. 2021-2291
- *Realtime Data, LLC v. MongoDB, Inc.*, D. Del. Case No. 19-492-CFC
- *Realtime Data, LLC v. Open Text, Inc.*, D. Del Case No. 19-394-CFC
- *Realtime Data, LLC v. Nimbus Data, Inc.*, D. Del. Case No. 19-279-CFC
- *Realtime Data, LLC v. Egnyte, Inc.*, D. Del. Case No. 20-1498-CFC
- *Realtime Data, LLC v. Reduxio Systems, Inc.*, D. Del. Case No. 17-1676-CFC
- *Realtime Data, LLC v. Fortinet, Inc.*, D. Del. Case No. 17-1635-CFC
- *Realtime Data, LLC v. Aryaka, Inc.*, D. Del. Case No. 18-2062-CFC
- *Realtime Data, LLC v. CTERA Networks, Inc.*, D. Del. Case No. 18-1200-CFC
- *Realtime Data, LLC v. Panzura, Inc.*, D. Del. Case No. 18-1200-CFC
- *Realtime Data, LLC v. Quest Software, Inc.*, D. Del. Case No. 18-1964-CFC
- *Realtime Data, LLC v. Acronis, Inc.*, D. Mass. Case No. 1:17-cv-012279-IT
- *Realtime Data, LLC v. Carbonite, Inc.*, D. Mass. Case No. 1:17-cv-12499-IT
- *Realtime Data, LLC v. Fujitsu America, Inc.*, N.D. Cal. Case No. 3:17-cv-02109-SK
- *Realtime Data, LLC v. Veritas Technologies, LLC*, N.D. Cal., Case No. 3:18-cv-06029-SI

6. Information required under Fed. R. App. P. 26.1(b) (organizational victims in criminal cases) and 26.1(c) (bankruptcy case debtors and trustees):

- None/not applicable.

Dated: December 7, 2021

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STATEMENT OF RELATED CASES

An appeal in this same action was previously before this Court in *Realtime Data LLC v. Reduxio Systems, Inc. et al.*, CAFC Nos. 2019-2198, 2019-2201, 2019-2202, 2019-2204. Judges Newman, O'Malley, and Taranto were on the panel. The Court's issued its decision on October 23, 2020 and can be found at 831 F. Appx. 492.

The following cases may be directly affected by the Court's decision in this appeal:

- *Realtime Data, LLC v. Spectra Logic Corp.*, CAFC No. 2021-2291
- *Realtime Data, LLC v. MongoDB, Inc.*, D. Del. Case No. 19-492-CFC
- *Realtime Data, LLC v. Open Text, Inc.*, D. Del Case No. 19-394-CFC
- *Realtime Data, LLC v. Nimbus Data, Inc.*, D. Del. Case No. 19-279-CFC
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- *Realtime Data, LLC v. Quest Software, Inc.*, D. Del. Case No. 18-1964-CFC
- *Realtime Data, LLC v. Acronis, Inc.*, D. Mass. Case No. No. 1:17-cv012279-IT
- *Realtime Data, LLC v. Carbonite, Inc.*, D. Mass. Case No. 1:17-cv-12499-IT
- *Realtime Data, LLC v. Fujitsu America, Inc.*, N.D. Cal. Case No. 3:17-cv-02109-SK

- *Realtime Data, LLC v. Veritas Technologies, LLC*, N.D. Cal. Case No. 3:18-cv-06029-SI

I. INTRODUCTION

In *Realtime Data LLC v. Reduxio Sys., Inc.*, 831 F. App'x 492 (Fed. Cir. 2020), this Court reversed the district court's judgments finding claims of the asserted patents ineligible under § 101. This Court identified several "shortcomings" in the district court's analysis, including its omission of "key aspects of the claims," "caution[ed] the district court away from sweeping generalizations," and "encourage[d] the court to carefully consider the 'directed to' question once more." *Id.* at 496–98. Instead of heeding this Court's warnings, the district court repeated the same errors. The district court once again overgeneralized the claims and stripped out key claim limitations directed to the patents' claimed advances to erroneously conclude that all 211 patent claims, across seven asserted patents and three distinct patent families, are directed to the abstract idea of "information processing." That was error. Indeed, in *Realtime*, this Court expressly found that "the claims expressly achieve [the claimed improvements in digital data compression] in certain ways, involving examining data blocks and not relying just on a descriptor." *Id.* at 497.

Further, in concluding that the patents lack inventive concept under *Alice* step two, the district court improperly focused on whether individual claim elements utilize "conventional hardware," failed to consider the claims as an ordered combination, and improperly resolved questions of fact based on its erroneous, unsupported conclusions. That was also error.

Contrary to the district court's ruling, as is clear from the faces of the patents, the claims are directed to specific improvements in computer functionality and thus are not abstract. More specifically, the patents provide improved, particularized methods of digital data compression that require specific, unconventional combinations of specially configured computer components. The patent claims thus fall squarely within the categories of claims that this Court has repeatedly held to be eligible under § 101.

The district court's failure to apply the correct legal standards and this Court's binding precedents, and its erroneous conclusions that the patents are directed to an abstract idea and lack inventive concept, constitute reversible error. The district court's order of dismissal under Rule 12(b)(6) should be reversed, and each of the asserted patents should be found eligible under § 101.

II. <u>JURISDICTIONAL STATEMENT</u>

Realtime began the proceedings below by filing patent infringement complaints against the Defendants-Appellees. The district court had jurisdiction of the cases pursuant to 28 U.S.C. §§ 1331 and 1338. Realtime timely appeals from the final judgments, wherein the district court found all asserted patents invalid as directed to patent ineligible subject matter under 35 U.S.C. § 101, and from all underlying decisions, orders, and rulings intertwined. This Court has jurisdiction under 28 U.S.C. §§ 1291 and 1295.

III. STATEMENT OF ISSUES FOR REVIEW

This appeal presents the following issues for review by this Court:

1. Did the district court err in concluding that all seven asserted patents in three distinct patent families comprising 211 total claims, each of which discloses discrete methods and systems for digital data compression aimed at solving known problems in conventional data compression systems, are directed to an abstract idea?

2. Did the district court err in concluding, without considering the claim elements as an ordered combination, that all 211 patent claims lack inventive concept, simply because some of the individual claim limitations utilize generic computer components?

3. Did the district court err in disregarding the patents' claimed advances and resolving disputed issues of fact to hold that the patents claim ineligible subject matter, despite the statements in the patent specifications and Realtime's detailed factual allegations in the amended complaints demonstrating that the disclosed methods of digital data compression were not well-understood, routine, or conventional?

IV. STATEMENT OF THE CASE

A. The Asserted Patents Claim Inventions Related to Digital Data Compression and Are Aimed at Solving Problems Unique to Digital Computer Data

This appeal concerns seven patents from three distinct patent families. U.S. Patent Nos. 9,054,728 ("'728 patent"), 8,717,203 ("'203 patent"), and 8,933,825 ("'825 patent") are in one family. U.S. Patent Nos. 9,116,908 ("'908 patent"), 7,415,530 ("'530 patent"), and 10,019,458 ("'458 patent") are in a second, distinct patent family. And U.S. Patent No. 9,667,751 ("'751 patent") is in a third, unrelated, patent family. *See* Appx87–564.

At a high level, these patent families have some commonality in that they teach various improved, particularized digital data compression systems and methods to address problems specific to digital data. Indeed, the patents themselves expressly state that they deal specifically with limitations and problems arising in the realm of compressing "[d]iffuse digital data," which is "a representation of data that . . . is typically *not easily recognizable to humans* in its native form." *See, e.g.*, Appx111 at 1:32–36, Appx175 at 1:33–37, Appx258 at 1:36–40, Appx333 at 1:50–54, Appx488 at 1:47–51; *see also* Appx551–552 at 1:25–36, 3:21–4:6 (discussing various methods of encryption and digital data compression used in the transmission of digital data). But while the patents are all generally directed to specific methods and systems for digital data compression, each patent represents a distinct invention, and each patent family is directed to different systems and methods of digital data compression.

1. The ’728, ’203, and ’825 Patents

The ’728, ’203, and ’825 patents, entitled “Data Compression Systems and Methods,” are directed to systems and methods for data compression using a combination of content-independent and content-dependent data compression and decompression.[1] *See* Appx269 at Abstract, Appx333 at 1:34–37, Appx334 at 3:59–62, Appx335 at 6:24–27. These patents address problems relating to lossless data compression techniques, including the “fundamental problem” of their “content sensitive behavior,” i.e., “data dependency,” which means that “the compression ratio achieved is highly contingent upon the content of the data being compressed.” Appx333 at 2:29–35. They also discuss various other problems with lossless data compression, including that “there are significant variations in the compression ratio obtained when using a single lossless data compression technique for data streams having different data content and data size,” i.e., “natural variation.” *Id.* at 2:41–45. *See also id.* at 2:46–67 (identifying additional problems in lossless data compression).

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[1] The ’728, ’203, and ’825 patents share a specification. To avoid repetition, Realtime cites to the ’728 specification for all three patents.

The ’728, ’203, and ’825 patents explain that while “conventional content dependent techniques,” which typically rely on file type descriptors appended to file names such as “.doc,” “.txt,” etc., may be utilized to combat some of these problems, those content dependent techniques had “[f]undamental limitations” including:

> (1) the extremely large number of application programs, some of which do not possess published or documented file formats, data structures, or data type descriptors;
>
> (2) the ability for any data compression supplier or consortium to acquire, store, and access the vast amounts of data required to identify known file descriptors and associated data types, data structures, and formats; and
>
> (3) the rate at which new application programs are developed and the need to update file format data descriptions accordingly.

Appx333–334 at 2:65–3:19.

The patents solved these and other problems with compression technology by providing a novel technological solution utilizing a combination of content-dependent and content-independent encoders to compress data blocks based on an analysis of the specific content or type of data being encoded, without relying solely on a descriptor such as a file extension. For example, when one or more digital-data parameters are identified in the content of a digital data block, the invention utilizes a content-dependent compression encoder. And if no such digital-data parameter is identified, the invention utilizes a content-independent encoder. The analysis of the digital data is not based solely a descriptor, thereby eliminating the problems associated with conventional content-dependent compression techniques. *See, e.g.*, Appx340–342 at 15:60–20:47. Figure 13A, below, is illustrative of one preferred embodiment depicting a system utilizing a combination of content-dependent and content-independent encoders.

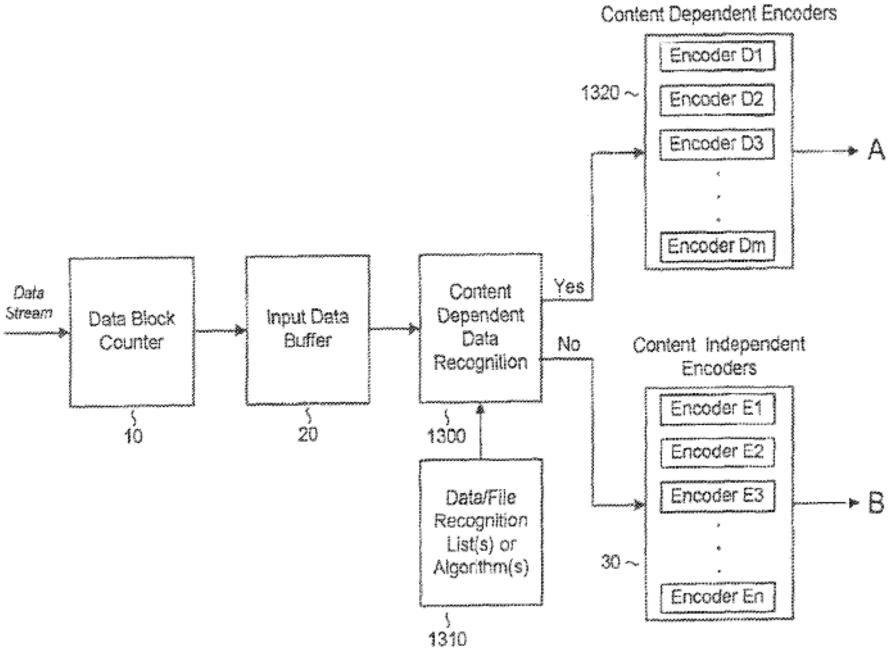

FIGURE 13A

Appx315.

2. The ’908, ’530 and ’458 Patents

The ’908, ’530, and ’458 patents, entitled “System and Methods for Accelerated Data Storage and Retrieval,” are directed to systems and methods for accelerated data storage and retrieval utilizing lossless data compression and decompression.[2] *See* Appx125 at Abstract, Appx175 at 1:15–18, 2:58–60, Appx176 at 4:42–44. These patents addressed problems in the current art relating to digital data compression, including that "high performance disk interface standards . . . offer only the promise of higher data transfer rates through intermediate data buffering in random access memory" and do not address the "fundamental problem" with physical media limitations. Appx175 at 2:34–42. The patents further explain that "[f]aster disk access data rates are only achieved by the high cost solution of simultaneously accessing multiple disk drives with a technique known within the art as data striping." *Id.* at 2:42–45. "Additional problems with bandwidth limitations similarly occur within the art by all other forms of sequential, pseudorandom, and random access mass storage devices." *Id.* at 2:46–51.

The '928, '530, and '458 patents solved these and other problems with digital data compression by providing novel technological solutions utilizing a plurality of different encoders, and optionally a compression descriptor, for accelerated storage and retrieval of data blocks. The novel approaches taught by the patents include, among other things:

- using a digital compression type descriptor "for output so as to indicate the type of compression format of the encoded data block";

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[2] The '908, '530, and '458 patents share a specification. To avoid repetition, Realtime cites to the '908 specification for all three patents.

- "the data storage and retrieval accelerator method and system [being] employed in a disk storage adapter to reduce the time required to store and retrieve data from computer to a disk memory device"; and
- "the data storage and retrieval accelerator method and system [being] employed in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory."

Appx176 at 3:25–33, Appx180–181 at 12:40–13:18.

Figure 8 illustrates one preferred embodiment of a compression system utilizing, *inter alia*, a plurality of encoders:

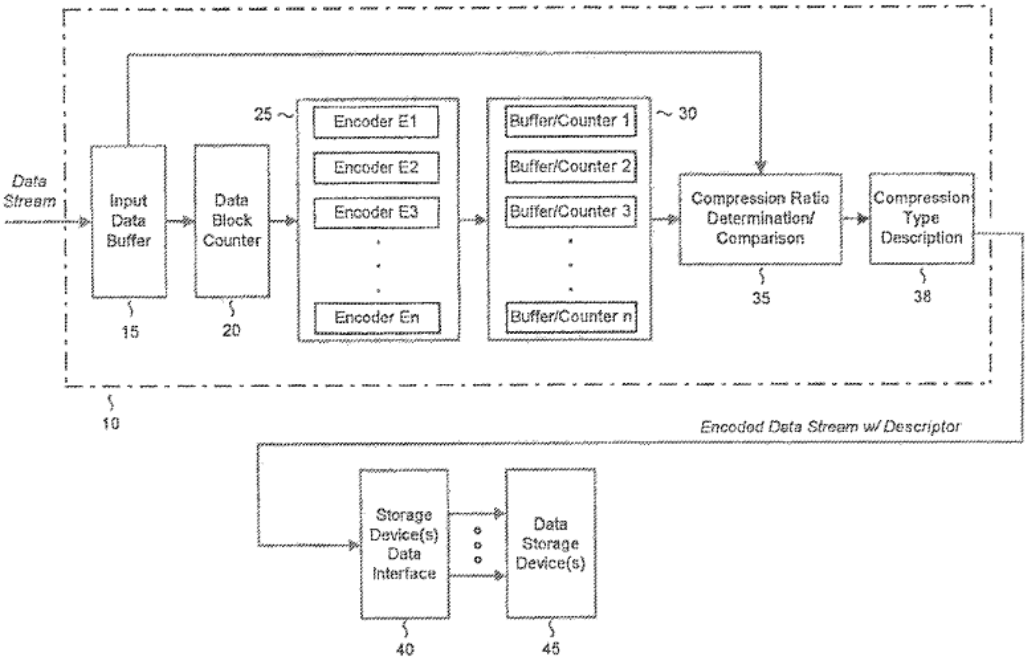

FIGURE 8

Appx166.

In a preferred embodiment, "the encoding techniques are selected based upon their ability to effectively encode different types of input data." Appx180 at 12:5–7. The encoder module comprising the multiple encoders "allows the user to tailor the operation of the data compression system for specific applications." *Id.* at 12:11–21. Further, the encoders may operate either in parallel "(i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof)" to "enhance encoding speed," or they "may operate sequentially on a given unbuffered or buffered input data block." *Id.* at 12:21–30, 35–39. This process "eliminate[s] the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination." *Id.* at 12:30–35. A "compression type descriptor" is appended to the encoded data block output "so as to indicate the type of compression format of the encoded data block." *Id.* at 12:40–67.

3. The '751 Patent

The '751 patent, entitled "Data Feed Acceleration," is directed to systems and methods for providing accelerated transmission of digital data over a communication channel using data compression and decompression to effectively increase the bandwidth of the communication channel and/or reduce the latency of data transmission. Appx502 at Abstract, Appx551 at 1:25–36, Appx553 at 5:33–43, 6:13–19. The '751 patent addressed specific problems with conventional data transmission systems, explaining that "current methods of encryption and compression take as much or substantially more time than the actual time to transmit the uncompressed, unencrypted data." Appx552 at 3:31–33. Thus, a "problem within the current art is the latency induced by the act of encryption, compression, decryption, and decompression." *Id.* at 3:34–36. The patent discusses additional problems and limitations in conventional data compression systems, including "high latency and poor compression due to the use of generic data compression algorithms," "substantial latency caused by aggregating data packets due to poor data compression efficiency and packet overhead," "the need for data redundancy," which "add[s] cost and complexity, while also increasing latency and inherent data error rates," capacity limitations of data transmission using existing T1 lines and associated costs, and "[t]he limitation of highly significant bandwidth and/or long delays with co-location processing and long latency times." Appx551–553 at 1:40–5:22.

The '751 patent solved these and other problems and limitations in the prior art by providing novel technological solutions in digital data transmission, allowing for, among other things, "secure transmission and transparent multiplication of communication bandwidth," and a reduction in the "latency associated with data transmission of conventional systems." Appx553 at 5:28–29, 6:13–19. "The effective increase in bandwidth and reduction of latency of the communication channel is achieved by virtue of the faster than real-time, real-time, near real-time, compression of a received data stream prior to transmission." *Id.* at 6:36–40. The claimed invention achieves this by, for example, recognizing a characteristic, attribute, or parameter of the data to select a compression encoder, and using a state machine to provide compressed data. *See, e.g.*, Appx563 at claim 25.

Advantages of the claimed invention include "a consistent reduction in latency" where "[t]he data compression ratio is substantial and repeatable on each data packet," and "no packet-to-packet data dependency," i.e., "packet independence." Appx554 at 7:52–8:3.

Figure 5 of the '751 patent is illustrative of one preferred embodiment depicting a content-independent data compression system:

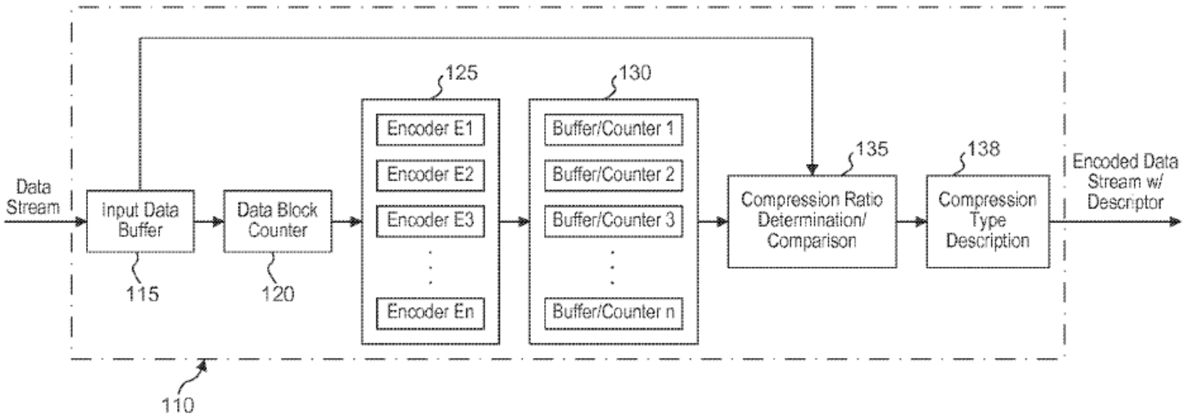

FIG. 5

Appx549; *see also* Appx558 at 15:1–16:67.

B. Prior § 101 Rulings Upholding the Patentability of Realtime's Patents

1. The *Carbonite* Ruling

On February 27, 2017, Realtime filed a complaint in the Eastern District of Texas, Case No. 6:17-cv-00121-RWS-JDL ("*Carbonite*"), alleging infringement of the '728, '530, and '908 patents, in addition to U.S. Patent No. 8,717,204 ("'204 patent"), which is in the same family as the '751 patent. The Carbonite defendants filed a Rule 12(b)(6) motion to dismiss arguing that all of the asserted patents are invalid under § 101.

On September 20, 2017, Magistrate Judge John Love issued a detailed, 22-page report and recommendation finding that the asserted patents are *not* abstract and thus are patent-eligible under § 101. Appx7481–7502. More specifically, Judge Love found that "[t]he '728 Patent is directed to patent eligible subject matter because it discloses a specific improvement in computer capabilities: a system for an improved data compression technique." Appx7487. Judge Love's report and recommendation further explains that the '728 patent improves known issues in lossless data compression techniques by "applying a plurality of compression techniques on an input data stream so as to achieve maximum compression in accordance with the real-time or pseudo real-time data rate constraints." Appx7488. Judge Love expressly rejected the defendants' reliance on *RecogniCorp, LLC v. Nintendo Co., Ltd.*, 855 F.3d 1322 (Fed. Cir. 2017), finding that "claim 1 of the '728

Patent is not simply encoding and decoding. Rather, it improves typical data compression by compressing the data stream through content dependent and independent data recognition, as well as a plethora of encoders to achieve its maximum compression. '728 Patent at 5:03–07. This results in real-time or pseudo-real-time compression." Appx7490.

Judge Love further found that "[e]ven if claim 1 of the '728 Patent is directed to an abstract idea, the claim, read as a whole, covers an 'inventive concept'" because "it utilizes a system and its structural elements in a way that is a solution to a computing problem." Appx7490–7491.

Regarding the '908 and '530 patents, Judge Love found that the claims are not abstract because "they utilize a system that improves computerized data compression through data storage and retrieval and bandwidth 'utilizing lossless data compression and decompression.'" Appx7493–7494. Judge Love further found that, "[s]imilar to the '728 Patent, these claims as a whole show a non-abstract idea despite disclosing generic, conventional computing elements." Appx7495. "The claims pair a data accelerator with a memory device, and then places a data stream with a proper technique that compresses the data stream and puts the stream into storage more efficiently." *Id.* As noted by Judge Love, "this goes beyond the abstract patents in [*RecogniCorp*]," as Realtime's patents "improve a technological process by pairing data blocks with specific techniques" to achieve "an effective increase of [] data storage and retrieval bandwidth of a memory storage device." *Id.*

As with the '728 patent, Judge Love found that "[e]ven if the ['530 and '908 patent] claims were abstract, they produce an inventive concept," explaining: "Despite some of the well-known elements and techniques, the '530 and '908 Patents create an unconventional solution that results in faster disk access and bandwidth limitations by using a memory device and a data accelerator to compresses the data stream using different compression techniques utilizing lossless data compression and decompression. . . . The claims create a specific combination of compressing a data stream that results in an inventive concept for data compression." Appx7496–7497.

Regarding the '204 patent, Judge Love found that the invention is "aimed at providing accelerated transmission of data in a communication channel using data compression and decompression to provide data feeds, transfers, and communications and effectively increase the bandwidth of the communication channel and/or reduce the latency of data transmission." Appx7498. Judge Love further found that the '204 patent "offers more than a generic use of data transmission; it provides specific steps of analyzing information and compressing data using specific encoders related to recognized parameters within the data," and therefore is "not abstract." Appx7500. And, similar to the other asserted patents, the

’204 patent provides inventive concept because it “uses a specific method with various steps to provide faster transmission of data.” Appx7501. In rejecting the defendants’ arguments that the claims rely on generic computer components, Judge Love found that “[a]lthough the claim may use some known technology, the system as a whole creates an unconventional solution because it utilizes ‘data compression and decompression to provide data transfer. . . [and] reduce the latency of data transmission.” *Id.*

After Judge Love issued his report and recommendation, the case was transferred to the District of Massachusetts. On March 7, 2018, the Massachusetts district court “[a]fter careful consideration” entered an order adopting Judge Love’s report and recommendation in full, and denied the motion to dismiss. Appx7522.

2. The *Actian* Ruling

The eligibility of Realtime’s patents under § 101 came under scrutiny once again in another case in the Eastern District of Texas, No. 6:15-cv-00463-RWS-JDL (“*Actian*”), and were again confirmed to be patent eligible and not abstract. On May 1, 2018, Magistrate Judge Love issued a report and recommendation recommending denial of the defendants’ Rule 12(b)(6) motion to dismiss regarding the ’908 and ’530 patents, as well as U.S. Patent Nos. 7,378,992 (“’992 patent”), 8,643,513 (“’513 patent”), and 6,597,812 (“’812 patent”). Appx7504–7515. The ’992 and ’513 patents are in the same family as, and share a specification with, the ’728 and ’203 patents.

In the report and recommendation, Judge Love found that "an assessment of the claims at issue—by a careful reading of the claims themselves—does not clearly reveal that the patents are abstract," thereby precluding dismissal at the pleading stage. Appx7514.

District Judge Robert Schroeder adopted Judge Love's report and recommendation in full, acknowledging that the patents themselves state that they are directed to problems unique to the realm of digital data, a form of data not easily "recognizable to humans." Appx7517–7520. Judge Schroeder further found that under Realtime's proposed constructions, the patents "provide technological solutions to problems arising specifically in the realm of computer technology," and therefore "Defendants' argument that the patents are directed to an abstract idea would fail." Appx7518. In particular, Judge Schroeder found that if the claim construction proceedings confirmed that the claimed inventions are directed to methods and systems for the compression of digital data—which they unquestionably are—then the claims would indeed be patent-eligible. *Id.*

C. This Court's Reversal of the Delaware District Court's Erroneous § 101 Ruling in CAFC Nos. 2019-2198, -2201, -2202, and -2204

Starting in 2017, Realtime filed patent infringement complaints in the District of Delaware against various accused infringers, including Defendants-Appellees in this appeal. In 2018 and 2019, Defendants-Appellees Fortinet, Inc., Panzura, Inc., Reduxio Systems, Inc., and Aryaka Networks, Inc. filed motions to dismiss for failure to state a claim under Rule 12(b)(6), arguing that the asserted ’728, ’203, ’908, and ’751 patents were invalid under § 101.

On July 19, 2019, the district court held a joint hearing on the motions. After the conclusion of oral argument, which was almost exclusively focused on only claim 25 of the ’728 patent, the district court ruled from the bench that all five patents are invalid under § 101, and granted Defendants’ motions to dismiss. Appx4939. The district court also denied Realtime’s request for leave to amend the complaints. Appx4942–4945. The district court did not issue any written decision.

Realtime appealed, and this Court vacated the judgments of the district court and remanded for further proceedings consistent with its opinion. *Realtime Data LLC v. Reduxio Sys., Inc.*, 831 F. App’x 492 (Fed. Cir. 2020). This Court held that the district court’s “short analysis” was “insufficient to facilitate meaningful appellate review,” and was “particularly concerned with four shortcomings” in that analysis:

> (1) the colloquy between the court and Realtime indicates an apparently improper focus on factual questions that are unsuitable for resolution at the pleading stage and a failure to evaluate the claims as a whole;
>
> (2) to the extent the district court purported to resolve the “directed to” question of *Alice* step 1, its process is unclear and its conclusion questionable;
>
> (3) the court did not address or even acknowledge Judge Love’s lengthy written opinions, which were adopted by two district courts, addressing the

> precise question faced by the court; and
>
> (4) although, as the district court requested, Realtime identified *Visual Memory LLC v. NVIDIA Corp.*, 867 F.3d 1253 (Fed. Cir. 2017), as the case most analogous to this one and directed the court to our decision in *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327 (Fed. Cir. 2016), and *DDR Holdings, LLC v. Hotels.com, L.P.*, 773 F.3d 1245 (Fed. Cir. 2014), the district court failed to address or distinguish those cases.

Id. at 496.

This Court "further question[ed] the district court's statements that the claims are, to use the '728 patent as an example, merely 'choosing a compression method based on the data type.'" *Id.* at 497. As explained by this Court, "[t]his statement seems to miss that ***the claims expressly achieve this result in certain ways, involving examining data blocks and not relying just on a descriptor***." *Id.*[3] The Court further noted that it "appears . . . that the district court improperly equated the presence of an abstract idea with a conclusion that the claims are directed to such an idea." *Id.* On remand, this Court "caution[ed] the district court away from sweeping generalizations and encourage[d] the court to carefully consider the 'directed to' question once more." *Id.*

Judge Taranto also issued a concurring opinion wherein he explained that district court committed a "foundational" error by characterizing the claims "without mention of what . . . the claim language and specifications make clear are important

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[3] All quotations cleaned up and emphases added unless otherwise noted.

parts of what the patents assert are the advances in the art." *Id.* at 499. Judge Taranto reiterated that "§ 101 inquiries demand close attention to the specific content of the patent claims at issue, and that courts must avoid 'overgeneralizing' and 'oversimplifying' the claims." *Id.* at 499. He further observed that Realtime's claims, "on their face and understood in light of the specifications, purport to ***solve engineering problems in the transfer of data***." *Id.* at 500. He concluded his opinion by directing the district court to consider "relevant precedents" of this Court that the district court failed to address, "including a number of post-July 2019 precedents that provide clarifying guidance concerning the inquiries pertinent to the analysis in cases like the ones before us," such as *TecSec*, *Uniloc*, *Packet Intelligence, Koninklijke*, *SRI*, and *Customedia*. *Id.* at 501. These cases are addressed below.

D. The District Court's Subsequent Rulings on Remand Again Finding the Claims of Realtime's Patents Invalid Under § 101

Following remand, on May 4, 2021, the district court issued a memorandum opinion finding all claims of the seven patents asserted in the consolidated cases invalid under § 101. Appx1–56. The court granted Realtime leave to amend, and Realtime filed amended complaints on May 18, 2021. Appx881–934, Appx1001–1058, Appx1285–1338, Appx1565–1614, Appx1819–1875, Appx2006–2065, Appx2196–2260, Appx2391–2456, Appx2587–2633, Appx2838–2904, Appx3035–3087, Appx3218–3280, Appx4009–4047. Those complaints contain detailed factual allegations regarding each asserted patent, and proposed constructions for certain claim terms, that, accepted as true, establish that the patents are directed to improvements in existing technology and do not merely claim abstract ideas. *See, e.g.*, Appx3037–3039 ¶¶ 10–15, Appx3040–3045 ¶¶ 18–32, Appx3050–3056 ¶¶ 49–61, Appx3061–3066 ¶¶ 79–91, Appx3073–3082 ¶¶ 109–125.

On June 29, 2021, Defendants moved to dismiss the amended complaints, again arguing that the asserted patents are invalid under § 101. Appx3411. On August 23, 2021, the district court issued another memorandum opinion and granted the motion. Appx57–84. The district court incorporated its prior May 4, 2021 decision into its opinion, and found that "none of Realtime's amendments materially change [its] prior analysis." Appx79, Appx84. Accordingly, the district court found that "all claims of the asserted patents are invalid under § 101 for lack of subject-matter eligibility," and granted Defendants' renewed motions to dismiss. Appx84.

Realtime timely appealed. Appx3536–3541.

V. SUMMARY OF ARGUMENT

The district court erred in finding that all 211 claims of the seven asserted patents, across three distinct families, are invalid under § 101. The asserted claims are directed to methods and systems for digital data compression and are aimed at solving known problems in conventional data compression systems. For example, the faces of the '728, '203, and '825 patents make clear that they are directed to systems and methods for data compression using a combination of content-independent and content-dependent encoders, and are aimed at solving problems in the prior art relating to, *inter alia*, data dependency. The faces of the ’908, ’530, and ’458 patents make clear that they are directed to systems and methods for accelerated data storage and retrieval utilizing lossless data compression and decompression, and are aimed at solving problems in the prior art relating to, *inter alia*, bandwidth limitations. And the face of the ’751 patent makes clear that it is directed to systems and methods for providing accelerated transmission of digital data over a communication channel using data compression and decompression to effectively increase the bandwidth of the communication channel and/or reduce the latency of data transmission. The ’751 patent is aimed at solving problems in the prior art relating to, *inter alia*, latency, data redundancy, increased error rates, and bandwidth limitations.

The claims are directed to specific improvements in computer functionality and thus are not abstract. And even assuming, *arguendo*, that they are abstract, they are nonetheless patent eligible because they require specific, unconventional combinations of specially configured computer elements, including, for example, a plurality of content-dependent and content-independent encoders, a data accelerator, and a state machine configured to perform specific functions.

The district court's conclusion that the patents are abstract and do not provide inventive concepts is contrary to fact and law. Indeed, instead of "“carefully consider[ing] the 'directed to' question once more," as this Court directed in *Realtime*, 831 F. App'x at 497, the district court doubled down and repeated the same errors. For example, under *Alice* step one, the district court oversimplified the claims and disregarded key aspects of the claims that the specification makes clear are important parts of the claimed advances in digital data compression to reach the erroneous conclusion that the claims are directed to "information processing." This Court rejected the district court's oversimplification of the claims in *Realtime*, and should likewise reject it here.

Further, under *Alice* step two, the district court erroneously concluded that the claims lack inventive concept merely because some of the claim limitations utilize known compression algorithms and generic hardware. In doing so, the district court failed to consider the claims in light of their respective specifications and claimed advances, and failed to consider the elements of each claim as an ordered combination. The district court also appeared to treat the '825 *patent* as representative of all seven patents, and only considered the "additional limitations" of the other six patents (four of which are in different patent families) in isolation. That was another of several errors committed by the district court.

The district court's determination that the asserted patents are invalid under § 101 and its order granting Defendants' motion to dismiss should be reversed.

VI. ARGUMENT

A. Standard of Review

A district court's dismissal for failure to state a claim is reviewed under the law of the regional circuit, here, the Third Circuit. *See Content Extraction & Transmission LLC v. Wells Fargo Bank, Nat. Ass'n*, 776 F.3d 1343, 1346 (Fed. Cir. 2014) (applying Third Circuit law). The Third Circuit reviews dismissals for failure to state a claim under Rule 12(b)(6) *de novo*. *Id.* (citing *Sands v. McCormick*, 502 F.3d 263, 267 (3d Cir. 2007)).

On a Rule 12(b)(6) motion to dismiss, the allegations in the complaint must be accepted as true and construed in the light most favorable to Realtime. *Alston v. Countrywide Fin. Corp.*, 585 F.3d 753, 758 (3d Cir. 2009). Further, in determining whether the complaint states a claim for relief, "[t]he issue is not whether a plaintiff will ultimately prevail but whether he or she is entitled to offer evidence to support the claims." *Ballentine v. United States*, 486 F.3d 806, 810 (3d Cir. 2007).

While patent eligibility can be determined at the Rule 12(b)(6) stage, "[t]his is true only when there are no factual allegations that, taken as true, prevent resolving the eligibility question as a matter of law." *Aatrix Software, Inc. v. Green Shades Software, Inc.*, 882 F.3d 1121, 1125 (Fed. Cir. 2018). "[P]lausible factual allegations may preclude dismissing a case under § 101 where, for example, 'nothing on th[e] record . . . refutes those allegations as a matter of law or justifies dismissal under Rule 12(b)(6).'" *Id.*

B. The Standard for Determining Patent Eligibility Under § 101

Section 101 defines patent-eligible subject matter as "any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof." 35 U.S.C. § 101. To determine patent eligibility under § 101, courts conduct a two-step analysis as articulated by the Supreme Court in *Alice Corp. Pty. v. CLS Bank Int'l*, 573 U.S. 208, 216 (2014). First, the court must determine "(1) whether the claim, as a whole, is 'directed to' patent-ineligible matter—here, an abstract idea—and (2) if so, whether the elements of the claim, considered individually or as an ordered combination 'transform the nature of the claim' into a patent-eligible application." *Ancora Techs., Inc. v. HTC Am., Inc.*, 908 F.3d 1343, 1347 (Fed. Cir. 2018).

This Court has emphasized the importance of the first step of the § 101 analysis, explaining that *Alice* "plainly contemplates that the first step of the inquiry is a meaningful one." *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1334 (Fed. Cir. 2016). "The 'directed to' inquiry, therefore, cannot simply ask whether the claims involve a patent-ineligible concept, because essentially every routinely patent-eligible claim involving physical products and actions involves a law of nature and/or natural phenomenon." *Id.* at 1335. Rather, the "directed to" inquiry requires consideration of the claims "in light of the specification" to determine whether "their character as a whole is directed to excluded subject matter." *Id.*

In determining whether patent claims are directed to an abstract idea, courts must examine the patent's "claimed advance." *Ancora*, 908 F.3d at 1347. "In cases involving software innovations, this inquiry often turns on whether the claims focus on 'the specific asserted improvement in computer capabilities . . . or, instead, on a process that qualifies as an 'abstract idea' for which computers are invoked merely as a tool.'" *Id.* (citing *Enfish*, 822 F.3d at 1335–36). This Court has repeatedly held claims focused on improvements in computer technology to "pass muster under *Alice* step one," explaining that both hardware and software can make such non-abstract improvements. *Id.* For example, in *Enfish*, this Court reversed an ineligibility ruling on a database patent, which the district court described as being directed to "storing, organizing, and retrieving memory in a logical table." *Enfish*, 822 F.3d at 1337. This Court held that "describing the claims at such a high level of abstraction and untethered from the language of the claims all but ensures that the exceptions to § 101 swallow the rule." *Id.* It further criticized the district court's analysis for "downplay[ing] the invention's benefits" disclosed in the specification. *Id.* at 1337–38. Because the claims were "designed to improve the way a computer stores and retrieves data in memory," they were "directed to a specific implementation of a solution to a problem in the software arts" and thus were "not directed to an abstract idea." *Id.* at 1339.

In *Visual Memory LLC v. NVIDIA Corp.*, this Court drew a similar conclusion about claims focused on a specific improvement in computer memory. 867 F.3d 1253, 1262 (Fed. Cir. 2017). The district court had determined that the claims were directed to the abstract concept of categorical data storage. *Id.* at 1257. This Court, however, determined that this was error because the patent was specifically "directed to an improved computer memory system, not to the abstract idea of categorical data storage." *Id.* at 1259. More specifically, as summarized in *Ancora*, the claims in *Visual Memory* were directed to "an 'improved memory system' that configured operational characteristics of a computer's cache memory based on the type of processor connected to the memory system," allowing "the claimed invention to accommodate different types of processors without compromising performance." *Ancora*, 908 F.3d at 1348. This was an improvement in computer functionality and therefore not abstract. *Visual Memory*, 867 F.3d at 1260; *see also Finjan, Inc. v. Blue Coat Sys., Inc.*, 879 F.3d 1299, 1303–06 (Fed. Cir. 2018) (claims to a "behavior-based virus scan" were directed to an improvement in computer security and thus not directed to an abstract idea); *Core Wireless Licensing v. LG Elecs., Inc.*, 880 F.3d 1356, 1362–63 (Fed. Cir. 2018) (claims to a method for making websites easier to navigate on a small-screen device not directed to an abstract idea); *Data Engine*

Techs. LLC v. Google LLC, 906 F.3d 999, 1007–11 (Fed. Cir. 2018) (claims to "a specific method for navigating through three-dimensional electronic spreadsheets" not directed to an abstract idea).

If the claims are not directed to an abstract idea, the inquiry ends and the claims are patent eligible under § 101. *Ancora*, 908 F.3d at 1349. Otherwise, the second step of the *Alice* analysis calls for the court to "consider the elements of each claim both individually and 'as an ordered combination' to determine whether [the claims contain] an element or combination of elements that is 'sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the [abstract idea] itself.'" *Alice*, 134 S. Ct. at 2355.

Inventions that "improve[] an existing technological process" or "solve[] a technological problem in 'conventional industry practice'" are patent eligible. *Id*. at 2358. Furthermore, a defendant *cannot* prevail on this step simply by showing that each individual claim element was "known in the art" or conventional. *BASCOM Glob. Internet Servs., Inc. v. AT&T Mobility LLC*, 827 F.3d 1341, 1349 (Fed. Cir. 2016) (holding that claims to a method and system of filtering Internet content using an Internet Service Provider (ISP) server were a patent eligible "improvement over the prior art ways of filtering such content"). Even where individual elements are conventional technologies, the specific arrangement of conventional technologies can also form the inventive concept. *Id.* at 1350. Indeed, "[t]he genius of invention is often a combination of known elements which in hindsight seems preordained." *McGinley v. Franklin Sports, Inc.*, 262 F.3d 1339, 1351 (Fed. Cir. 2001).

C. The District Court Erred in Holding that All Seven Asserted Patents Across Three Distinct Patent Families Are Directed to an Abstract Idea Under *Alice* Step One

1. This Court's precedents confirm that the asserted claims are not abstract

This Court has repeatedly upheld the patentability of claims that claim specific improvements in computer functionality. *See, e.g.*, *Finjan*, *Enfish*, *DDR*, *Visual Memory*, and *Core Wireless*, *supra*. This Court's analysis and holding in *Visual Memory* is particularly salient here. In that case, this Court rejected the district court's conclusion that the claims were directed to abstract concept of categorical data storage, and found that they were instead "directed to an improved computer memory system," which is not abstract. *Visual Memory*, 867 F.3d at 1259. Indeed, the directly analogous claims in *Visual Memory*, which recited "memory" and a "processor" with "operational characteristics" that "determines a type of data," were directed to "an 'improved memory system' that configured operational characteristics of a computer's cache memory *based on the type of processor* connected to the memory system," allowing "the claimed invention to accommodate different types of processors without compromising performance." *Ancora*, 908 F.3d at 1348 (summarizing *Visual Memory*). The Court concluded that this type of improvement in computer functionality is not abstract. *Visual Memory*, 867 F.3d at 1260.

Further, Judge Taranto specifically directed the district court to several recent opinions upholding the patentability of claims, noting that they "provide clarifying guidance concerning the inquiries pertinent to the analysis" in this case. *Realtime*, 831 F. App'x at 501. For example, in *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 930 F.3d 1295 (Fed. Cir. 2019) , this Court held claims drawn to a method of computer network monitoring to be patent-eligible. At *Alice* step one, the Court found the claims were not directed to an abstract idea because they were "necessarily rooted in computer technology in order to solve a specific problem in the realm of computer networks." *Id.* at 1303. The Court recognized that the claims did not merely use a computer as a tool, but instead recited a "specific technique for improving computer network security." *Id.* at 1303–04. The Court further relied on statements in the specification explaining that the claimed invention was "directed to solving … weaknesses in conventional networks," which "bolster[ed] [its] conclusion that the claims are directed to a technological solution to a technological problem." *Id.*

In *Koninklijke KPN N.V. v. Gemalto M2M GmbH*, 942 F.3d 1143 (Fed. Cir. 2019) , this Court reversed the district court's grant of judgment on the pleadings and held that claims directed to an improved check data generating device were patent eligible. At *Alice* step one, the district court found that the claims were directed to the abstract idea of "reordering data and generating additional data," analogizing the claims to data manipulation claims found ineligible in cases like *RecogniCorp* (on which Defendants and the district court in this case heavily relied). *Id.* at 1148. This Court rejected this oversimplification, and held that they were "directed to a non-abstract improvement in an existing technological process (i.e., error checking in data transmissions)." *Id.* at 1150. The Court further explained that by "requiring that the permutation applied to original data be modified 'in time,'" the claims recite a "specific implementation of varying the way check data is generated that improves the ability of prior art error detection systems to detect systematic errors." *Id.*

In *Uniloc USA, Inc. v. LG Elecs. USA, Inc.*, 957 F.3d 1303 (Fed. Cir. 2020) , this Court reversed yet another order of dismissal under § 101, this time concerning claims directed to an improvement in wireless technology for exchanging data between a primary station and a secondary station. The Court held that the claims were directed to a "patent-eligible improvement to computer functionality, namely the reduction of latency" experienced in conventional systems. *Id.* at 1306–07. In so holding, the Court rejected the defendant's argument that the claims merely used "result-based functional language" and "generic" components, and that they were analogous to "data manipulation" claims previously deemed ineligible. *Id.* at 1308. The Court explained that the claims were directed to a "specific asserted improvement in the functionality of the communication system itself," and that the "invention's compatibility with conventional communication systems does not render it abstract." *Id.* at 1308–09.

In *Packet Intelligence LLC v. NetScout Sys., Inc.*, 965 F.3d 1299 (Fed. Cir. 2020) , this Court upheld the eligibility of patents that disclosed a method for monitoring data packets exchanged over a computer network. The district court rejected the defendants' oversimplification of the claims as being directed to "collection, comparison, and classification of information," and held that they were instead directed to "specific technological solutions." *Id.* at 1308. This Court affirmed, holding that, as in *SRI*, the claim "purports to meet a challenge unique to computer networks," as confirmed by statements in the specifications identifying limitations in conventional network monitoring systems which the claimed inventions sought to address. *Id.* at 1309–10.

In *TecSec, Inc. v. Adobe Inc.*, 978 F.3d 1278 (Fed. Cir. 2020) , this Court upheld the eligibility of patents directed to a system for restricting access to computer data. As in *Realtime*, this Court "reiterated the Supreme Court's caution against 'overgeneralizing claims' in the § 101 analysis, explaining that characterizing the claims at 'a high level of abstraction' that is 'untethered from the language of the claims all but ensures that the exceptions to § 101 swallow the rule.'" *Id.* at 1293. The Court explained that it has upheld the eligibility of patents directed to improvements in computer technology "in a number of cases" where it has made two significant inquiries: (1) "whether the focus of the claimed advance is on a solution to 'a problem specifically arising in the realm of computer networks' or computers," and (2) "whether the claim is properly characterized as identifying a 'specific' improvement in computer capabilities or network functionality, rather than only claiming a desirable result or function." *Id.* The Court emphasized that "accurate characterization of what the claims require and of what the patent asserts to be the claimed advance" is "**crucial**" to the step one "directed to" analysis. *Id.* at 1294.

Under this framework, this Court rejected the defendant's oversimplification of the claims as being directed to the abstract idea of managing access to objects using multiple levels of encryption. *Id.* The Court found that this characterization was "materially inaccurate," and that to arrive at it, defendant "had to disregard elements of the claims at issue that the specification makes clear are important parts of the claimed advance in the combination of elements," such as "accessing an 'object-oriented key manager," and using a "label" as well as "encryption for the access management." *Id.* at 1294–95. The Court further relied on statements in the specification expressly identifying deficiencies in the current art, demonstrating that "the claims at issue are directed at solving a problem 'specific to computer data networks.'" *Id.* at 1295. In light of the claim language and specification, the Court concluded that the claims were directed to "improving a data network's basic functioning" by "enabling secure and efficient data transmission," and that defendant's attempt to ignore the focus of the claimed advance could not render them abstract. *Id.* at 1296.[4]

More recently, in *Mentone Solutions LLC v. Digi International Inc.*, No. 2021-1202, 2021 WL 5291802 (Fed. Cir. Nov. 15, 2021), the patent at issue related to dynamic resource allocation in general packet radio systems. As set forth in the specification, the invention increased the capacity of networks to communicate data by addressing a known limitation in the prior art, resulting in a "system capable of a higher rate of data transmission." *Id.* at *2. On a Rule 12(b)(6) motion to dismiss, the district court held that the claims were directed to the abstract idea of "receiving [an uplink status flag] and transmitting data during the appropriate timeslots." *Id.* at *6. This Court disagreed with the district court's "high-level description" of the claims as "untethered to the invention as claimed," and found that, like the claims in *Packet Intelligence*, the claims purported to "solve a challenge unique to computer networks" and increased the rate of network data transmission. *Id.* at *5–6. This

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[4] Judge Taranto's concurring opinion also mentioned *Customedia Techs., LLC v. Dish Network Corp.*, 951 F.3d 1359, 1364–65 (Fed. Cir. 2020). That case is factually distinguishable for the reasons discussed below. However, it likewise holds that claims "directed to an improvement in the functionality of the computer or network platform itself" are patent eligible. *Id.*

Court further rejected the argument that the claims merely recite "data manipulation on a generic computer" or that they use "result-based functional language," holding that "there is no functional claiming, nor are there abstract steps." *Id.* at *5.

As in *SRI*, *Koninklijke*, *Uniloc*, *Packet Intelligence*, *TecSec*, and *Mentone*, the claimed inventions here are "necessarily rooted in computer technology" in order to solve specific problems in the realm of digital data compression, which problems are expressly identified and addressed in the patent specifications, and also set forth in detail in Realtime's amended complaints. For example, the '728, '203, and '825 patents describe various problems in the conventional art, including the "content sensitive behavior" of conventional systems and the "extremely large number of application programs" and data types or content. Appx333–334 at 2:29–3:19. The claimed inventions solved these problems by providing systems utilizing two digital-data compression techniques (*e.g.*, content dependent and content independent) to compress/decompress data blocks based on analysis of the specific content of data. And the patents addressed limitations in conventional systems which relied solely on a descriptor by requiring a direct examination of the digital-data payload rather than examining just the descriptor. *See, e.g.*, Appx500 at claim 1.

The '908, '530, and '458 patents are directed to solving problems in conventional digital data compression and data storage systems, including, for example, that "high performance disk interface standards … offer only the promise of higher data transfer rates through intermediate data buffering in random access memory," and do not address the "fundamental problem" with physical media limitations. Appx175 at 2:34–42. The claimed inventions solved these problems by utilizing a plurality of different encoders, and optionally a compression descriptor, for accelerated storage and retrieval of data blocks. *See, e.g.,* Appx267 at claim 1.

The '751 patent is directed to systems and methods for providing accelerated transmission of digital data over a communication channel using data compression and decompression to effectively increase the bandwidth of the communication channel and/or reduce the latency of data transmission associated with conventional systems. The disclosed inventions solved these problems by utilizing a state machine to compress data blocks based on an analysis of the specific content of the data being encoded. *See, e.g.,* Appx562 at claim 1.

These inventions fall squarely within the category of claims that this Court has repeatedly held are not abstract. The patent specifications make clear that the claimed advances are focused on solutions to problems specifically arising in the realm of computer technology (more specifically, digital data compression), and the claims identify "specific techniques" to address these problems and improve computer functionality. *TecSec*, 978 F.3d at 1294; *SRI*, 930 F.3d at 1303.

The district court found that *DDR Holdings*, *Core Wireless*, *Enfish*, *Finjan*, and *Visual Memory* are "inapposite" because the patents in those cases were "necessarily rooted in computer technology." Appx48 at n.4. But the district court did not explain how Realtime's patents, which even at their most basic level are directed to improved methods of digital data compression, are not rooted in computer technology. Digital data compression simply cannot take place outside the realm of computers and networks. In fact, this Court has on multiple occasions highlighted "an improved, particularized method of digital data compression" as an example of a non-abstract, "technologically complex" invention. *See, e.g.*, *DDR Holdings*, 773 F.3d at 1259; *Intell. Ventures I LLC v. Symantec Corp.*, 838 F.3d 1307, 1315 (Fed. Cir. 2016) (holding that the claims at issue were abstract because they "do not 'improve the functioning of the computer itself,' for example by disclosing an 'improved, particularized method of digital data compression'").

In its later opinion regarding Defendants' renewed motion to dismiss the amended complaints, the district court found that *Koninklijke*, *Packet Intelligence*, *TecSec*, *Uniloc*, and *SRI* are inapposite because the patents in those cases were "genuinely directed to technical problems grounded in computer technology" and "offered specific solutions," whereas the claims in Realtime's patents "may be performed by using any means or methods that can implement the ideas to which the patents are directed." Appx82–83. The district court was wrong again. For example, with respect to the '728 patent claims, this Court criticized the district court for "omitting key aspects of the claims," and expressly recognized that "***the claims***

expressly achieve this result in certain ways, involving examining data blocks and not relying just on a descriptor." *Realtime*, 831 F. App'x at 497. Contrary to the district court's findings, and as recognized by this Court, Realtime's patents do offer "specific solutions" to specific problems rooted in digital data compression, and thus are not abstract.

2. The district court once again conducted an improper "directed to" analysis in its August 23, 2021 memorandum opinion

In *Realtime*, this Court found that the district court had "improperly equated the presence of an abstract idea with a conclusion that the claims are directed to such an idea," and directed the district court to "carefully consider the 'directed to' question once more." 831 F. App'x at 497. On remand, the district court not only repeated the same errors, but also questioned the entire *Alice* framework established by the Supreme Court:

> As a matter of logic, I do not see how the first step of the *Alice/Mayo* framework can distinguish (or even help to distinguish) patents in terms of these two categories (i.e., the categories of (1) "patents that claim laws of nature, natural phenomena, and abstract ideas" and (2) patents "that claim patent-eligible applications of [laws of nature, natural phenomena, and abstract ideas]"). Both categories by definition claim laws of nature, natural phenomena, and abstract ideas; and only one of *Alice*'s steps (i.e., the second, "inventive concept" step) could distinguish the two categories.

Appx14 at n.1.

In other words, the district court appears to have taken the position that there *is no difference* between claims directed to applications of abstract ideas, and claims that are directed to the abstract ideas themselves. Under the district court's rationale, any claims that simply involved an abstract idea would fail at *Alice* step one, and could only be saved at *Alice* step two. This, of course, flies in the face of years of Supreme Court and Federal Circuit precedent, including this Court's express directive set forth in *Realtime*.

The district court's misunderstanding and misapplication of the *Alice* framework is apparent in its analysis of what Realtime's patent claims are purportedly directed to. According to the district court, the "unavoidable problem for Realtime is that data compression by itself is a type of information processing and information processing, without more, is patent-ineligible subject matter." Appx80. The district court further found that "[c]ompression is an idea relevant to information in general and is not inherently grounded in a particular technical environment." Appx80–81. Based on these findings, the district court concluded that the "patents are directed to abstract ideas." Appx81.

In other words, the district court found that all seven "patents" are directed to abstract ideas simply because they involve "information processing." This is plainly improper. Even a cursory review of the claims reveals that they are not directed to information processing, but rather are directed specific improvements in digital data compression (i.e., they improve computer functionality). Indeed, this Court rejected the district court's prior characterization of the '728 patent as "merely 'choosing a compression method based on the data type." *Realtime*, 831 F. App'x at 497. But instead of heeding this Court's warning to avoid "sweeping generalizations" and "omitting key aspects of the claims" (*id.*), the district court doubled down and generalized the claims even further. That was error.

Furthermore, the district court again improperly focused the inquiry on whether the *patents* are directed to abstract ideas, instead of analyzing the specific claims. As this Court pointed out in *Realtime*, it is "incorrect to consider whether a patent as a whole is abstract. The analysis is claim specific." *Id.* And while the district court's May 4, 2021 memorandum opinion purported to provide a more detailed analysis of each patent, its characterizations of the claims still impermissibly stripped out key elements and oversimplified the claims, and failed to properly consider the patents' claimed advances, as discussed further below.

3. The district court also conducted an improper "directed to" analysis in its prior May 4, 2021 memorandum opinion

In its May 4, 2021 memorandum opinion, the district court purported to "consider each patent individually, beginning with the #825 patent." Appx15. But before the district court even began its analysis, it determined that "each of the asserted patents are directed to abstract ideas that are the same as or related to those in the #825 patent or another asserted patent," and therefore would only "address subsequent patents by discussing whether any of the limitations they add change the § 101 analysis." *Id.* It thus appears that the district court treated the '825 *patent* as representative of *all seven asserted patents*, including the '908, '530, '458, and '751 patents, which are in distinct patent families and unrelated to the '825 patent. That was error. Setting aside the district court's failure to provide any analysis to support such a conclusion, there is no precedent for treating a *patent* as representative of other *patents*. As reiterated by this Court in *Realtime*, the analysis is "*claim* specific." 831 F. App'x at 497.

The district court further erred in its analysis of each patent. For the '825 patent, the district court determined that claim 18 is representative, that it "consists entirely of general, abstract steps," and is "directed to . . . abstract information processing." Appx18–23. This is the wrong analysis. Supreme Court and Federal Circuit precedent make clear that under *Alice* step one, courts must look at the claims *as a whole*—not analyze individual steps to determine whether each is abstract—and must look to the specifications to inform its understanding of what the claims are "directed to." *See, e.g.*, *TecSec*, 978 F.3d at 1292 ("We have approached the Step 1 'directed to' inquiry by asking what the ***patent asserts*** to be the focus of the claimed advance over the prior art. In conducting that inquiry, we must focus on the language of the Asserted Claims themselves, considered in light of the specification." (cleaned up)); *Realtime*, 831 F. App'x at 496 (finding the Court's "failure to evaluate the claims as a whole" was reversible error). And here, the patents assert non-abstract improvements to digital data compression. For example, the '825 patent claims are not directed solely to compressing data based on the content of the data (which is not abstract in any event), but also to selecting an encoder to encode data based on the content of the data instead of just a file descriptor. *See* Appx1599–1600 at ¶ 77, Appx500 at 3:49–67.

The district court's finding that "[n]othing in the #825 patent's claims goes beyond conducting data analysis and performing mathematical operations" (Appx25) is also wrong. The only way to reach that conclusion would be to simply "disregard elements of the claims at issue that the specification makes clear are important parts of the claimed advance in the combination of elements" (*e.g.*, Appx500 at claim 1). *TecSec*, 978 F.3d at 1294–95. Characterizing the claims at such a "'high level of abstraction' that is 'untethered from the language of the claims all but ensures that the exceptions to § 101 swallow the rule.'" *Id.* at 1293. Indeed, essentially all software patents could be generalized as simply "conducting data analysis and performing mathematical operations" (or "information processing") when stripping away critical claim limitations, as the district court did here. This Court, however, has expressly rejected such characterizations which would in effect create a "categorical ban on software patents." *Uniloc*, 957 F.3d at 1309 (rejecting characterization of the claims as being directed to mere "data manipulation"); *Koninklijke*, 942 F.3d at 1148 (same); *SRI*, 930 F.3d at 1304 (rejecting argument that the claims were simply directed to "generic steps required to collect and analyze data"); *Packet Intelligence*, 965 F.3d at 1308 (rejecting oversimplification of the claims as being directed to "collection, comparison, and classification of information").

The district court also erred in its analysis of the other six patents under *Alice* step one. The district court found that the "#728 patent is directed to the same idea as the #825 patent—compressing data based on the content of that data," and that "[b]oth patents are directed to abstract information processing." Appx30. And for the '203 patent, the district court similarly found that the "claims are directed to an inherently abstract procedure for transforming data." Appx40. But again, this Court already rejected this overgeneralization of the '728 claims in *Realtime*. 831 F. App'x at 497 ("We further question the district court's statements that the claims are, to use the '728 patent as an example, merely 'choosing a compression method based on the data type.' . . . This statement seems to miss that the claims expressly achieve this result in certain ways, involving examining data blocks and not relying just on a descriptor.").

For the '908 patent, the district court found that it is "directed to the combination of two abstract ideas"—"compressing two different data blocks with different methods," and requiring that "compression and storage together are faster than storage of the uncompressed data alone." Appx33. The district court further found that the '530 and '458 patents are "very similar to the #908 patent" and "directed to the same abstract idea." Appx34–38. But the entire premise of parsing a patent into multiple purported abstract ideas is wrong. As discussed above, determining what the claims are "directed to" requires looking at the claims as a whole, considered in light of the specification, and "asking what the patent asserts to be the focus of the claimed advance over the prior art." *TecSec*, 978 F.3d at 1292; *see also Realtime*, 831 F. App'x at 496. The '908, '530, and '458 patents addressed problems in the current art relating to digital data compression, including, *inter alia*, problems relating to bandwidth limitations. Appx175–176 at 1:15–3:58. Contrary to the district court's findings, the claims do not merely recite a result—the patents solved these problems found in conventional digital data compression by providing specific technological solutions utilizing a plurality of encoders, and optionally a compression descriptor, for accelerated storage and retrieval of data blocks. *See, e.g.*, *id.* at 3:25–33, 12:40–13:18, claim 1.

For the '751 patent, the district court found that the claims are "directed to the abstract idea of compressing data with a state machine, under conditions where compressing and storing the data is faster than storing the uncompressed data and where the compression method applied to the data is based on the content of the data." Appx39. But even this oversimplified characterization of the claims demonstrates that they are not abstract. "Compressing data with a state machine … based on the content of the data" is *not* abstract. *See, e.g.*, *TecSec*, 978 F.3d at 1295; *DDR*, 773 F.3d at 1259. The district court's finding that a state machine is an "abstract component" (Appx37) is incorrect and unsupported. And in any event, the district court's oversimplification of the '751 claims is wrong, as it improperly ignores the patent's claimed advance, discussed above.

This Court's recent decision in *Mentone*, discussed above, is instructive. In that case, this Court rejected the district court's "high-level description" of the claims as "untethered to the invention as claimed," and found that the claims purported to "solve a challenge unique to computer networks" and increased the rate of network data transmission. *Mentone*, 2021 WL 5291802, at *5–6. This Court further rejected the argument that the claims merely recite "data manipulation on a generic computer" or that they use "result-based functional language," holding that "there is no functional claiming, nor are there abstract steps." *Id.* at *5.

The district court's analysis of Realtime's patent claims fails for the same reasons. In determining what the claims are purportedly directed to, the district court failed to consider the patents' claimed advances over the problems in the prior art, set forth in detail in the patent specifications, and merely provided high level descriptions which failed to capture key claim elements. As in *Mentone* and *Packet*

Intelligence, the patents provide specific solutions that allow for faster and more efficient data transmission, by, as just one example, eliminating problems associated with data dependency. They do not recite abstract steps, nor do they merely recite functional language. The district court's entire analysis of each patent under *Alice* step one contains numerous legal errors and should be reversed.

4. The district court again failed to distinguish the prior § 101 rulings upholding the patentability of Realtime's patents

As recognized by this Court in *Realtime*, in the prior *Carbonite* and *Actian* cases, Judge Love recommended that the challenged claims be deemed patent eligible at both *Alice* step one and step two, and his reports and recommendations were "fully adopted" by two different district court judges, "each with significant experience in patent cases." *Realtime*, 831 F. App'x at 494. In reversing the Delaware district court's decision finding the patents ineligible under § 101, this Court specifically pointed out the district court's failure to "address or even acknowledge Judge Love's lengthy written opinions," and held that the district court "should have, at a minimum, provided a *considered explanation* as to why those judges were wrong." *Id.* at 496, 498.

The district court's analysis on remand, however, was still deficient. Although the district court did at least briefly mention (in a footnote) the prior § 101 rulings, it failed to provide any meaningful analysis of those decisions. Appx48 at n.4, Appx77.[5] The district court simply stated: "I disagree with Magistrate Judge Love's conclusions, and note that since those opinions were issued, the Federal Circuit has reaffirmed that the processing of information, without more, is not patent eligible." Appx48 at n.4; *see also* Appx77 (summarily dismissing the prior rulings as "non-binding"). This is far from the "considered explanation" requested by this Court. The district court did not explain how it arrived at the conclusion that the claims are directed to "information processing," despite the decisions from multiple other judges across two different districts finding that the claims are directed to specific improvements in digital data compression systems. Appx7481–7502, Appx7504–7515, Appx7517–7520, Appx7522.

Nor do the cases cited by the district court support that Realtime's patents are directed to mere "information processing." Appx48 at n.4. None of the claims at issue in those cases were directed to improving the functionality of a computer. In *Ericsson Inc. v. TCL Commc'n Tech. Holdings Ltd.*, the claims were directed to the abstract idea of "controlling access to resources," did not improve computer functionality, and could be "performed in the human mind." 955 F.3d 1317, 1327 (Fed. Cir. 2020). In *Customedia Techs., LLC v. Dish Network Corp* the claim recited

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[5] The district court incorrectly stated that the prior rulings only addressed the '530 and '908 patents, when they in fact also addressed the '728 patent and multiple other patents in the same families as the patents at issue in this case. *See* Appx48 at n.4, Appx7481–7502, Appx7504–7515, Appx7517–7520, Appx7522.

a "data delivery system for providing automatic delivery of … specifically identified advertising data." 951 F.3d 1359, 1363 (Fed. Cir. 2020). The claim did not "improve the functionality of the computer itself," but rather, at best, "merely improve[d] the abstract concept of delivering targeted advertising using a computer only as a tool." *Id.* And in *SAP Am., Inc. v. InvestPic, LLC*, the claims recited systems and methods for performing certain statistical analyses of investment information. 898 F.3d 1161 (Fed. Cir. 2018). The "focus of the claims" was "not any improved computer or network, but the improved mathematical analysis." *Id.* at 1168. These cases are easily distinguishable, as Realtime's claims are directed to improvements in computer functionality.

Moreover, the district court's purported "analysis" of the prior § 101 rulings focused solely on *Alice* step one and whether the claims are directed to an abstract idea. But the prior *Carbonite* and *Actian* rulings found that the claims were patent eligible at both step one *and step two*. The district court made no attempt to distinguish its decision and explain why the other courts were wrong at step two, revealing yet another shortcoming in its erroneous analysis.

D. The District Court Erred in Holding that the Seven Asserted Patents Do Not Provide Inventive Concepts Under *Alice* Step Two

As discussed above, the asserted patents are eligible under *Alice* step one, and this Court should reverse for that reason alone. However, the district court also erred in finding that the patents do not provide inventive concept under *Alice* step two.

1. The intrinsic record confirms that the claimed inventions involve unconventional technological solutions

As expressly set forth in the patents, the disclosed inventions provide improvements in digital data compression systems that addressed known problems in conventional prior art systems. The ’728, ’203, and ’825 patents addressed problems relating to “data dependency,” among other problems.” Appx333 at 2:7–3:55. To solve these technological issues, the claims require specific, unconventional combinations of specially configured computer elements. For example, claim 1 of the ’728 patent requires (a) “content dependent data compression encoders”; (b) a different “single data compression encoder”; and (c) and a processor configured to (i) “analyze data within a data block to identify one or more parameters or attributes of the data,” where the “analyzing … excludes analyzing based solely on a descriptor”; (ii) “perform content dependent data compression … if the one or more parameters or attributes of the data are identified,” and (iii) otherwise “perform data compression with the single data compression encoder.” Appx345; *see also* Appx346 at claims 24, 25, Appx3042–3044 at ¶¶ 22–29. The ’203 and ’825 patents likewise claim unconventional combinations of computer elements utilizing content dependent and content independent data compression. *See, e.g.*, Appx422–424 at claims 1, 14, 21, 27, Appx500–501 at claims 1, 18, 23, Appx3062–3066 at ¶¶ 83–88, Appx1601–1604 ¶¶ 81–86.

The ’908, ’530, and ’458 patents addressed problems in conventional digital data compression systems, including, *inter alia*, “problems with bandwidth limitations … by all other forms of sequential, pseudorandom, and random access mass storage devices.” Appx175 at 2:20–54. To solve these technological issues, the claims require specific, unconventional combinations of specially configured computer elements. For example, claim 1 of the ’908 patent requires (a) “a memory device”; and (b) “a data accelerator” configured to utilize two different data compression techniques to provide a first and second compressed data block, which data blocks are stored on the memory device, and where the “compression and storage occurs faster than the first and second data blocks are able to be stored on the memory device in uncompressed form.” Appx183; *see also* Appx183–185, claims 2–8, 13, 18–20, 22, 23, 25, 26, 28, 29, Appx3078–3082 ¶¶ 118–22. The claimed data accelerator is unconventional, as it requires two different compression techniques and the structural capability of compressing and storing digital data faster than the digital data can be stored in uncompressed form. *Id.* Claim 1 of the ’530 patent additionally requires that “a first data descriptor is stored on said memory device indicative of said first compression technique, and said first descriptor is utilized to decompress the portion of said compressed data stream associated with said first data block." Appx119; *see also* Appx119–120, claims 2–5, 7–12, 16, 19, 22, 23, 25, 26, Appx2876–2879 ¶¶ 88–92. And the '458 patent requires "compressing, if the parameter or attribute of the data within the data block or attribute of the data within the data block is not identified, the data block with at least one encoder associated with a non-identifiable parameter or attribute of the data." Appx267–268, claims 1, 18, 23, Appx1325–1328 ¶¶ 82–87.

Lastly, the '751 patent addressed specific problems in the prior art data compression systems, including, *inter alia*, "latency induced by the act of encryption, compression, decryption, and decompression." Appx551 at 1:40–5:22. The '751 patent solved these technological problems by providing an unconventional compression system allowing for a multiplication of bandwidth and a reduction in transmission latency. Appx553 at 5:28–29. For example, claim 25 of the '751 patent discloses a "system for compressing data" requiring a specific and unconventional combination of specially configured computer elements, including "a data server implemented on one or more processors and one or more memory systems and configured to" (a) "analyze content of a data block to identify a parameter, attribute, or value of the data block that excludes analysis based solely on reading a descriptor," (b) "select an encoder associated with the identified parameter, attribute, or value," (c) "compress data in the data block with the selected encoder to produce a compressed data block, wherein the compression utilizes a state machine," and (d) "store the compressed data block." Appx563. Claim 25 further requires that "the time of the compressing the data block and the storing the compressed data block is less than the time of storing the data block in uncompressed form." *Id.*; *see also* Appx562–564, claims 1–3, 5, 10, 12, 16–23, 26, 27, 29, 33, 36–42, 44–47, Appx3051–3055 ¶¶ 53–58.

In sum, the disclosed inventions do not merely recite well-understood, routine, conventional activities, but are necessarily rooted in computer technology and provide specific, unconventional technological solutions that improve computer functionality and overcome problems specifically arising in the realm of compression of digital computer data. Thus, even assuming that the patents were directed to the abstract idea of "information processing"—which they clearly are not—it is clear that each claim "amounts to significantly more than a patent upon the [abstract idea] itself" and thus are patent eligible. *Alice*, 134 S. Ct. at 2355.

2. The district court's findings that the patents lack inventive concept are unsupported and contrary to law.

a. *The '728, '203, and '825 patents*

The district court erred in its analysis of the '728, '203, and '825 patents under *Alice* step two. Regarding the '825 patent, which, as discussed above, the district court improperly treated as representative of all seven asserted patents, the district court found that the claims "take the abstract idea of compressing data based on the content of that data and simply apply that idea." Appx26. The district court rejected Realtime's arguments regarding inventiveness as "inconsistent with the plain language of the patent" because the specification "explains that all the constituent elements are generic and well-understood in the art." Appx26–27; *see also* Appx72 (finding that the claims "apply the claimed abstract ideas on generic hardware"). These findings are unsupported and contrary to this Court's longstanding precedent.

As an initial matter, the claimed components are not all generic. For example, the processor recited in claim 1 of the '728 patent must be specially configured to perform the recited, non-conventional functions, including analyzing the data to identify one or more parameters or attributes and performing compression with a plurality of different encoders based on that analysis. Moreover, this Court has repeatedly rejected the notion that the disclosure of conventional computing elements renders claims ineligible. "The inventive concept inquiry requires more than recognizing that each claim element, by itself, was known in the art." *BASCOM*, 827 F.3d at 1350. "[I]nventive concept can be found in the non-conventional and non-generic arrangement of known, conventional pieces." *Id.*; *see also Enfish*, 822 F.3d at 1338; *Visual Memory*, 867 F.3d at 1262.

That the patents utilize known encoding techniques/algorithms is also unavailing. Realtime does not assert that it invented a new type of encoding algorithm. Rather, the specification makes clear that the inventive aspect of the patents is their utilization of multiple encoders to compress data blocks based on an analysis of the specific content or type of the data being encoded without relying solely on a descriptor. *See BASCOM*, 827 F.3d at 1349–50 (upholding eligibility of claims despite their recitation of "generic computer, network and Internet components, none of which is inventive by itself," as neither the patentee nor the specification described these elements as inventive).

Properly viewing the claims as a whole in light of the specification, it is clear that the claims recite specific, discrete implementations of digital data compression, and the recited claim elements "operate in an unconventional manner to achieve an improvement in computer functionality." *See Amdocs (Israel) Ltd. v. Openet Telecom, Inc.*, 841 F.3d 1288, 1300–01 (Fed. Cir. 2016). The inventiveness of the asserted claims lies in the their direct examination of the digital-data payload rather than examining just the descriptor. The district court did not point to anything support that this was a previously known technique, and the patent specifications confirm that it was not previously known. The district court simply ignored these statements. That was error.

The district court further found that "none of the claims in the #825 patent even require physical components," and thus the patent "clearly does not provide 'technological solutions.'" Appx28. This Court has repeatedly rejected these arguments too. For example, in *Uniloc*, this Court held that the fact that the claimed improvement to the functionality of communication systems is “compatible with conventional communication systems,” and is “not defined by reference to ‘physical’ components,” does not render it abstract. 957 F.3d at 1309. “To hold otherwise risks resurrecting a bright-line machine-or-transformation test, or creating a categorical ban on software patents.” *Id.* And this Court’s “precedent is clear that software can make patent-eligible improvements to computer technology, and related claims are eligible as long as they are directed to non-abstract improvements to the functionality of a computer or network platform itself.” *Id.* The district court did not cite any authority to support its finding that claims must “require physical components” to claim eligible subject matter. This finding constitutes legal error and requires reversal.

The district court’s findings regarding the related ’728 and ’203 patents repeated these same errors. Regarding the ’728 patent, the district court found that claim 1 “consists of nothing more than a processor and compression encoders, “ and that “encoders are inherently abstract, and the processor is a generic computer component.” Appx31. This gross oversimplification of the claims disregards key claim limitations that are the focus of the asserted advances (e.g., the requirement that the identification of the data type rely on examination of data blocks and not on a file extension or comparable descriptor of the data type). The district court’s finding that "encoders are inherently abstract" also constitutes and improper (and incorrect) factual conclusion, which, in any event, is completely unsupported.

Regarding the '203 patent, the district court found that "the claims do not add any 'additional features' such that the claims cover eligible subject-matter." Appx43. The district court did not provide any analysis, evidence, or authority to support this conclusory statement, which itself is reversible error. *See Realtime*, 831 F. App'x at 496 (holding that "the district court's short analysis is insufficient to facilitate meaningful appellate review" and vacating the district court's judgments of ineligibility under § 101).

b. *The '908, '530, and '458 patents*

The district court's scant analyses of the '908, '530, and '458 patents likewise contain numerous legal errors. For the '908 patent, the district court's *Alice* step two findings consisted of a single sentence: "Because the additional limitations of the #908 patent relative to the #825 and #728 patents are purely abstract and do not provide any inventive steps, the #908 patent's claims are invalid for the same reasons that the #825 and #728 patents." Appx34. That the district court considered this patent a "relative to" the '825 and '728 patents (which are not related to the '908 patent) shows that the district court failed to properly consider the '908 claim limitations as an ordered combination. Instead, the district court appears to have just looked at the '908 claim limitations not found in the '825 and '728 patents in isolation. Indeed, the district court failed to even identify the "additional limitations" of the '908 patent it was referring to. Accordingly, the district court did not view the claims as a whole, which was error.

Regarding the '530 patent, the district court found that the claims lack inventive concept because they utilize "generic hardware." Appx35–36, Appx72. The district court further found that the dependent claims "simply add additional abstract steps or apply the same idea on routine and conventional hardware." *Id.* But the patent specification, and Realtime's allegations in the amended complaints, make clear that the claimed components, such as the specially configured data accelerator, are not all generic. Moreover, "inventive concept can be found in the non-conventional and non-generic arrangement of known, conventional pieces." *BASCOM*, 827 F.3d at 1350. The specification provides that the claims' inventiveness lies in their use of a plurality of different encoders, and optionally a compression descriptor, for accelerated storage and retrieval of data blocks. The district court failed to address these limitations, and appears to have limited its step two analysis to determining whether the claims recite any "nonconventional hardware." This was plainly improper. *See, e.g.*, *Uniloc*, 957 F.3d at 1309.

Regarding the '458 patent, the district court found that "lossless compression algorithms were well-understood at the time of patenting," and that "[i]n all other respects relevant to the *Alice* test, the #458 patent is identical to the #908 patent."

Appx38. But as discussed above, the ’458 patent’s use of known compression algorithms is inconsequential—the ’458 patent does not purport to disclose a new type of compression algorithm. The district court also improperly treated the ’908 *patent* as representative of all the claims of the ’458 *patent*, which was also error. “The analysis is claim specific,” and the district court erred in failing to consider the ’458 claims as a whole. *See Realtime*, 831 F. App’x at 497.

c. *The ’751 patent*

The district court found that “the #751 patent is invalid for the same reasons the previously considered patents are invalid,” namely, that the claims utilize “conventional computer hardware” and “known compression algorithms.” Appx40. This was error for the same reasons discussed above. Use of conventional components does not doom the patent claims. *BASCOM*, 827 F.3d at 1350; *Enfish*, 822 F.3d at 1338; *Uniloc*, 957 F.3d at 1309. Further, the district court’s conclusory, unsupported, and improper factual findings do not and cannot overcome the statements in the specification and the claim language showing that the ’751 patent provides unconventional technological solutions in digital data transmission, which provide, among other things, transmission and transparent multiplication of digital-data communication bandwidth, as well as a potential reduction of the latency associated with data transmission of conventional systems, and also by utilizing a state machine to compress data blocks based on an analysis of the specific content of the data being encoded. *See* Appx553 at 5:13–29, 6:13–40. The district court's failure to consider the limitations of the '751 claims as an ordered combination, and its improper resolution of disputed factual issues on a motion to dismiss, constitutes reversible error.

3. The district court improperly and prematurely resolved disputed issues of fact

Realtime's amended complaints set forth detailed factual allegations demonstrating the inventiveness of each of the patents, as well as setting forth claim constructions which further underscore the eligibility of the patents. *See, e.g.*, Appx3037–3039 ¶¶ 10–15, Appx3041–3045 ¶¶ 20–32. For example, the complaints cite to statements in patents filed by Altera and Western Digital which confirm the then-existing technological problems with computer capacity and demonstrate that there was still a need for more efficient compression systems—which Realtime's patents are directed to. Appx3045 ¶¶ 30–31. In addition, multiple judges across different districts have considered the asserted patents and determined that they are inventive and directed to patent eligible subject matter. Appx3038–3039 ¶¶ 12–15.

These allegations contradicted Defendants' unsupported assertions that the claims are conventional. At minimum, they raised factual disputes which were inappropriate for resolution on a motion to dismiss. *See Aatrix*, 882 F.3d at 1126–28 (holding that plaintiff's allegations "at a minimum raised factual disputes underlying the § 101 analysis, such as whether the claim term 'data file' constitutes an inventive concept, alone or in combination with other elements," and reversing Rule 12(b)(6) dismissal). As held by this Court, "[t]he question of whether a claim element or combination of elements is well-understood, routine and conventional to a skilled artisan in the relevant field is a question of fact." *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1368–69 (Fed. Cir. 2018). The district court's failure to give Realtime's factual allegations the proper weight and its premature resolution of disputed issues of fact on a Rule 12(b)(6) motion to dismiss was error.

E. Realtime's Amended Complaints Set Forth Claim Constructions Which Further Confirm that the Claims Are Patent Eligible Under § 101

Realtime's amended complaints offered fact-based claim constructions which demonstrate that the claimed solutions do not just cover any form of digital data compression techniques, but instead are more focused and cover a technical sub-species of digital data compression. *See, e.g.*, Appx3037–3038 ¶ 10, Appx3073 ¶ 109, Appx3075 ¶ 113, Appx3078–3079 ¶¶ 117–119. Prior constructions in earlier cases further confirm that the claimed methods and systems are in fact limited to the compression of digital data, and are not just generally directed to "information processing" or "data analysis." For example, a Texas court construed the term "compress"—a term used in all of the patents—as "represent data with fewer bits." Appx3038 ¶ 11. This construction supports that the claimed inventions are limited to the realm of digital-data compression, as a "bit" is a unit of digital data. Constructions of other claim terms, such as "data block" and "accelerator," also support that the patented inventions are unique to the compression of digital data. *Id.*

The district court found that these constructions "do not impact the *Alice* test," and "only 'confirm that the claims are directed to data analysis.'" Appx74–75. For example, regarding Realtime's proposed construction of "data accelerator" as "hardware or software with one or more compression encoders," the district court found that this "effectively concedes that a 'data accelerator' does not require any components beyond a generic processer that can run software." Appx75. These findings miss the mark. Once again, the district court confused claims *involving* an abstract concept as being *directed to* that abstract concept. The district court also oversimplified the claims, ignored key limitations directed to the patents' claimed advances, and erroneously concluded that non-conventional hardware is required for patent eligibility—all errors that have been repeatedly rejected by this Court, including in the prior *Realtime* appeal in this same case on the same patents.

VII. CONCLUSION

For the foregoing reasons, the district court's orders granting Defendants' Rule 12(b)(6) motions to dismiss should be reversed, and the asserted patents should be found patent eligible under § 101.

Dated: December 7, 2021

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IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

Realtime Data LLC, Plaintiff, v. Array Networks Inc., et al., Defendant.	Civil Action No. 17-0800-CFC CONSOLIDATED
Realtime Data LLC, Plaintiff, v. Spectra Logic Corp., Defendant.	Civil Action No. 17-0925-CFC

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MEMORANDUM OPINION

May 4, 2021
Wilmington, Delaware

COLM F. CONNOLLY
UNITED STATES DISTRICT JUDGE

Plaintiff Realtime Data LLC has sued fourteen Defendants for infringement of various combinations of eight patents it holds: U.S. Patent Nos. 7,415,530 (the #530 patent), 8,717,203 (the #203 patent), 8,717,204 (the #204 patent), 8,933,825 (the #825 patent), 9,054,728 (the #728 patent), 9,116,908 (the #908 patent), 9,667,751 (the #751 patent), and 10,019,458 (the #458 patent). The asserted patents are directed to systems and methods involving data compression.

Pending before me are motions to dismiss pursuant to Federal Rule of Civil Procedure 12(b)(6) filed by six Defendants. *Realtime Data LLC v. Fortinet, Inc.*, No. 17-1635, D.I. 11; *Realtime Data LLC v. Spectra Logic Corp.*, No. 17-0925, D.I. 41; *Realtime Data LLC v. Reduxio Systems, Inc.*, No. 17-1676, D.I. 9; *Realtime Data LLC v. Panzura, Inc.*, No. 18-1200, D.I. 21; *Realtime Data LLC v. Aryaka Networks, Inc.*, No. 18-2062, D.I. 15; *Realtime Data LLC v. Kaminario, Inc.*, No. 19-0350, D.I. 23. All six Defendants argue that I should dismiss Realtime Data's complaints because the asserted patents are invalid under 35 U.S.C. § 101 for failing to claim patentable subject matter. Some Defendants argue additional grounds for dismissal, but because I find all the asserted patents invalid on § 101 grounds I do not reach those arguments.

I. BACKGROUND

Realtime alleges that it is a developer of data compression technology and that it maintains an active patent licensing business. *See Fortinet*, No. 17-1635, D.I. 1 ¶ 1. The asserted patents claim variations on a common theme. The patents all relate to methods and systems for compression and decompression of data. Each of the eight patents has one of three shared written descriptions. The #825, #728, and #203 patents share one written description; the #530, #908, and #458 patents share another written description; and the #204 and #751 patents share a third written description.

Kaminario challenges as ineligible the #825 and #458 patents. Kamanario, Fortinet, Reduxio, Panzaura, and Aryaka challenge the #751 patent. Fortinet, Spectra, Reduxio, Panzaura, and Aryaka challenge the #728 and #908 patents. Fortinet and Reduxio challenge the #203 patent. Spectra challenges the #204 patent. And Spectra, Panzura, and Aryaka challenge the #530 patent.

Claim 18 of the #825 recites

> [a] method comprising:
> associating at least one encoder to each one of a
> plurality of parameters or attributes of data:
> analyzing data within a data block to determine whether
> a parameter or attribute of the data within the data
> block is identified for the data block;
> wherein the analyzing of the data within the data block
> to identify a parameter or attribute of the data
> excludes analyzing based only on a descriptor that

> is indicative of the parameter or attribute of the data within the data block;
> identifying a first parameter or attribute of the data of the data block;
> compressing, if the first parameter or attribute of the data is the same as one of the plurality of parameter or attributes of the data, the data block with the at least one encoder associated with the one of the plurality of parameters or attributes of the data that is the same as the first parameter or attribute of the data to provide a compressed data block; and
> compressing, if the first parameter or attribute of the data is not the same as one of the plurality of parameters or attributes of the data, the data block with a default encoder to provide the compressed data block.

Claim 25 of the #728 patent recites

> [a] computer implemented method comprising:
> analyzing, using a processor, data within a data block to identify one or more parameters or attributes of the data within the data block;
> determining, using the processor, whether to output the data block in a received form or in a compressed form; and
> outputting, using the processor, the data block in the received form or the compressed form based on the determination,
> wherein the outputting the data block in the compressed form comprises determining whether to compress the data block with content dependent data compression based on the one or more parameters or attributes of the data within the data block or to compress the data block with a single data compression encoder; and
> wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based only on a

> descriptor that is indicative of the one or more parameters or attributes of the data within the data block.

Claim 1 of the #908 patent recites

> [a] system comprising:
> a memory device; and
> a data accelerator configured to compress: (i) a first data block with a first compression technique to provide a first compressed data block; and (ii) a second data block with a second compression technique, different from the first compression technique, to provide a second compressed data block;
> wherein the compressed first and second data blocks are stored on the memory device, and the compression and storage occurs faster than the first and second data blocks are able to be stored on the memory device in uncompressed form.

Clam 1 of the #530 patent recites

> [a] system comprising:
> a memory device; and
> a data accelerator, wherein said data accelerator is coupled to said memory device, a data stream is received by said data accelerator in received form, said data stream includes a first data block and a second data block, said data stream is compressed by said data accelerator to provide a compressed data stream by compressing said first data block with a first compression technique and said second data block with a second compression technique, said first and second compression techniques are different, said compressed data stream is stored on said memory device, said compression and storage occurs faster than said data stream is able to be stored on said memory device in said received form, a first data descriptor is stored on said

> memory device indicative of said first compression technique, and said first descriptor is utilized to decompress the portion of said compressed data stream associated with said first data block.

Claim 9 of the #458 patent recites

> [a] method for accelerating data storage comprising:
> analyzing a first data block to determine a parameter of the first data block;
> applying a first encoder associated with the determined parameter of the first data block to create a first encoded, data block wherein the first encoder utilizes a lossless dictionary compression technique;
> analyzing a second data block to determine a parameter of the second data block;
> applying a second encoder associated with the determined parameter of the second data block to create a second encoded data block, wherein the second encoder utilizes a lossless compression technique different than the lossless dictionary compression technique; and
> storing the first and second encoded data blocks on a memory device, wherein encoding and storage of the first encoded data block occur faster than the first data block is able to be stored on the memory device in unencoded form.

Claim 1 of the #751 patent recites

> [a] method for compressing data comprising:
> analyzing content of a data block to identify a parameter, attribute, or value of the data block that excludes analyzing based solely on reading a descriptor;
> selecting an encoder associated with the identified parameter, attribute, or value;
> compressing data in the data block with the selected encoder to produce a compressed data block,

> wherein the compressing includes utilizing a state machine; and
> storing the compressed data block;
> wherein the time of the compressing the data block and the storing the compressed data block is less than the time of storing the data block in uncompressed form.

Claim 12 of the #204 patent recites

> [a] method for processing data, the data residing in data fields, comprising:
> recognizing any characteristic, attribute, or parameter of the data;
> selecting an encoder associated with the recognized characteristic, attribute, or parameter of the data;
> compressing the data with the selected encoder utilizing at least one state machine to provide compressed data having a compression ratio of over 4:1; and
> point-to-point transmitting the compressed data to a client;
> wherein the compressing and the transmitting occur over a period of time which is less than a time to transmit the data in an uncompressed form.

Claim 14 of the #203 patent recites

> [a] system for decompressing, one or more compressed data blocks included in one or more data packets using a data decompression engine, the one or more data packets being transmitted in sequence from a source that is internal or external to the data decompression engine, wherein a data packet from among the one or more data packets comprises a header containing control information followed by one or more compressed data blocks of the data packet the system comprising:
> a data decompression processor configured to analyze the data packet to identify one or more recognizable data tokens associated with the data packet, the

> one or more recognizable data identifying a selected encoder used to compress one or more data blocks to provide the one or more compressed data blocks, the encoder being selected based on content of the one or more data blocks on which a compression algorithm was applied;
>
> one or more decompression decoders configured to decompress a compressed data block from among the one or more compressed data blocks associated with the data packet based on the one or more recognizable data tokens; wherein:
>
> the one or more decompression decoders are further configured to decompress the compressed data block utilizing content dependent data decompression to provide a first decompressed data block when the one or more recognizable data tokens indicate that the data block was encoded utilizing content dependent data compression; and
>
> the one or more decompression decoders are further configured to decompress the compressed data block utilizing content independent data decompression to provide a second decompressed data block when the one or more recognizable data tokens indicate that the data block was encoded utilizing content independent data compression; and
>
> an output interface, coupled to the data decompression engine, configured to output a decompressed data packet including the first or the second decompressed data block.

In a prior oral ruling on motions to dismiss brought by Aryaka, Panzura, Fortinet, and Reduxio, I found the #728, #908, #530, and #751 patents invalid for claiming ineligible subject matter. *Reduxio*, No. 17-1676, D.I. 46 (oral order). Realtime appealed, and the Federal Circuit vacated my prior ruling as insufficient.

Realtime Data LLC v. Reduxio Sys., Inc., 831 F. App'x 492, 499 (Fed. Cir. 2020). The Federal Circuit cautioned that "[n]othing in [its] opinion should be read as opining on the relative merits of the parties' arguments or the proper resolution of the case." *Id.*

II. LEGAL STANDARDS

A. Legal Standards for Stating a Claim

To state a claim on which relief can be granted, a complaint must contain "a short and plain statement of the claim showing that the pleader is entitled to relief." Fed. R. Civ. P. 8(a)(2). Detailed factual allegations are not required, but the complaint must include more than mere "labels and conclusions" or "a formulaic recitation of the elements of a cause of action." *Bell Atl. Corp. v. Twombly*, 550 U.S. 544, 555 (2007) (citation omitted). The complaint must set forth enough facts, accepted as true, to "state a claim to relief that is plausible on its face." *Id.* at 570. A claim is facially plausible "when the plaintiff pleads factual content that allows the court to draw the reasonable inference that the defendant is liable for the misconduct alleged." *Ashcroft v. Iqbal*, 556 U.S. 662, 678 (2009) (citation omitted). Deciding whether a claim is plausible is a "context-specific task that requires the reviewing court to draw on its judicial experience and common sense." *Id.* at 679 (citation omitted).

When assessing the merits of a Rule 12(b)(6) motion to dismiss, a court must accept as true all factual allegations in the complaint and in documents explicitly relied upon in the complaint, and it must view those facts in the light most favorable to the plaintiff. *See Umland v. Planco Fin. Servs.*, 542 F.3d 59, 64 (3d Cir. 2008).

B. Legal Standards for Patent-Eligible Subject Matter

Section 101 of the Patent Act defines patent-eligible subject matter. It provides: "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title." 35 U.S.C. § 101.

There are three judicially created limitations on the literal words of § 101. The Supreme Court has long held that laws of nature, natural phenomena, and abstract ideas are not patentable subject matter. *Alice Corp. Pty. v. CLS Bank Int'l*, 573 U.S. 208, 216 (2014). These exceptions to patentable subject matter arise from the concern that the monopolization of "these basic tools of scientific and technological work" "might tend to impede innovation more than it would tend to promote it." *Id.* (internal quotation marks and citations omitted). Abstract ideas include mathematical formulas and calculations. *Gottschalk v. Benson*, 409 U.S. 63, 71–72 (1972).

"[A]n invention is not rendered ineligible for patent [protection] simply because it involves an abstract concept[.]" *Alice*, 573 U.S.. at 217. "[A]pplication[s] of such concepts to a new and useful end . . . remain eligible for patent protection." *Id.* (internal quotation marks and citations omitted). But in order "to transform an unpatentable law of nature [or abstract idea] into a patent-eligible application of such law [or abstract idea], one must do more than simply state the law of nature [or abstract idea] while adding the words 'apply it.'" *Mayo Collaborative Servs. v. Prometheus Lab'ys, Inc.*, 566 U.S. 66, 71 (2012) (emphasis omitted).

In *Alice*, the Supreme Court established a two-step framework by which courts are to distinguish patents that claim eligible subject matter under § 101 from patents that do not claim eligible subject matter under § 101. The court must first determine whether the patent's claims are drawn to a patent-ineligible concept—i.e., are the claims directed to a law of nature, natural phenomenon, or abstract idea? *Alice*, 573 U.S. at 217. If the answer to this question is no, then the patent is not invalid for teaching ineligible subject matter. If the answer to this question is yes, then the court must proceed to step two, where it considers "the elements of each claim both individually and as an ordered combination" to determine if there is an "inventive concept—*i.e.*, an element or combination of elements that is sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the [ineligible concept] itself." *Id.* at 217–18 (alteration in original) (internal quotations and citations omitted).[1]

Issued patents are presumed to be valid, but this presumption is rebuttable. *Microsoft Corp. v. i4i Ltd. Partnership*, 564 U.S. 91, 96 (2011). Subject-matter eligibility is a matter of law, but underlying facts must be shown by clear and convincing evidence. *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1368 (Fed. Cir. 2018).

III. DISCUSSION

Applying the two-step framework from *Alice*, I find that the asserted patents are invalid under § 101. The Federal Circuit has repeatedly held that manipulation of information is inherently abstract. *RecogniCorp, LLC v. Nintendo Co.*, 855 F.3d 1322, 1327 (Fed. Cir. 2017) ("A process that start[s] with data, add[s] an

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[1] The Court in *Alice* literally said that this two-step framework is "for distinguishing patents that claim laws of nature, natural phenomena, and abstract ideas from those that claim patent-eligible applications of those concepts." 573 U.S. at 217. But as a matter of logic, I do not see how the first step of the *Alice/Mayo* framework can distinguish (or even help to distinguish) patents in terms of these two categories (i.e., the categories of (1) "patents that claim laws of nature, natural phenomena, and abstract ideas" and (2) patents "that claim patent-eligible applications of [laws of nature, natural phenomena, and abstract ideas]"). *Both* categories *by definition* claim laws of nature, natural phenomena, and abstract ideas; and only one of *Alice*'s steps (i.e., the second, "inventive concept" step) could distinguish the two categories. I therefore understand *Alice*'s two-step framework to be the framework by which courts are to distinguish patents that claim eligible subject matter under § 101 from patents that do not claim eligible subject matter under § 101.

algorithm, and end[s] with a new form of data [i]s directed to an abstract idea."); *SAP Am., Inc. v. InvestPic, LLC*, 898 F.3d 1161, 1167 (Fed. Cir. 2018) ("[S]electing certain information, analyzing it using mathematical techniques, and reporting or displaying the results of the analysis . . . is all abstract."); *Elec. Power Grp.*, 830 F.3d 1350, 1353 (Fed. Cir. 2016) ("[W]e have treated collecting information, including when limited to particular content (which does not change its character as information), as within the realm of abstract ideas."). The asserted patents purport to teach the abstract manipulation of data and they lack any additional inventive features. They are thus ineligible for patent protection.

I structure my analysis as follows. I first consider whether it is appropriate to declare the patents invalid at the motion to dismiss stage. I conclude that it is. I then consider each patent individually, beginning with the #825 patent. I apply the two-part *Alice* test and consider whether each patents' claims should be considered together for the purpose of subject-matter eligibility. Because each of the asserted patents are directed to abstract ideas that are the same as or related to those in the #825 patent or another asserted patent, I address subsequent patents by discussing whether any of the limitations they add change the § 101 analysis I have already provided for previously considered patents. In all cases I find that these subsequent patents are directed to substantively similar abstract ideas and add no inventive features. I conclude by considering arguments Realtime directed to all the asserted patents without distinguishing among the patents.

A. It Is Appropriate to Resolve This Case on a Motion to Dismiss

"[W]hether a claim recites patent eligible subject matter is a question of law [that] may contain underlying facts." *Berkheimer*, 881 F.3d at 1368. But "not every § 101 determination contains genuine disputes over the underlying facts . . . ." *Id.* When there is no dispute of material fact, § 101 arguments may be resolved at the pleading stage. *Id.* The Federal Circuit has "repeatedly affirmed § 101 rejections at the motion to dismiss stage, before claim construction or significant discovery has commenced." *Cleveland Clinic Found. v. True Health Diagnostics LLC*, 859 F.3d 1352, 1360 (Fed. Cir. 2017); *see also SAP Am.*, 898 F.3d at 1166 (citing cases); *Epic IP LLC v. Backblaze, Inc.*, 351 F. Supp. 3d 733, 751–52 (D. Del. 2018) (discussing when it is appropriate to resolve a § 101 motion on the pleadings).

Consideration of the asserted patents' subject-matter eligibility is appropriate at this stage of the case. Realtime argues that there are underlying factual disputes about whether the patents cover new solutions to existing technological problems and that fact discovery is necessary before ruling on the § 101 motions. But the patents themselves explain that the technologies and methods used in the claimed analyses were well-known and routine. *See, e.g.,*

#825 patent at 6:24–31, 7:5–11. And precedent makes clear that the inventive feature in a patent cannot be the abstract idea itself. *See Mayo*, 566 U.S. at 72–73 (explaining the inventive concept must be "significantly more" than the abstract idea itself); *BSG Tech LLC v. Buyseasons, Inc.*, 899 F.3d 1281, 1290 (Fed. Cir. 2018) ("a claimed invention's use of the ineligible concept to which it is directed cannot supply the inventive concept").

Realtime also argues that 42 paragraphs in its First Amended Complaint against Kaminario contain relevant factual assertions. *Kaminario*, 19-0350, D.I. 33 at 29 (citing D.I. 18 at ¶¶ 9–14, 16–27, 45–56, 72–83). But the cited paragraphs recite legal conclusions, quotations from the patents, and conclusory allegations that the patents contain inventive features. None of the cited paragraphs identify an inventive feature that is distinct from one of the claimed abstract ideas. Even taking as true all facts as alleged, Realtime has not identified any elements of any claims that amount to "significantly more" than the abstract idea to which the claims are directed. Thus, discovery is not necessary.

Resolving eligibility on the pleadings minimizes "expenditure of time and money by the parties and the court" and "protects the public" from illegitimate patents. *Ultramercial, Inc. v. Hulu, LLC*, 772 F.3d 709, 719 (Fed. Cir. 2014) (Mayer, J., concurring) (citation omitted). Such resolution is appropriate in these cases.

B. The #825 Patent

The #825 patent claims methods for selecting and performing data compression based on the data being compressed.

1. Claim 18 is Representative in the #825 Patent

Kaminario argues that claim 18 is representative. No. 19-0350, D.I. 24 at 4. Realtime's response to this assertion (and Kaminario's other proposed representative claims) is that Kaminario "provides no clear and convincing evidence that ***all*** of the claims of the asserted patents (totaling 100 claims across three different, unrelated patents) are ineligible." D.I. 33 at 35 (emphasis in original). If accepted, this response would effectively make dismissal on § 101 grounds impossible at the pleadings stage. Realtime's only substantive responses are to dismiss Kaminario's arguments as "conclusory attorney argument" and to offer a single sentence footnote listing terms from the patents asserted against Kaminario without any context. D.I. 33 at 36 n. 12. Realtime makes no effort to explain how the listed terms affect the *Alice* inquiry or to meaningfully respond to Kaminario's arguments about why claim 18 is representative. I have reviewed the claims and agree that claim 18 is representative.

Substantially similar claims directed to the same abstract idea can be considered together for subject-matter eligibility. *Content Extraction & Transmission LLC v. Wells Fargo Bank*, 776 F.3d 1343, 1348 (Fed. Cir. 2014).

The #825 patent's independent claims (1, 18, 23, and 28) all recite a common algorithmic procedure with inconsequential variations. Each of the independent claims covers a method where (1) encoders are associated with particular parameters; (2) the presence or absence of those parameters in the data to be compressed, excluding any descriptive metadata, is identified; and (3) the associated encoder is used to compress the data. *See* #825 patent at claims 1, 18, 23, 28. In other words, the data is compressed based on the attributes of the data itself, rather than a descriptor such as ".txt," ".png," ".doc," or ".csv." The independent claims are all directed to various wordings of this same procedure. Claims 23 and 28 add the additional step of providing a token indicative of the compression technique, but this extra algorithmic step does not alter the *Alice* analysis. *See Smart Sys. Innovations, LLC v. Chi. Transit Auth.*, 873 F.3d 1364, 1374 & n.9 (Fed. Cir. 2017) (finding claims covering an algorithmic step with "identifying tokens" invalid for lack of patentable-subject matter and explaining that adding a "hash identifier" did not impact the *Alice* test because it did not add the requisite inventive concept).

The dependent claims also do not add any limitations that affect the § 101 analysis. Those claims merely specify additional steps of abstract data analysis or limit the claims to particular operations. "A claim is not patent eligible merely because it applies an abstract idea in a narrow way." *BSG*, 899 F.3d at 1287 & n.1

(dependent claims focused on same abstract idea despite minor differences); *see also buySAFE, Inc. v. Google, Inc.*, 765 F.3d 1350, 1355 (Fed. Cir. 2014) (explaining that narrowing the use of an abstract idea "to a particular technological environment" does not make a claim directed to an otherwise abstract idea patent eligible).

Several claims recite additional abstract steps for the receiving, storing, or manipulation of information. #825 patent at claims 2, 10, 19, 24, 27. Other claims recite well-known compression methods. #825 patents at claims 12–16. Claims 6, 7, 20, 25, and 29 add the arbitrary condition that compression occur in "real time," and claims 8 and 9 specify whether the data is of variable or fixed size. Claims 3, 21, and 30 add as an additional step the provision of a token identifying the compression technique; and claims 17 and 26 allow the user to disable certain compression methods. The remaining claims combine some of these limitations. #825 patent at claims 4–5, 11, 22. For example, claims 5 and 22 require both the transmission of a token indicating the method of compression and decompression based on that token. If the independent claims are invalid for claiming ineligible subject matter, the dependent claims are also invalid for the same reasons. The dependent claims are directed to the same abstract process and do not add any unconventional or inventive steps. None of the additional limitations alter the § 101 analysis.

Accordingly, I adopt claim 18 as representative of the #825 patent for the purposes of § 101 subject-matter eligibility.

2. *Alice* Step One

The court determines at step one whether the claims at issue are directed to a patent-ineligible concept. *Alice*, 573 U.S. at 217. "[C]laims are considered in their entirety [at step one] to ascertain whether their character as a whole is directed to excluded subject matter." *Internet Patents Corp. v. Active Network, Inc.*, 790 F.3d 1343, 1346 (Fed. Cir. 2015). In conducting step one, I "look at the focus of the claimed advance over the prior art to determine if the claim's character as a whole is directed to excluded subject matter." *Affinity Labs of Texas, LLC v. DIRECTV, LLC*, 838 F.3d 1253, 1257 (Fed. Cir. 2016) (quotation marks omitted).

"The Supreme Court has not established a definitive rule to determine what constitutes an 'abstract idea' sufficient to satisfy the first step of the *Mayo/Alice* inquiry." *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1334 (Fed. Cir. 2016) (citation omitted). The Court has recognized, however, that fundamental economic practices, methods of organizing human activity, and mathematical formulae are abstract ideas. *See Bilski v. Kappos*, 561 U.S. 593, 611 (2010) ("fundamental economic practice" of hedging is unpatentable abstract idea); *Alice*, 573 U.S. at 220–21 ("organizing human activity" of intermediated settlement falls "squarely within realm of 'abstract ideas'"); *Gottschalk*, 409 U.S.at 68, 71–72 (mathematical algorithm to convert binary-coded decimal numerals into pure binary code is unpatentable abstract idea); *Parker v. Flook*, 437 U.S. 584, 594–95 (1978) (mathematical formula for computing "alarm limits" in a catalytic conversion process is unpatentable abstract idea).

To determine whether claims are directed to an abstract idea courts generally "compare the claims at issue to those claims already found to be directed to an abstract idea in previous cases." *Enfish*, 822 F.3d at 1334. The Federal Circuit has also instructed district courts to consider as part of *Alice*'s step one whether the claims "focus on a specific means or method that improves the relevant technology or are instead directed to a result or effect that itself is the abstract idea and merely invoke generic processes and machinery." *McRO, Inc. v. Bandai Namco Games Am. Inc.*, 837 F.3d 1299, 1314 (Fed. Cir. 2016) (citing *Enfish*, 822 F.3d at 1336).

Claims directed to the manipulation of data are abstract absent additional features, because, "information as such is an intangible." *Elec. Power*, 830 F.3d at 1353. "[A]nalyzing information by steps people go through in their minds, or by mathematical algorithms, without more" is "within the abstract-idea category." *Id.* at 1354. In other words, "[a] process that start[s] with data, add[s] an algorithm, and end[s] with a new form of data [is] directed to an abstract idea." *RecogniCorp*, 855 F.3d at 1327 (citing *Digitech Image Techs., LLC v. Elecs. for Imaging, Inc.*, 758 F.3d 1344 (Fed. Cir. 2014)).

Because the #825 patent covers a procedure for manipulating information, the Federal Circuit's prior cases considering patents directed to the manipulation of information are directly relevant. Applying these standards, I find that the #825 patent is directed to the abstract idea of compressing data based on the content of that data.

Claim 18 consists entirely of general, abstract steps. The claim requires "associating [an] encoder," "analyzing data," "identifying a [] parameter," and "compressing." The other requirements of the claim are logical conditions that limit the claim's scope and do not change the focus of the claims from the abstract manipulation of information. Illustrating their abstract nature, the claimed steps are captured in a simple flow chart. #825 patent at 6:7–10, figs. 17a. 17b. Claim 18 is directed to precisely the type of abstract information processing that the Federal Circuit has repeatedly found patent ineligible. *See, e.g.*, *RecogniCorp*, 855 F.3d at 1327 (encoding and decoding data is an abstract idea); *In re Bd. of Trustees of Leland Stanford Junior Univ.*, 2021 WL 922727, at *4 (Fed. Cir. Mar. 11, 2021) ("mathematical algorithms for performing calculations, without more, are patent ineligible under § 101"); *iLife Techs., Inc. v. Nintendo of Am., Inc.*, 2021 WL 117027, at *2 (Fed. Cir. Jan. 13, 2021) ("We have routinely held that claims directed to gathering and processing data are directed to an abstract idea."); *Two-Way Media Ltd. v. Comcast Cable Commc'ns, LLC*, 874 F.3d 1329, 1337 (Fed.

Cir. 2017) (claims focused on sending and monitoring information are directed to an abstract idea); *In re TLI Commc'ns LLC Pat. Litig.*, 823 F.3d 607, 612 (Fed. Cir. 2016) (classifying and storing information is abstract); *Digitech Image Techs.*, 758 F.3d at 1351 (method claims for organizing information through mathematical analyses was directed to an abstract idea); *Mortg. Application Techs., LLC v. MeridianLink, Inc.*, 2021 WL 97347, at *4 (Fed. Cir. Jan. 12, 2021) ("information storage and exchange is an abstract idea even when it uses computers as a tool or is limited to a particular technological environment").

The Federal Circuit's decision in *SAP America* confirms this analysis. 889 F.3d 1161. In that case, the claims were focused on "selecting certain information, analyzing it using mathematical techniques, and reporting or displaying the results of the analysis." *Id.* at 1167. The Federal Circuit held that the asserted claims were ineligible because the claimed operations were "all abstract." *Id.* at 1167. The claims in the #825 patent are not materially different from the claims considered in *SAP America*. Indeed, Realtime itself alleges in its complaint against Kaminario that the #825 patent is "directed to systems and methods of digital-data compression utilizing multiple encoders to compress data blocks *based on an analysis of the specific content or type of the data being encoded*." *Kaminario*, 19-350, D.I. 18 ¶ 74 (emphasis added).

Nothing in the #825 patent's claims goes beyond conducting data analysis and performing mathematical operations. The disclosed analysis could be implemented using pen and paper. Because there is "no particular concrete or tangible form" to the claims, they are abstract. *Ultramercial*, 772 F.3d at 715; *see also CyberSource Corp. v. Retail Decisions, Inc.*, 654 F.3d 1366, 1373 (Fed. Cir. 2011) ("[A] method that can be performed by human thought alone is merely an abstract idea and is not patent-eligible under § 101."). The patent is, in short, focused on an abstract idea for analyzing data.

3. *Alice* Step Two

Having found that the claims are directed to an abstract idea, I next ascertain whether the claims contain an "'inventive concept' sufficient to 'transform' the claimed abstract idea into a patent-eligible application." *Alice*, 573 U.S. at 221 (quoting *Mayo*, 566 U.S. at 77). It is insufficient for the patent to "simply state the law of nature while adding the words 'apply it.'" *Mayo,* 566 U.S. at 72. A claim directed towards an abstract idea must include "'additional features' to ensure 'that the [claim] is more than a drafting effort designed to monopolize the [abstract idea].'" *Alice*, 573 U.S. at 221 (alterations in original) (quoting *Mayo*, 566 U.S. at 77). No such additional features exist here, and I find that, whether considered individually or as an ordered combination, the claim elements of the #825 patent do not "transform" the claimed abstract idea into patent-eligible subject matter.

The patent's claims take the abstract idea of compressing data based on the content of that data and simply apply that idea. Reciting the application of an abstract idea without more does not provide an inventive concept. *See, e.g.*, *Alice*, 573 U.S. at 221 ("transformation into a patent-eligible application requires more than simply stating the abstract idea while adding the words 'apply it'" (alterations, internal citations, and quotation marks omitted)); *BSG*, 899 F.3d at 1290 ("[A] claimed invention's use of the ineligible concept to which it is directed cannot supply the inventive concept that renders the invention 'significantly more' than that ineligible concept."); *Content Extraction*, 776 F.3d at 1347–48 ("For the role of a computer in a computer-implemented invention to be deemed meaningful in the context of this analysis, it must involve more than performance of well-understood, routine, and conventional activities previously known to the industry." (quotation marks and alterations omitted)).

Realtime argues the #825 patent teaches "specific improvements to the function of [] computer parts themselves," and therefore contains an inventive feature. *Kaminario*, 19-350, D.I. 33 at 9.[2] But this argument is inconsistent with

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[2] Realtime argues at both steps of the *Alice* inquiry that the #825 patent is subject-matter eligible because the patent covers technological solutions. Realtime phrases its arguments slightly differently at each step to correspond to the *Alice* test as it has been articulated in Federal Circuit case law. At step one, Realtime argues that the #825 patent is subject-matter eligible because it is "directed to technological solutions" and therefore is not directed to an abstract idea. D.I. 33 at 12 (citing *DDR Holdings, LLC v. Hotels.com, L.P.*, 773 F.3d 1245, 1259 (Fed. Cir. 2014) and

the plain language of the patent. The #825 patent's written description explains that all the constituent elements are generic and well-understood in the art. The claimed methods are preferably implemented on "a general purpose computer or any machine or device" with a microprocessor using any of the "many conventional content dependent techniques" for compression, including many that are "currently well known." #825 patent at 2:65–66, 6:26–31, 7:7–11. And these elements are not combined in an inventive way; rather, they are simply combined in the order logic requires. *Two-Way Media*, 874 F.3d at 1339 (claiming the "conventional ordering of steps" to implement an abstract idea on a generic

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Enfish, 822 F.3d at 1339). Its argument at step two is summarized in the main text above. Both arguments are premised on finding that the #825 patent covers technical solutions for improved computer functionality.

The Federal Circuit has at times considered computer functionality at step one of the *Alice* inquiry and at times at step two. *Compare Enfish*, 822 F.3d at 1335 ("Therefore, we find it relevant to ask whether the claims are directed to an improvement to computer functionality versus being directed to an abstract idea, even at the first step of the *Alice* analysis."), *Cellspin Soft, Inc. v. Fitbit, Inc.*, 927 F.3d 1306, 1315–16 (Fed. Cir. 2019) (considering introduction of computer functionality into claims at step one of *Alice* inquiry), *and TLI Commc'ns*, 823 F.3d at 611–13 (same), *with Trading Techs. Int'l, Inc. v. IBG LLC*, 921 F.3d 1084, 1094 (Fed. Cir. 2019) (considering whether the claims "improve computer functionality" at step two), *Intell. Ventures I LLC v. Symantec*, 838 F.3d 1307, 1320 (Fed. Cir. 2016) (considering whether "the asserted claim improve[s] or change[s] the way a computer functions" at step two), *and BASCOM Glob. Internet Servs., Inc. v. AT&T Mobility LLC*, 827 F.3d 1341, 1351 (Fed. Cir. 2016) (finding that "the claims may be read to improve an existing technological process" at step two (internal quotation marks and alteration omitted)). I have followed the Supreme Court's lead in *Alice* and consider computer functionality at step two.

computer is not inventive); *see also In re TLI Commc'ns*, 823 F.3d at 615 ("vague, functional descriptions" are insufficient to transform an abstract idea into a patent-eligible invention").

Indeed, none of the claims in the #825 patent even require physical components. *See, e.g.*, #825 patent claims 1, 18, 23, 28. The claims recite an "encoder," but "encoder" is simply the patent's name for a mathematical compression algorithm. *See* #825 patent at 7:5–11 (distinguishing between an "encoder module" and "encoders," and explaining that the encoders can be any number of compression algorithms). Since the patent neither requires any hardware nor otherwise teaches any technical improvement to computer technology, it clearly does not provide "technological solutions."

The #825 patent's claims do not contain additional limitations, whether considered individually or as an ordered combination, that "transform" the claimed abstract idea into patent-eligible subject matter. I therefore find the #825 patent invalid for claiming ineligible subject matter.

C. The #728 Patent

The #728 patent is directed to systems and a method that compress data based on the characteristics of the data to be compressed.

1. The #728 Patent Claims are Equivalent for the Purposes of § 101

None of the claims in the #728 patent are materially different from each other for the purposes of § 101. The #728 patent has three independent claims—1, 24, and 25. Though they are drafted slightly differently, they all are directed to the same idea of compressing data based on the characteristics of that data. Claim 25 differs from claim 1 insofar as claim 25 is a method and claim 1 is a system claim. Claim 24 claims essentially the same system as claim 1 but uses a "default data compression encoder" instead of a "single data compression encoder." When the only difference between claims is the form in which they are drafted, it is appropriate to treat them as "as equivalent for purposes of patent eligibility under § 101." *Bancorp Servs., L.L.C. v. Sun Life Assur. Co. of Can. (U.S.)*, 687 F.3d 1266, 1277 (Fed. Cir. 2012).

The dependent claims, all of which depend from claim 1, add additional steps or criteria that limit the scope of the claims, but they too are directed to the same idea and do not add additional limitations that would alter the *Alice* analysis. For example, claims 2 and 3 indicate whether the data block is transmitted from an internal or external source, and claims 4–6 require that some or all of the data compression happen in real time. Claim 14 requires that the single data compression encoder be "lossy" and claim 15 requires that the compressed data block be stored.[3] I have reviewed each of the dependent claims and find that if claim 1 is directed to an abstract idea and is implemented on generic hardware, the same is true of every dependent claim. When claims "require performance of the same basic process . . . they should rise or fall together." *Smart Sys.*, 873 F.3d at 1368 n.7. I will therefore not separately analyze the dependent claims.

2. *Alice* Test

The #728 patent is directed to the same idea as the #825 patent—compressing data based on the content of that data. The #728 patent is for all relevant purposes the same as the #825 patent. Both patents are directed to abstract information processing. The fact that most of the #728 patent's claims are written in system form and reference generic processors, does not make the claims less directed to the abstract processing of information. *See In re TLI Commc'ns*, 823 F.3d at 613 ("although the claims limit the abstract idea to a particular environment[,] . . . that does not make the claims any less abstract for the step 1 analysis"). Accordingly, the #728 patent is directed to ineligible subject matter for the same reasons as the #825 patent.

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[3] A "lossy" data compression technique is one in which information is lost upon compression, such that the compressed data differs from the original. #530 patent at 1:56–59. A "lossless" compression technique avoids any information loss. #530 patent at 2:4–7.

At step two of the *Alice* test, the #728 patent's claims do not contain any additional features that make them patent eligible. The claims teach nothing beyond the notion of applying the identified abstract idea on generic computer technology. For example, claim 1 of the #728 patent, consists of nothing more than a processor and compression encoders. The encoders are inherently abstract, and the processor is a generic computer component. Claim 1 describes the configuration of the processor, but the configuration simply captures the identified abstract idea for information processing. *Ultramercial*, 772 F.3d at 716 ("[C]onventional steps, specified at a high level of generality, [are] insufficient to supply an inventive concept." (citing *Alice*, at 2357)).

In sum, like the #825 patent's claims, the #728 patent's claims are directed to ineligible subject matter and lack additional features that would make them valid under § 101.

D. The #908 Patent

The #908 patent claims systems and methods for compressing data with two key characteristics. First, the #908 patent teaches compressing a data stream in two separate blocks, with each block being compressed with a different method. Second, the #908 patent requires the logical condition that the combined time of compressing and storing the compressed data be faster than storing the uncompressed data.

1. The #908 Patent Claims are Equivalent for the Purposes of § 101

The #908 patent has four independent claims. Claim 1 is a system claim, and claims 21, 25, and 29 provide three method claims for the process performed by the system in claim 1. Each of the three independent method claims contain only incidental variations on the same process. Claim 21 is simply a rewriting of claim 1 in a different form, claim 25 adds a "receiving" step to claim 21, and claim 29 is written in terms of data retrieval rather than data storage. These differences do not affect the *Alice* analysis. *See Smart Sys.*, 873 F.3d at 1368 n.7 (explaining that when claims "require performance of the same basic process . . . they should rise or fall together.").

The dependent claims of the #908 patent add limitations that are similar to those already discussed for the #825 patent. Claims 2–7, 14, 19, 22–23, and 26–28 add additional informational processing steps, specify conditions for the input or output of data analysis, or impose additional speed conditions. Claims 8–13, 20, and 30 specify either generic hardware or known compression methods. Claim 18 requires that the data blocks represent audio or video information. Claims 15–17, and 24 combine some of these same limitations. None of these additional limitations affect eligibility under § 101.

Since all the claims in the #908 patent share the same focus and no claim includes additional elements requiring separate § 101 analysis, I consider the subject-matter eligibility of all the claims together.

2. *Alice* Test

The #908 patent is directed to the combination of two abstract ideas. First, the #908 patent claims require compressing two different data blocks with different methods. This requirement is nothing more than duplicating the idea of compressing data plus an abstract logical conditional. The Federal Circuit has explained that duplication of an abstract idea does not affect the *Alice* test. *See Content Extraction*, 776 F.3d at 1348–49 ("repeating some steps" is not inventive). And requiring that the two methods are distinct is itself an abstract condition that does not redirect the claims away from the abstract analysis of information.

Second, the #908 patent requires that compression and storage together are faster than storage of the uncompressed data alone. This results-based limitation does not affect the subject-matter eligibility of the #908 patent compared to the previously considered patents. *Two-Way Media*, 874 F.3d at 1337 ("result-based functional language" is abstract). This speed requirement is simply a results-based logical condition, and nothing in the patent teaches how to achieve such a result. *Cf. Intell. Ventures I LLC v. Symantec Corp.*, 838 F.3d 1307, 1316 (Fed. Cir. 2016) ("[W]hen a claim directed to an abstract idea contains no restriction on how the result is accomplished and the mechanism is not described, although this is stated to be the essential innovation, then the claim is not patent-eligible." (internal quotation marks, alterations, and citations omitted)). The speed result is asserted without any guidance and the written description explains that such speed benefits were already well-known in the art. *See* #908 patent at 2:13-19.

Because the additional limitations of the #908 patent relative to the #825 and #728 patents are purely abstract and do not provide any inventive steps, the #908 patent's claims are invalid for the same reasons that the #825 and #728 patents' claims are invalid.

E. The #530 Patent

The #530 patent covers systems for compressing data that are almost identical to the systems claimed in the #908 patent. The additional limitation in claim 1 of the #530 patent compared to claim 1 of the #908 patent is that the #530 patent requires that the first data block be stored with an indicator of how it was compressed and that the descriptor be used to decompress that first data block.

Having already found that the #908 patent is invalid for claiming ineligible subject matter, it follows that claim 1 of the #530 patent is also invalid. Like the #908 patent, the #530 patent is directed to the abstract idea of compressing data with multiple distinct compression methods with the required result that storage is faster. Requiring that a descriptor is stored and used to decompress is simply another example of abstract data manipulation on generic hardware. *See Smart Sys. Innovations*, 873 F.3d at 1372.

The claims that depend from claim 1 are all the same as claim 1 for the purposes of the *Alice* test. These claims simply add additional abstract steps or apply the same idea on routine and conventional hardware. For example, claim 2 requires that the data accelerator store the first descriptor on the memory device, and claim 4 requires that the data accelerator retrieve the compressed data from the memory device. Claims 9–12 specify generic types of memory devices, claims 13 and 14 require known compression methods, and claims 22 and 23 limit the claims to certain types of data streams. None of these dependent claims have limitations that effect patent eligibility, and they are invalid for the same reasons that the #908 patent's claims are invalid.

The #530 patent also has three claims that were added during reexamination. Claim 24 is an independent system claim that adds steps requiring that the compressed data stream is buffered to be compatible with the bandwidth of the memory device. Nothing in the patent suggests that buffering a data stream to match the bandwidth limits of the receiving device was new or in any way unconventional. #530 patent at 2:33–37 (discussing the need for buffering in the prior art). The claim is the direct application of the logical flow chart illustrated in Figure 6b, which represents abstract data manipulation. #530 patent at 4:9–10 &

fig. 6b. Dependent claim 25 adds a requirement of appending encoder type descriptors to the data and dependent claim 26 requires compressing the data with a lossless encoder, where the rate of compression is adjusted based on the encoder's compression ratio. Neither of these additional limitations affects the § 101 analysis because both claims remain directed to the manipulation of information using generic hardware.

All the claims in the #530 patent are directed to the same idea as the #908 patent and are nothing more than directions to apply an abstract idea in conventional settings. Accordingly, I find that they are all invalid for claiming ineligible subject matter for the same reasons the #908 patent's claims are invalid. *See Content Extraction*, 776 F.3d at 1348 (explaining substantially similar claims directed to the same abstract idea can be considered together for subject-matter eligibility).

F. The #458 Patent

The #458 patent is also very similar to the #908 patent. Like the #908 patent, the #458 patent requires the compression of at least two distinct data blocks and that the time for compression and storage be faster than the time for storage without compression for the first data block. The major difference between the two patents is that the #458 patent requires two distinct lossless compression techniques. *See, e.g.*, #458 patent at claims 1, 9, and 17.

The § 101 analysis is identical for all claims of the #458 patent. Kaminario argues that claim 9 is representative, and I agree. Independent claims 1 and 9 of the #458 patent are directed to the same idea even though claim 1 is written in system form and claim 9 is written in method form. Independent claim 17 is nearly identical to claim 1, except that it is written in terms of a "computer-readable storage device" rather than in terms of a general system. Since these claims are directed to the same ideas and are merely expressed in slightly different ways, they are equivalent for *Alice* purposes. The dependent claims are also equivalent for § 101 purposes. All the dependent claims are directed to the same informational process, but merely limit the process to well-understood environments or add additional abstract steps. For instance, claim 10 extends the speed requirements to both data blocks, not only the first data block; and claim 11 specifies that the first data block must be analyzed based on its contents rather than a metadata descriptor. Having reviewed all the claims and finding them equivalent for the purposes of subject-matter eligibility, I adopt claim 9 as representative.

The #458 patent is directed to the abstract idea of compressing data using two distinct lossless compression algorithms such that the time to compress and store the first data block is less than the time to store the uncompressed data block. The restriction to lossless compression algorithms in the #458 patent does not make the patent any less directed to an abstract idea than the #908 patent is. A lossless compression algorithm, like any compression algorithm, is a mathematical procedure and is thus not patent-eligible on its own. *In re Stanford*, 2021 WL 922727, at *4.

The written description of the #458 patent explains that lossless compression algorithms were well-understood at the time of patenting. #908 patent at 1:54–59. Limiting the claimed abstract idea to certain well-known algorithms does not add an inventive step. *TLI Commc'ns*, 823 F.3d at 613 (at step two "the components must involve more than performance of well-understood, routine, conventional activities previously known to the industry" (quoting *Alice*, 573 U.S. at 225) (internal quotation marks and alterations omitted)).

In all other respects relevant to the *Alice* test, the #458 patent is identical to the #908 patent. Since the #458 patent is also directed to an abstract idea and lacks any inventive features that would make it patent eligible, I find that the #458 patent's claims cover ineligible subject matter and are invalid. *See Content Extraction*, 776 F.3d at 1348 (explaining substantially similar claims directed to the same abstract idea can be considered together for subject-matter eligibility).

G. The #751 Patent

The #751 patent is directed to another variation on the theme of using compression to achieve faster data storage. The #751 patent does not require repeating the compression step over two distinct data blocks, but it does require choosing a compression method based on the content of the data. It combines ideas from the #825 and #908 patents. The #751 patent's claims also require that the "compression uses a state machine." *See, e.g.*, #751 patent at claim 1. A state machine is an abstract model in certain compression methods. #751 patent at 9:6–10, 15:27–29.

Kaminario argues that claim 1 is representative. *Kaminario*, 19-0350, D.I. 24 at 8. I agree. The #751 patent contains two independent claims and 46 dependent claims. Although claim 1 is written in method form and claim 25 is written in system form, the two claims are identical in all material respects. The dependent claims add limitations requiring additional abstract steps or conditions relating to the receipt, processing, or transmission of data. For example, claim 2 adds the additional abstract step of transmitting both control information and the compressed data, claims 17 and 18 describe the type of table used in the state machine, and claim 21 specifies that that compression method is lossless. None of the limitations in any of the dependent claims affect the *Alice* inquiry.

I find that the #751 patent is directed to the abstract idea of compressing data with a state machine, under conditions where compressing and storing the data is faster than storing the uncompressed data and where the compression method applied to the data is based on the content of the data. The #751 patent explains that a "state machine" is an element in "Huffman or Arithmetic encoding" and that these compression methods were well known in the art. #751 patent at 9:6–10, 15:27–29. The written description teaches that each state machine is a set of nodes and pointers containing encoding tables and pointers based on the data's character sequence. #751 patent at 9:11–20. Essentially, the state machine is a form of a cipher, which makes the state machine an abstract component in a method for information processing. *See Elec. Power Grp*, 830 F.3d at 1353. Thus, the #751 patent's claims are directed to abstract information processing.

The #751 patent also does not contain any inventive features beyond the abstract idea. The #751 patent fully incorporates by reference the written description of the #825 patent, and therefore also provides that the claimed systems and methods can be performed on conventional computer hardware with well-known compression techniques. *See* #751 patent at 6:20–27; #825 patent at 2:65–66, 6:26–31, 7:7–11. The patent further explains that compression methods using state machines were well-known. #751 patent at 15:27–29. The addition of the "state machine" limitation therefore neither redirects the focus of the invention away from the claimed abstract idea nor adds any inventive step capable of transforming the claimed processes and methods into a patent-eligible invention. Thus, the #751 patent is invalid for the same reasons the previously considered patents are invalid.

H. The #204 Patent

The #204 patent claims methods for compressing and broadcasting data. Every claim in the #204 is directed to the abstract idea of compressing information before transmitting it. All the patent's claims require taking data, selecting an encoding scheme, compressing the data with that encoding scheme, and then transmitting or broadcasting the data. All of these steps are abstract because they are nothing more than information processing. *See SAP Am.*, 898 F.3d at 1167.

The #204 patent also lacks any additional features that transform the claimed idea into a patent-eligible invention. The #204 patent does not teach how to achieve faster transmission. Rather, it simply includes faster transmission or a higher compression ratio as limitations in the claims. These results-based limitations are abstract and do not change the § 101 analysis. *See Two-Way Media*, 874 F.3d at 1337. And, as with the other asserted patents, the disclosed analysis can be performed with well-understood compression methods on generic computers. #204 patent at 8:3-25; 15:13–17.

The three independent claims are informative. The claims vary in how they specify the required amount of compression. Claim 1 requires a compression ratio of 10:1. Claim 12 requires a compression ratio of at least 4:1 and adds a speed requirement that compression and transmission be faster than transmission without compression. This speed requirement is for all relevant purposes identical to the speed requirement previously discussed in the #908 patent. Claim 22 repeats the speed and compression ratio limitations of claim 12 but is restricted to financial data and requires a list mapping data fields to particular encoders. Despite these differences, the focus of all the claims is still on the abstract operations of receiving, processing, and transmitting information. The dependent claims add information processing steps and narrowing limitations, such as limiting the data to financial information or requiring the data field to include stock information. #204 patent at claims 5 and 6. As additional examples, claim 4 requires that more than one message be within a data packet, and claim 8 specifies that compression is lossy. But none of these limitations alter the focus of the claims or add any new inventive steps.

Accordingly, the #204 patent is invalid under § 101.

I. The #203 Patent

The #203 patent covers systems and methods for compression and decompression that are similar to the systems and methods claimed in the previously discussed patents.

Claims 21 and 27 recite another version of a compression system that compresses data based on the characteristics of that data and that has an output interface that provides a data token identifying the selected encoding method. Claim 21 is written as a method and claim 27 is written as a system. Dependent claims 22–26 and 28–30 add additional informational processing steps or narrow the claims to certain contexts and applications. None of these limitations affect the § 101 inquiry. These claims are another variation on the compression claims previously discussed. They are directed to the abstract idea of compressing data based on the characteristics of that data and contain no additional features that make them patent eligible.

Claims 1 and 14 cover the corresponding decompression method and system. In these claims the data token provided during compression is used to decompress the data. In other words, these claims are directed to the abstract idea of decompressing data based on a token signifying the compression method where that method was selected based on the characteristics of the data. The dependent claims again add additional information processing steps or narrow the application of the claimed idea to certain contexts and applications without providing any additional features that would make the claims patent eligible. Once again, at step one of the *Alice* test, the claims are directed to an inherently abstract procedure for transforming data. And at step two, the claims do not add any "additional features" such that the claims cover eligible subject-matter.

For these reasons, I find that the #203 patent is invalid for claiming ineligible subject matter.

J. General Discussion

The preceding discussion of the eight asserted patents can be summarized as follows. At step one of the *Alice* test, every claim in every asserted patent is directed to the concept of manipulating information using compression. Because data compression is, without more, simply a form of data analysis, the claims are directed to abstract ideas. *See SAP Am.*, 898 F.3d at 1167. At step two of the *Alice* test, a claim must provide "'additional features' to ensure 'that the [claim] is more than a drafting effort designed to monopolize the [abstract idea].'" *Alice*, 573 U.S. at 221 (alterations in original) (quoting *Mayo*, 566 U.S. at 77). But the asserted patents contain no such features. Rather, they simply apply an abstract idea on generic computers with generic techniques. This is not enough to transform the claimed idea into a patent-eligible invention. *Id.* at 225.

Realtime's principal argument is that the asserted patents are not directed to an abstract idea, because they "provide particular technological solutions to overcome technological problems specific to the field of digital data compression." *Kaminario*, 19-0350, D.I. 33 at 9. But the patents do not provide technological solutions. To the extent that the patents teach anything, it is simply the benefits of data compression. *See, e.g.,* #825 patent at 1:65–67 ("Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information."); #825 patent at 2:64–3:3 (noting that there are many known techniques for content dependent encoding); #908 patent at 2:14–19 ("First, data compression can reduce the time to transmit data by more efficiently utilizing low bandwidth data links. Second, data compression economizes on data storage and allows more information to be stored for a fixed memory size by representing information more efficiently.").

The patents do not provide a technical solution to a technical problem because they do not teach how to engineer an improved system. *See Interval Licensing LLC v. AOL, Inc.*, 896 F.3d 1335, 1345 (Fed. Cir. 2018) (explaining that a patent is not directed to a technical solution when it covers results without teaching how to obtain those results). The asserted patents allow the use of *any* compression method. *See* #908 patent 16:49–54 ("the data storage accelerator 10 employs . . . any conventional data compression method suitable for compressing data at a rate necessary for obtaining accelerated data storage); #825 patent at 7:7–11; #204 patent at 15:12–22; #203 patent at 16:30–16:42. The patents do not teach a technical solution to analyze data. *See, e.g.*, #825 patent at 16:15–24 (describing a content dependent data recognition module without any specificity). Nor do the patents teach how to achieve the claimed efficiency benefits, beyond directing the skilled artisan to apply well-known techniques. *See WhiteServe LLC v. Dropbox, Inc.*, No. 19-2334, slip op. at 9, (Fed. Cir. Apr. 26, 2021) (finding patent invalid under § 101 when "[t]he specification d[id] not [] explain the technological processes underlying the purported technological improvement."). In arguing that the patents teach a specific way of or structure for performing compression, Realtime is only able offer conclusory statements while repeating the same generic language in the claims. *See, e.g.*, *Reduxio*, 17-1676, D.I. 14 at 10–12. In short, while the patents do disclose potential challenges (e.g., the problem of selecting the best compression method for given data), they do not teach *how* to address those challenges.

Realtime argues that I must be careful to not oversimply the patents, because "all inventions at some level embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas." *Mayo.,* 566 U.S. at 71 (2012). I do not disagree with the premise of this argument; but, in this case, the asserted patents are written at a high level of generality and the identified abstract ideas fairly capture the focus of the claims. Realtime's own descriptions of the patents are substantially similar to the abstract ideas I find the patents directed to. For example, Realtime describes the #728 patent as being directed to "digital data compression/decompression utilizing two encoders[/decoders] (e.g., content dependent and content independent) to compress/decompress data blocks based on an analysis of the specific content of the data." *Tegile Systems,* No. 18-1267, D.I. 20 at 7. Even under Realtime's own characterization of the asserted patents, they are directed to the abstract analysis of data.

The asserted patents are not, as Realtime argues, "highly specific." *Kaminario*, 19-0350, D.I. 33 at 14. The Federal Circuit recently remarked in *In re Stanford* that it was "hard to imagine a patent claim that recites hardware limitations in more generic terms," because it required a "computer" with a "processor" and "memory." That observation applies equally here. *See, e.g.*, #458 patent at claim 1 (reciting a "memory device" and "one or more processors"). Indeed, in this case many of the asserted patents do not even require generic computer components. The #825 patent's claims are written even more generically than the claims at issue in *In re Stanford*. They require "associating," "analyzing," "identifying," and "compressing" without mentioning any hardware to implement these processes. Similarly, in the #530 patent, claim 1 requires a "memory device" and a "data accelerator," neither of which are limited to computer devices. (The patent describes a "memory device" as covering "all forms and manners of memory devices," and the "data accelerator" is functionally defined and could be nearly anything. #530 patent at 2:51, 5:8–13.) "Claims directed to generalized steps to be performed on a computer using conventional computer activity are not patent eligible." *Internet Pats.*, 790 F.3d at 1348–49; *see also WhiteServe*, slip op.

at 8 (reiterating that claims invoking computer functionality to manipulate data are subject-matter ineligible).[4]

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[4] The cases cited by Realtime where patents were found eligible under § 101 are inapposite because the patents in those cases were "necessarily rooted in computer technology." *DDR Holdings, LLC v. Hotels.com, L.P.*, 773 F.3d 1245, 1257 (Fed. Cir. 2014). In *Core Wireless Licensing S.A.R.L. v. LG Electronics, Inc.* the patents were directed to improvements in graphical user interfaces for electronic devices with small screens. 880 F.3d 1356, 1362 (Fed. Cir. 2018). In *Enfish* the claimed invention provided a new method to construct databases. 822 F.3d at 1335–36. In *Visual Memory LLC v. NVIDIA Corp.* the patents taught a new, particularized memory system. 867 F.3d 1253, 1259–60 (Fed Cir. 2017). And in *Finjan, Inc. v. Blue Coat Systems, Inc.* the asserted patent was directed to improvements in computer virus scanning, which is a concern unique to computers. 879 F.3d 1299, 1305 (Fed. Cir. 2018).

Realtime also relies heavily on Magistrate Judge Love's opinions regarding the #530 and #908 patents and their adoption by judges in other districts in different proceedings. *See* Order Adopting Report and Recommendation of United States Magistrate Judge, *Realtime Data, LLC v. Actian Corp.*, 2016 WL 11089485 (E.D. Tex. Jan. 21, 2016); Report and Recommendation of United States Magistrate Judge, *Realtime Data, LLC v. Actian Corp.*, 2016 WL 11089485 (E.D. Tex. Nov. 30, 2015); Report and Recommendation of United States Magistrate Judge, *Realtime Data, LLC v. Carbonite, Inc.*, 2017 WL 4693969 (E.D. Tex. Sept. 20, 2017). I disagree with Magistrate Judge Love's conclusions, and note that since those opinions were issued, the Federal Circuit has reaffirmed that the processing of information, without more, is not patent eligible. *See, e.g.*, *Ericsson Inc. v. TCL Commc'n Tech. Holdings Ltd.*, 955 F.3d 1317, 1327–28 (Fed. Cir. 2020) (rejecting plaintiff's argument that the claims solved a specific computer problem because the claims lack specificity and were not particularized to any technical environment); *Customedia Techs., LLC v. Dish Network Corp.*, 951 F.3d 1359, 1364 (Fed. Cir. 2020) (explaining that a patent is not directed to a patent-eligible improvement in computer functionality when computers are invoked as the tools for abstract processes).

The patents' lack of a technical solution is highlighted by the claims' focus on results and benefits without teaching how to achieve those results and benefits. The faster speed and compression ratio limitations of the #530, #204, #908, #751, and #458 patents are paradigmatic examples of results-based claiming. And assertions of beneficial results do not allow a claim directed to an abstract idea to bypass the requirements of § 101. *Elec. Power Grp.*, 830 F.3d at 1351 (holding that claims on a "desirable information-based result" that are "not limited to inventive means of achieving th[at] result" are invalid under § 101); *Apple, Inc. v. Ameranth, Inc.*, 842 F.3d 1229, 1241 (Fed. Cir. 2016) (finding patent claims directed to abstract ideas because they did "not claim a particular way of programming or designing . . . but instead merely claim the resulting systems."); *Affinity Labs of Texas, LLC v. Amazon.com Inc.*, 838 F.3d 1266, 1269 (Fed. Cir. 2016) (finding claims abstract because they did "no more than describe a desired function or outcome, without providing any limiting detail that confines the claim to a particular solution to an identified problem.").

While it might be the case that the patents' claims describe systems and methods that are useful when applied on computers, that fact does not by itself make the claims patent eligible. Many ideas are useful, but their utility does not make them patentable. Einstein's theory of relativity is useful, but it is not patent eligible. *Mayo*, 566 U.S. at 71 ("Einstein could not patent his celebrated law that $E=mc^2$; nor could Newton have patented the law of gravity.").

Here, the utility of the ideas to which the asserted patents are directed does not change the fact that the patents are directed to abstract ideas. *See Secured Mail Sols. LLC v. Universal Wilde, Inc.*, 873 F.3d 905, 910 (Fed. Cir. 2017) ("The fact that an [idea] can be used to make a process more efficient, however, does not necessarily render an abstract idea less abstract."); *Voit Techs. LLC v. Del-Ton, Inc.*, 757 F. App'x 1000, 1003–04 (Fed. Cir. 2019) ("claims directed to 'improved speed or efficiency inherent with applying the abstract idea on a computer' are insufficient to demonstrate an inventive concept" (quoting *Intell. Ventures I LLC v. Capital One Bank (USA)*, 792 F.3d 1363, 1367 (Fed. Cir. 2015)). This is a case where "patent-ineligible abstract ideas are plainly identifiable and divisible from the generic computer limitations recited by the remainder of the claim." *DDR Holdings*, 773 F.3d at 1256 (noting that such patents are subject-matter ineligible).

Efficiency gains are not the same as a technical solution to a technical problem. *DDR Holdings* teaches that because it can be difficult to distinguish between abstract ideas and patent-eligible inventions in the realm of computer software, one test is to ask if the patent teaches improvements that resolve problems unique to computers. 773 F.3d at 1255–59 (finding a patent claimed eligible subject matter because "the claimed solution is necessarily rooted in computer technology in order to overcome a problem specifically arising in the realm of computer networks"). Since such technical problems *only* exist in the context of computers, solutions to those problems are effectively directed to improved computers, which are not abstract. But here the claims are not directed to a problem that is unique to digital computers. In other words, they are not directed to improved computers but to various ideas involving compression that may be usefully applied by computers.

Realtime argues that its claims "are necessarily directed to improved systems of **digital data compression**." *Reduxio*, No. 17-1676, D.I. 14 at 13 (emphasis in original). But digital data compression is abstract. Compression has a long history outside of computer technology. Everyday uses of compression include shorthand, abbreviations, the repeat symbol in musical notation, and scientific notation. These methods of compression are chosen in part based on the content of the information being compressed. Problems related to the bandwidth of information transfer and receipt are inevitable for any form of information exchange, including exchanges of digital data, which is simply the representation of information in the form of "0"s and "1"s. The digital compression described in the asserted patents involves applying an (unspecified) algorithm to that sequence of "0"s and "1"s. Nothing prevents this type of analysis from being done on pen and paper.

Realtime relies on the patents' statement that "**digital data** is thus a representation of data that [is] **not easily recognizable to humans** in its native form." *Reduxio*, No. 17-1676, D.I. 14 at 14 (emphasis and alterations in original) (citing #908 patent at 1:35–37; #728 patent at 1:52–54). But the fact that digital data is not easily recognizable does not mean that a human is incapable of analyzing it or that it is inherently rooted in computer technology. Indeed, the written descriptions of the patents, while sometimes focusing on computer applications, also recognize the pervasive nature of information exchange and attempt to reach any and all such communication. For instance, the #751 patent describes itself as "universally applicable to all forms of data communication." #751 patent at 1:43–44; *see also* #204 patent at 8:29–33 ("It should be noted that the techniques, methods, and algorithms and teachings of the present invention are representative and the present invention may be applied to any financial network, trading system, data feed or other information system."). The problems of information storage and transmission are not limited to a particular technological environment, and so an idea that addresses such problems generally is not a technological solution. *See DDR Holdings*, 773 F.3d at 1257.

At an oral argument, Realtime agreed that claim 25 of the #751 patent, which it treated as representative, was directed to "analyz[ing] the content of a data block to identify a parameter or attribute or value of that block" where the analysis is not "based solely on reading a descriptor." Hr'g at 26:18–21, Jul. 21, 2019. Realtime was then unable to cogently articulate how this focus was anything more than the abstract analysis of information. When I pressed counsel during argument to "show me where [claim 25 is] not abstract," he replied: "So, you're analyzing that data block in a specific fashion, and by that what I mean is, you are looking at the content of the data block itself, not at a descriptor." *Id.* at 27:3–8. But looking at the content of the data as opposed to the data's descriptor is an abstract concept. A human being can look at the data's content instead of its descriptor. Counsel did not identify, and the patent does not teach, a technical solution that makes it possible for a computer to look at content as opposed to a descriptor.

Realtime also raises an argument based on its proposed claim constructions. Realtime proposes the following constructions:

- "compressing" / "compressed" / "compression": representing / represented / representation of data with fewer bits
- "descriptor": recognizable digital data
- "data stream": one or more data blocks transmitted in sequence
- "data block": a single unit of data, which may range in size from individual bits through complete files or collection of multiple files
- "analyze": directly examine

D.I. 33 at 36. Realtime argues that its proposed constructions "confirm" that the asserted patents are "focused" on "a technical sub-species of digital data compression." D.I. 33 at 36. But "[t]he mere fact that Defendants' proposed constructions might be more specific and therefore limited to a particular technological environment does not transform an otherwise abstract idea into a patent-eligible application." *Reese v. Sprint Nextel Corp.*, 774 F. App'x 656, 660 (Fed. Cir. 2019), *cert. denied*, 140 S. Ct. 2507 (2020). Realtime's proposed constructions confirm that the claims are directed to data analysis. And Kaminario, the sole defendant against which Realtime has identified particular constructions, does not dispute Realtime's constructions for the purposes of its motion. D.I. 34 at 19–20. Accordingly, there is no claim construction dispute relevant to eligibility, and therefore I do not need to engage in claim construction before ruling on the pending motions. *Cleveland Clinic*, 859 F.3d at 1360 ("[Plaintiffs] provided no proposed construction of any terms . . . that would change the § 101 analysis. Accordingly, it was appropriate for the district court to determine that the testing patents were ineligible under § 101 at the motion to dismiss stage.").

Realtime also emphasizes dicta in *DDR Holdings* in which the Federal Circuit remarked that the claims at issue were not "as technologically complex as an improved, particularized method of digital data compression." *DDR Holdings*, 773 F.3d at 1259. But this statement does not mean that all patents related to compression are subject-matter eligible. The asserted patents do not in fact offer a "technologically complex . . . improved, particularized method" for compression but instead recite abstract ideas with only the most general directions to apply those ideas.

Finally, Realtime argues that even if every individual element of the claims were well-understood or conventional at the time of patenting, the combination of those elements is not. *Tegile Systems*, No. 18-1367, D.I. 20 at 19 (citing *BASCOM Global Internet Servs. v. AT&T Mobility LLC*, 827 F.3d 1341, 1350 (Fed. Cir. 2016)). But simply combining understood steps and generic hardware in a logical, straightforward sequence in order to implement an abstract idea does not provide an "inventive concept." In *BASCOM*, the arrangement of elements was essential to the claimed invention, and the Federal Circuit explained that the "particular arrangement of elements [was] a technical improvement over [the] prior art." *BASCOM*, 827 F.3d at 1350. But the asserted patents here do not provide a technical improvement. Rather they "merely recite [an] abstract idea . . . along with the requirement . . . to perform it on a set of generic computer components." *Id.* *BASCOM* explained that "[s]uch claims [do] not contain an inventive concept." *Id.* Even when considered as an "ordered combination," the asserted patents lack the additional features requires at step two of the *Alice* inquiry. *Alice*, 573 U.S. at 217.

In short, the asserted patents are nothing "more than a drafting effort designed to monopolize" abstract ideas for data compression. *Mayo*, 566 U.S. at 77 (2012). Accordingly, they are invalid under § 101.

IV. CONCLUSION

For the reasons stated above, I find that all claims of the asserted patent are invalid under § 101 for lack of subject-matter eligibility. Accordingly, I will grant Defendants' motions to the extent they seek dismissal of the operative complaints on § 101 grounds.

Realtime has requested leave to amend some of its operative complaints, and accordingly I will give it 14 days to do so in each case.

The Court will issue Orders consistent with this Memorandum Opinion.

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

Realtime Data LLC, Plaintiff, v. Array Networks Inc., et al., Defendants.	Civil Action No. 17-0800-CFC CONSOLIDATED
Realtime Data LLC, Plaintiff, v. Spectra Logic Corp., Defendant.	Civil Action No. 17-0925-CFC

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MEMORANDUM OPINION

August 23, 2021
Wilmington, Delaware

COLM F. CONNOLLY
CHIEF JUDGE

Plaintiff Realtime Data LLC has sued Defendants for infringement of various combinations of seven patents it holds: U.S. Patent Nos. 7,415,530 (the #530 patent), 8,717,203 (the #203 patent), 8,933,825 (the #825 patent), 9,054,728 (the #728 patent), 9,116,908 (the #908 patent), 9,667,751 (the #751 patent), and 10,019,458 (the #458 patent). The asserted patents pertain to systems and methods involving data compression.

Pending before me are motions to dismiss pursuant to Federal Rule of Civil Procedure 12(b)(6) filed by the consolidated Defendants and Spectra Logic. D.I. 78;[1] *Realtime Data LLC v. Spectra Logic Corp.*, No. 17-0925, D.I. 68. Defendants argue that I should dismiss Realtime's complaints because the asserted patents are invalid under 35 U.S.C. § 101 for failing to claim patentable subject matter.

I. BACKGROUND

A. Asserted Patents

The asserted patents all relate to methods and systems for compression and decompression of data. The asserted patents come from three patent families. The #203, #825, and #728 patents share one written description; the #530, #908, and

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[1] All citations are to *Realtime Data v. Array Networks, Inc.*, No. 17-800 unless otherwise noted.

#458 patents share another written description; and the #751 has a distinct written description. The #751 patent is titled "Data Feed Acceleration." The #530, #908, and #458 patents are titled "Systems and Methods for Accelerated Data Storage and Retrieval." And the #203, #825, and #728 patents are titled "Data Compression Systems and Methods." Not every patent is asserted against every defendant, but collectively Defendants challenge the validity of all asserted patents.

Claim 1 of the #751 patent recites

> [a] method for compressing data comprising:
> analyzing content of a data block to identify a parameter, attribute, or value of the data block that excludes analyzing based solely on reading a descriptor;
> selecting an encoder associated with the identified parameter, attribute, or value;
> compressing data in the data block with the selected encoder to produce a compressed data block, wherein the compressing includes utilizing a state machine; and
> storing the compressed data block;
> wherein the time of the compressing the data block and the storing the compressed data block is less than the time of storing the data block in uncompressed form.

Clam 1 of the #530 patent recites

> [a] system comprising:
> a memory device; and
> a data accelerator, wherein said data accelerator is coupled to said memory device, a data stream is received by said data accelerator in received form, said data stream includes a first data block and a

> second data block, said data stream is compressed by said data accelerator to provide a compressed data stream by compressing said first data block with a first compression technique and said second data block with a second compression technique, said first and second compression techniques are different, said compressed data stream is stored on said memory device, said compression and storage occurs faster than said data stream is able to be stored on said memory device in said received form, a first data descriptor is stored on said memory device indicative of said first compression technique, and said first descriptor is utilized to decompress the portion of said compressed data stream associated with said first data block.

Claim 1 of the #908 patent recites

> [a] system comprising:
> a memory device; and
> a data accelerator configured to compress: (i) a first data block with a first compression technique to provide a first compressed data block; and (ii) a second data block with a second compression technique, different from the first compression technique, to provide a second compressed data block;
> wherein the compressed first and second data blocks are stored on the memory device, and the compression and storage occurs faster than the first and second data blocks are able to be stored on the memory device in uncompressed form.

Claim 9 of the #458 patent recites

> [a] method for accelerating data storage comprising:
> analyzing a first data block to determine a parameter of the first data block;
> applying a first encoder associated with the determined parameter of the first data block to create a first

> encoded, data block wherein the first encoder utilizes a lossless dictionary compression technique;
>
> analyzing a second data block to determine a parameter of the second data block;
>
> applying a second encoder associated with the determined parameter of the second data block to create a second encoded data block, wherein the second encoder utilizes a lossless compression technique different than the lossless dictionary compression technique; and
>
> storing the first and second encoded data blocks on a memory device, wherein encoding and storage of the first encoded data block occur faster than the first data block is able to be stored on the memory device in unencoded form.

Claim 14 of the #203 patent recites

> [a] system for decompressing, one or more compressed data blocks included in one or more data packets using a data decompression engine, the one or more data packets being transmitted in sequence from a source that is internal or external to the data decompression engine, wherein a data packet from among the one or more data packets comprises a header containing control information followed by one or more compressed data blocks of the data packet the system comprising:
>
> a data decompression processor configured to analyze the data packet to identify one or more recognizable data tokens associated with the data packet, the one or more recognizable data identifying a selected encoder used to compress one or more data blocks to provide the one or more compressed data blocks, the encoder being selected based on content of the one or more data blocks on which a compression algorithm was applied;
>
> one or more decompression decoders configured to decompress a compressed data block from among

> the one or more compressed data blocks associated with the data packet based on the one or more recognizable data tokens; wherein:
>
> the one or more decompression decoders are further configured to decompress the compressed data block utilizing content dependent data decompression to provide a first decompressed data block when the one or more recognizable data tokens indicate that the data block was encoded utilizing content dependent data compression; and
>
> the one or more decompression decoders are further configured to decompress the compressed data block utilizing content independent data decompression to provide a second decompressed data block when the one or more recognizable data tokens indicate that the data block was encoded utilizing content independent data compression; and
>
> an output interface, coupled to the data decompression engine, configured to output a decompressed data packet including the first or the second decompressed data block.

Claim 18 of the #825 recites

> [a] method comprising:
>
> associating at least one encoder to each one of a plurality of parameters or attributes of data:
>
> analyzing data within a data block to determine whether a parameter or attribute of the data within the data block is identified for the data block;
>
> wherein the analyzing of the data within the data block to identify a parameter or attribute of the data excludes analyzing based only on a descriptor that is indicative of the parameter or attribute of the data within the data block;
>
> identifying a first parameter or attribute of the data of the data block;

> compressing, if the first parameter or attribute of the data is the same as one of the plurality of parameter or attributes of the data, the data block with the at least one encoder associated with the one of the plurality of parameters or attributes of the data that is the same as the first parameter or attribute of the data to provide a compressed data block; and
>
> compressing, if the first parameter or attribute of the data is not the same as one of the plurality of parameters or attributes of the data, the data block with a default encoder to provide the compressed data block.

Claim 25 of the #728 patent recites

> [a] computer implemented method comprising:
>
> analyzing, using a processor, data within a data block to identify one or more parameters or attributes of the data within the data block;
>
> determining, using the processor, whether to output the data block in a received form or in a compressed form; and
>
> outputting, using the processor, the data block in the received form or the compressed form based on the determination,
>
> wherein the outputting the data block in the compressed form comprises determining whether to compress the data block with content dependent data compression based on the one or more parameters or attributes of the data within the data block or to compress the data block with a single data compression encoder; and
>
> wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based only on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block.

B. Procedural History

This is the third time I am ruling on the subject-matter eligibility of some of these patents. The first time was an oral ruling on motions to dismiss brought by Aryaka, Panzura, Fortinet, and Reduxio. I found the #728, #908, #530, and #751 patents invalid under § 101. *Reduxio*, No. 17-1676, D.I. 46 (oral order). These four patents were the only patents before me at that hearing. Realtime appealed, and the Federal Circuit vacated my prior ruling as insufficient. *Realtime Data LLC v. Reduxio Sys., Inc.*, 831 F. App'x 492, 499 (Fed. Cir. 2020). The Federal Circuit cautioned that "[n]othing in [its] opinion should be read as opining on the relative merits of the parties' arguments or the proper resolution of the case." *Id.*

I subsequently issued a written opinion finding all the asserted patents invalid for claiming ineligible subject-matter.[2] D.I. 41. I found the #825 and #728 patents directed to the abstract idea of compressing data based on the content of that data. D.I. 41 at 20, 27. I found the #908 and #530 patents directed to the combination of the abstract idea of compressing two different data blocks with different methods and the logical condition that compression and storage together are faster than storage of the uncompressed data alone. D.I. 41 at 30. I found that combination to itself be an abstract idea. D.I. 41 at 30. I found that the #458

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[2] I also found U.S. Patent No 8,717,204 (the #204 patent) invalid, but it is no longer asserted in Realtime's amended complaints.

patent is directed to the abstract idea of compressing data using two distinct lossless compression algorithms such that the time to compress and store the first data block is less than the time to store the uncompressed data block. D.I. 41 at 34. I found the #751 patent directed to the abstract idea of compressing data with a state machine under conditions where compressing and storing the data is faster than storing the uncompressed data and where the compression method applied to the data is based on the content of the data. D.I. 41 at 36. And lastly, I found the #203 patent directed to the abstract idea of compressing or decompressing data based on the characteristics of that data where a token is used to signify the compression method used. D.I. 41 at 40.

I gave Realtime the opportunity to file amended complaints, and it did. Defendants have renewed their motion to dismiss. The case against Spectra Logic has not been consolidated with the other case, and so Spectra Logic moves for dismissal separately but joins the other Defendants in briefing. *See* No. 17-925, D.I. 65; No. 17-925, D.I. 68; No. 17-925, D.I. 69; No. 17-925, D.I. 71.

II. LEGAL STANDARDS

A. Legal Standards for Stating a Claim

To state a claim on which relief can be granted, a complaint must contain "a short and plain statement of the claim showing that the pleader is entitled to relief." Fed. R. Civ. P. 8(a)(2). Detailed factual allegations are not required, but the complaint must include more than mere "labels and conclusions" or "a formulaic recitation of the elements of a cause of action." *Bell Atl. Corp. v. Twombly*, 550 U.S. 544, 555 (2007) (citation omitted). The complaint must set forth enough facts, accepted as true, to "state a claim to relief that is plausible on its face." *Id.* at 570. A claim is facially plausible "when the plaintiff pleads factual content that allows the court to draw the reasonable inference that the defendant is liable for the misconduct alleged." *Ashcroft v. Iqbal*, 556 U.S. 662, 678 (2009) (citation omitted). Deciding whether a claim is plausible is a "context-specific task that requires the reviewing court to draw on its judicial experience and common sense." *Id.* at 679 (citation omitted).

When assessing the merits of a Rule 12(b)(6) motion to dismiss, a court must accept as true all factual allegations in the complaint and in documents explicitly relied upon in the complaint, and it must view those facts in the light most favorable to the plaintiff. *See Umland v. Planco Fin. Servs.*, 542 F.3d 59, 64 (3d Cir. 2008).

B. Legal Standards for Patent-Eligible Subject Matter

Section 101 of the Patent Act defines patent-eligible subject matter. It provides: "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title." 35 U.S.C. § 101.

There are three judicially created limitations on the literal words of § 101. The Supreme Court has long held that laws of nature, natural phenomena, and abstract ideas are not patentable subject matter. *Alice Corp. Pty. v. CLS Bank Int'l*, 573 U.S. 208, 216 (2014). These exceptions to patentable subject matter arise from the concern that the monopolization of "these basic tools of scientific and technological work" "might tend to impede innovation more than it would tend to promote it." *Id.* (internal quotation marks and citations omitted). Abstract ideas include mathematical formulas and calculations. *Gottschalk v. Benson*, 409 U.S. 63, 71–72 (1972).

"[A]n invention is not rendered ineligible for patent [protection] simply because it involves an abstract concept[.]" *Alice*, 573 U.S.. at 217. "[A]pplication[s] of such concepts to a new and useful end . . . remain eligible for patent protection." *Id.* (internal quotation marks and citations omitted). But in order "to transform an unpatentable law of nature [or abstract idea] into a patent-eligible application of such law [or abstract idea], one must do more than simply state the law of nature [or abstract idea] while adding the words 'apply it.'" *Mayo Collaborative Servs. v. Prometheus Lab'ys, Inc.*, 566 U.S. 66, 71 (2012) (emphasis omitted).

In *Alice*, the Supreme Court established a two-step framework by which courts are to distinguish patents that claim eligible subject matter under § 101 from patents that do not claim eligible subject matter under § 101. The court must first determine whether the patent's claims are drawn to a patent-ineligible concept—i.e., are the claims directed to a law of nature, natural phenomenon, or abstract idea? *Alice*, 573 U.S. at 217. If the answer to this question is no, then the patent is not invalid for teaching ineligible subject matter. If the answer to this question is yes, then the court must proceed to step two, where it considers "the elements of each claim both individually and as an ordered combination" to determine if there is an "inventive concept—*i.e.*, an element or combination of elements that is sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the [ineligible concept] itself." *Id.* at 217–18 (alteration in original) (internal quotations and citations omitted).[3]

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[3] The Court in *Alice* literally said that this two-step framework is "for distinguishing patents that claim laws of nature, natural phenomena, and abstract ideas from those that claim patent-eligible applications of those concepts." 573 U.S. at 217. But as a matter of logic, I do not see how the first step of the *Alice/Mayo* framework can distinguish (or even help to distinguish) patents in terms of these two categories (i.e., the categories of (1) "patents that claim laws of nature, natural phenomena, and abstract ideas" and (2) patents "that claim patent-eligible applications of [laws of nature, natural phenomena, and abstract ideas]"). *Both* categories *by definition* claim laws of nature, natural phenomena, and abstract ideas; and only one of *Alice*'s steps (i.e., the second, "inventive concept" step) could distinguish the two categories. I therefore understand *Alice*'s two-step framework to be the framework by which courts are to distinguish patents that

Issued patents are presumed to be valid, but this presumption is rebuttable. *Microsoft Corp. v. i4i Ltd. Partnership*, 564 U.S. 91, 96 (2011). Subject-matter eligibility is a matter of law, but underlying facts must be shown by clear and convincing evidence. *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1368 (Fed. Cir. 2018).

III. DISCUSSION

I previously considered whether the asserted patents were invalid under § 101 and found them subject-matter ineligible. D.I. 41 at 11–53. In summary, I found at step one that each of the patents are directed to related abstract ideas involving the compression of data. Data compression is an example of abstract information processing. *RecogniCorp, LLC v. Nintendo Co.*, 855 F.3d 1322, 1327 (Fed. Cir. 2017) ("A process that start[s] with data, add[s] an algorithm, and end[s] with a new form of data [is] directed to an abstract idea."). In order to be patentable claims must do more than simply process data. *See Elec. Power Grp., LLC v. Alstom S.A.*, 830 F.3d 1350, 1353–54 (Fed. Cir. 2016) (explaining claims that "analyz[e] information . . . by mathematical algorithms, without more" are directed to abstract ideas). The asserted claims lack this something more. This is a case where "although written in technical jargon, a close analysis of the claims

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claim eligible subject matter under § 101 from patents that do not claim eligible subject matter under § 101.

reveals that they require nothing more than . . . abstract idea[s]" for the algorithmic processing of information. *Ericsson Inc. v. TCL Commc'n Tech. Holdings Ltd.*, 955 F.3d 1317, 1326 (Fed. Cir. 2020), *cert. denied sub nom. Ericsson Inc. v. TCL Commc'n*, 209 L. Ed. 2d 752 (May 17, 2021).

At step two, I found that the patents do not contain any inventive step other than the abstract ideas to which the patents are directed. The patents' written description makes clear that the only inventions are the ineligible abstract ideas. *See* #530 patent at 4:47–61, 5:20–24, 11:5–10, 40–46, 14: 19–23 (describing how the invention can be implanted on generic technology using any compression technique "currently well known within the art"), #203 patent at 6:24–41, 7:7–11, 9:24–26, 12:50–54, 14:66–15:3, 16:30–37 (same), #751 patent at 6:20–27, 7:17–25 (incorporating the parents of the #530 and #203 patents by reference). The patents simply apply the claimed abstract ideas on generic hardware in a straightforward manner. This does not constitute an inventive step sufficient for subject-matter eligibility. *Alice*, 573 U.S. 208 at 223–24 (explaining an abstract idea is not patent eligible when simply applied on generic computer hardware).

In considering the renewed motions to dismiss, I will first examine whether there are any material differences in Realtime's complaints. Then, I consider whether Realtime has presented new legal arguments that require me to reconsider my original analysis.

A. New Pleadings

I first consider whether any of the new pleadings in Realtime's amended complaints requires me to change my prior analysis. Realtime argues that it has introduced new factual pleadings relevant to § 101 that preclude dismissal, because its "amended complaints contain numerous detailed factual allegations demonstrating the inventiveness of each of the patents . . . ." D.I. 91 at 34. The new paragraphs in the complaints assert that certain claims are not representative, offer proposed claim constructions, repeat numerous quotations from the patents' written descriptions, summarize the results of other proceedings involving the asserted patents, assert that the claims cannot be performed by hand, offer conclusory statements, and contain legal argumentation. *See, e.g.*, D.I. 53 ¶¶ 10–15, 20–32. None of these changes impact the § 101 inquiry for the following reasons.

1. Representative Claims

In my previous opinion, I explained my decision to adopt certain claims as representative and to treat each patents' claims as equivalent for the purpose of § 101 eligibility. D.I. 41 at 15–18, 26–27, 29–30, 32–34, 36, 39–40. In short, the claims of each patent can be considered together for the purposes of the *Alice* test, because the independent claims reflect the same ideas written in different ways and because the dependent claims do not add limitations that affect eligibility under §

101. *See Content Extraction & Transmission LLC v. Wells Fargo Bank*, 776 F.3d 1343, 1348 (Fed. Cir. 2014).

Subsequently, Realtime amended its complaints to emphasize the fact that the claims do not have identical limitations. *See, e.g.*, D.I. 43 ¶ 26 ("Claim 1 is not representative of all claims of the [#]728 patent. For example, claim 24 claims the use of a "default" compression encoder."), ¶ 28 ("The dependent claims contain limitations not found in the independent claims."). Realtime also argues that Defendants have failed to uniquely explain the lack of subject-matter eligibility for all 211 asserted claims. D.I. 92 at 35.

Realtime's new pleadings do not change my prior analysis. Realtime simply provides quotations from the asserted claims and provides conclusory assertions that these limitations must be considered separately for the purposes of § 101. But Realtime does not explain why these limitations are relevant to subject-matter eligibility, and I have already concluded otherwise. Since Realtime provides neither affirmative argument nor new factual pleadings relevant to representativeness, there is no need to revisit my prior analysis.

2. Claim Construction

Realtime asserts that its proposed claim constructions preclude a decision on subject-matter eligibility at this time because the proposed constructions would, if adopted, confirm that that the patents are directed to technological solutions. D.I.

91 at 36. But I already considered five of the six suggested claim constructions in my prior opinion. *See* D.I. 41 at 50–51 (discussing the "compressing" terms, "descriptor," "data stream," "data block," and "analyze"). The same constructions were proposed as part of the complaint against Kaminario that was before me at the time. *See Realtime Data, LLC v. Kaminario*, No. 19-cv-350, D.I. 18 ¶ 9 (D. Del. Aug. 16, 2019). I concluded that the proposed claim constructions did not require postponing a decision on § 101 eligibility, because the constructions did not change the *Alice* inquiry. D.I. 41 at 51. I also noted that the proposed constructions only "confirm that the claims are directed to data analysis." D.I. 41 at 50–51.

The only new proposal is to construe "data accelerator" as "hardware or software with one or more compression encoders" in the #530 and #908 patents. *See, e.g.*, D.I. 43 ¶ 48. Not only does this broad construction not impact the § 101 analysis, it also effectively concedes that a "data accelerator" does not require any components beyond a generic processer that can run software. Once again, I conclude that the proposed claim constructions do not impact the *Alice* test, and, accordingly, I simply choose to adopt Realtime's proposed constructions for the purposes of these motions to dismiss.

3. Additional Citations to the Patents

Realtime quotes extensively from the asserted patents in its amended complaints. *See, e.g.*, D.I. 43 ¶¶ 20–24, 28. Adding quotations from the asserted patents' written descriptions does not create a factual dispute (or otherwise alter my analysis), because the patents were already in the record before me. To the extent that the pleadings interpret the text of the patents, I am free to look directly to the patents. *Secured Mail Sols. LLC v. Universal Wilde, Inc.*, 873 F.3d 905, 913 (Fed. Cir. 2017) ("In ruling on a 12(b)(6) motion, a court need not accept as true allegations that contradict matters properly subject to judicial notice or by exhibit, such as the claims and the patent specification." (internal quotation marks omitted)). I previously considered the written descriptions in my earlier ruling. These amendments to the complaints are immaterial.

Realtime also argues that the file histories for the patents show that the claimed inventions were not well-understood, routine, and conventional, because the U.S. Patent and Trademark Office "considered hundreds of references." *See, e.g.*, D.I. 43 ¶¶ 25, 60, 95. But the Patent and Trademark Office has always reviewed prior art in the course of issuing a patent before a district court rules on the patent's § 101 eligibility. The number of references the Patent and Trademark Office examined is of no consequence.

4. Non-Binding Rulings from Other Districts

Realtime has included in its complaints the outcomes of other cases involving the same patents. *See, e.g.*, D.I. 43 ¶¶ 10–13. Realtime previously presented these same arguments in briefing and in its First Amended Complaint against Kaminario. No. 19-cv-350, D.I. 18 ¶¶ 10–14; D.I. 33 at 36–37. In my prior opinion, I considered these non-binding rulings. D.I. 41 at 45 n.4. I conducted an independent analysis and reached a different conclusion.

5. Statements in Unrelated Patents

Realtime has pled that patents filed in 2012 and 2013 by Altera and Western Digital "admitted that there was still a technical problem associated with computer capacity and a need for a more efficient compression system." D.I. 43 ¶¶ 29–31. I previously considered these pleadings as they were included in the First Amended Complaint against Kaminario. *See* No. 19-cv-350, D.I. 18 ¶¶ 25–27. Even taking as true that there was a technical problem associated with compression, that does not imply that the claims in the asserted patents are directed to a subject-matter eligible solution. I must consider the asserted patents based on what they claim and statements in unrelated patents do not change that analysis.

6. Pen and Paper Argument

Realtime now pleads that the asserted claims cannot be carried out on "pen and pencil." *See, e.g.*, D.I. 43 ¶¶ 18, 50. Even assuming, without deciding, that this is a factual assertion I must take as true, it does not change my analysis. A patent can be directed to an abstract idea even if it cannot literally be performed on pen and paper. *FairWarning IP, LLC v. Iatric Sysc.*, 839 F.3d 1089, 1098 (Fed. Cirl. 2016) ("[T]he inability for the human mind to perform each claim step does not alone confer patentability."). Regardless of whether the asserted patents are limited to being carried out in a computational environment, they are still directed to the type of abstract data manipulation that is not patent eligible. Otherwise, a patentee could ensure subject-matter eligibility simply by including as a limitation that the invention cannot be performed on pen and paper or in the human mind. This is inconsistent with governing law. *See Intell. Ventures I LLC v. Cap. One Bank (USA)*, 792 F.3d 1363, 1366 (Fed. Cir. 2015) ("An abstract idea does not become nonabstract by limiting the invention to a particular field of use or technological environment.").

7. Conclusory Statements

The remaining amendments to the complaints consist of conclusory statements and legal argument. *See, e.g.*, D.I. 43 ¶ 14 ("[T]he patents are directed to patent eligible subject matter."), ¶ 17 ("The claims of the patent are not abstract . . . ."), ¶ 27 ("The claims do not merely recite a result.").[4] I am to ignore such

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[4] Some of the legal conclusions in the complaint are assertions of novelty. *See, e.g.*, D.I. ¶ 21 ("The [#]728 patent solves the foregoing problems with novel technological solutions . . . ."). But novelty under § 102 is a separate issue than subject-matter eligibility under § 101. A novel abstract idea is still a patent-

pleadings in ruling on a motion to dismiss. *Iqbal*, 556 U.S. at 678 ("[W]e are not bound to accept as true a legal conclusion couched as a factual allegation.); *Simio, LLC v. FlexSim Software Prod., Inc.*, 983 F.3d 1353, 1365 (Fed. Cir. 2020) ("We disregard conclusory statements when evaluating a complaint under Rule 12(b)(6). A statement that a feature 'improves the functioning and operations of the computer' is, by itself, conclusory." (internal citation omitted)); *Boom! Payments, Inc. v. Stripe, Inc.*, 839 F. App'x 528, 533 (Fed. Cir. 2021) (finding allegations that the claims were not routine or conventional were conclusory statements to be disregarded).

B. Renewed Legal Arguments

Having found that none of Realtime's amendments materially change my prior analysis, I incorporate my previous decision into this opinion, subject to the preceding discussion about the significance of the pen-and-paper criterion.[5]

Realtime's legal arguments on these renewed motions are substantially similar to its previous arguments. Realtime again argues that the asserted patents "claim specific improvements in computer functionality." D.I. 91 at 4. Because

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ineligible abstract idea. *Adaptive Streaming Inc. v. Netflix, Inc.*, 836 F. App'x 900, 904 (Fed. Cir. 2020) ("We have explained that satisfying the requirements of novelty and non-obviousness does not imply eligibility under § 101, . . . because what may be novel and non-obvious may still be abstract.").

[5] Additionally, the discussion of U.S. Patent No. #204 is now moot because Realtime no longer asserts that patent.

Realtime repeats essentially the same arguments, there is no reason to reconsider my prior analysis. I again find that the asserted patents lack subject-matter eligibility under § 101. The unavoidable problem for Realtime is that data compression by itself is a type of information processing and information processing, without more, is patent-ineligible subject matter. The asserted patents do not have that something "more." *See Elec. Power*, 830 F.3d at 1353–54. For the reasons I previously explained, the asserted claims do not identify specific techniques that provide a technical solution.[6] Compression is an idea relevant to

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[6] As I explained in my prior opinion,

> The patents do not provide a technical solution to a technical problem because they do not teach how to engineer an improved system. *See Interval Licensing LLC v. AOL, Inc.*, 896 F.3d 1335, 1345 (Fed. Cir. 2018) (explaining that a patent is not directed to a technical solution when it covers results without teaching how to obtain those results). The asserted patents allow the use of *any* compression method. *See* #908 patent 16:49–54 ("the data storage accelerator 10 employs . . . any conventional data compression method suitable for compressing data at a rate necessary for obtaining accelerated data storage); #825 patent at 7:7–11; #204 patent at 15:12–22; #203 patent at 16:30–16:42. The patents do not teach a technical solution to analyze data. *See, e.g.*, #825 patent at 16:15–24 (describing a content dependent data recognition module without any specificity). Nor do the patents teach how to achieve the claimed efficiency benefits, beyond directing the skilled artisan to apply well-known techniques. *See WhiteServe LLC v. Dropbox, Inc.*, No. 19-2334, slip op. at 9, (Fed.

information in general and is not inherently grounded in a particular technical environment. The results-based claims describe desirable outcomes and functionality, but do not offer ways to achieve these results. *See Affinity Labs of Texas, LLC v. Amazon.com Inc.*, 838 F.3d 1266, 1269 (Fed. Cir. 2016) (finding claims abstract because they did "no more than describe a desired function or outcome, without providing any limiting detail that confines the claim to a particular solution to an identified problem."). The patents are directed to abstract ideas. And the patents simply direct artisans to apply those ideas without teaching any additional inventive features. They are, therefore, subject-matter ineligible under the *Alice* test. *Alice*, 573 U.S. at 222–24.

> Cir. Apr. 26, 2021) (finding patent invalid under § 101 when "[t]he specification d[id] not [] explain the technological processes underlying the purported technological improvement."). In arguing that the patents teach a specific way of or structure for performing compression, Realtime is only able offer conclusory statements while repeating the same generic language in the claims. *See, e.g.*, *Reduxio*, 17-1676, D.I. 14 at 10–12. In short, while the patents do disclose potential challenges (e.g., the problem of selecting the best compression method for given data), they do not teach *how* to address those challenges.

D.I. 41 at 42–43.

The cases cited by Realtime do not suggest a different outcome.[7] In *Koninklijke KPN N.V. v. Gemalto M2M GmbH*, for example, the Federal Circuit explained that for a software patent "[t]o be patent-eligible, the claims must recite a specific means or method that solves a problem in an existing technological process." 942 F.3d 1143, 1150 (Fed. Cir. 2019). The asserted claims, by contrast, may be performed using any means or methods that can implement the ideas to which the patents are directed. Realtime's other cited cases are not applicable here because those opinions considered claims that were genuinely directed to technical problems inherently grounded in computer technology and that offered specific technical solutions. *See Packet Intel. LLC v. NetScout Sys., Inc.*, 965 F.3d 1299, 1309 (Fed. Cir. 2020), *cert. denied*, 209 L. Ed. 2d 552 (Apr. 19, 2021) (finding that the asserted patent solved a technical problem "unique to computer networks");

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[7] Realtime filed as an exhibit a claim chart comparing claim 1 of the #728 patent to claims Realtime represents as being invalid. D.I. 91-1, Ex. 1. First, review of this claim chart shows substantial differences between claim 1 of the #728 patent and the comparison claims. The large differences make clear that the claims are not directly comparable. Second, Realtime compared claim 1 of the #728 patent to a claim that was in fact found invalid. D.I. 91-1, Ex. 1 at 1. The comparison claim, claim 1 of the patent at issue in *Koninklijeke KPN*, was found invalid under § 101 and this finding was not appealed. *Koninklijke KPN N.V. v. Gemalto M2M GmbH*, 942 F.3d 1143, 1149 (Fed. Cir. 2019). And in finding the appealed claims valid, the Federal Circuit relied on a claim limitation that was in the appealed claims but not in claim 1 to show that the claims had a technological solution. *Id.* at 1150. Thus, comparing claim 1 of the #728 patent to claim 1 of the patent at issue in *Koninklijeke KPN* only suggests that the #728 patent should also be invalid.

TecSec, Inc. v. Adobe Inc., 978 F.3d 1278, 1295 (Fed. Cir. 2020) (finding claims patent eligible because they were directed to solving a technical problem specific to computer network security); *Uniloc USA, Inc. v. LG Elecs. USA, Inc.*, 957 F.3d 1303, 1308 (Fed. Cir. 2020) (finding that "the claims at issue do not merely recite generalized steps to be performed on a computer using conventional computer activity"); *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 930 F.3d 1295, 1303 (Fed. Cir. 2019), *cert. denied*, 140 S. Ct. 1108 (2020) (finding claims eligible at *Alice* step one because the claims were "directed to using a specific technique . . . to solve a technological problem" in network security).

There can be a fine—and often unclear—line between applying an abstract idea on technology and claiming a software-based improvement to technology. But in my view, the line here is clear, and the asserted claims do not have the specificity required of a technical solution. *See Elec. Power*, 830 F.3d at 1356 ("[T]here is a critical difference between patenting a particular concrete solution to a problem and attempting to patent the abstract idea of a solution to the problem in general."); *Cf. Ericsson*, 955 F.3d at 1328 (finding claims invalid when they did "not have the specificity required to transform a claim from one claiming only a result to one claiming a way of achieving it" (internal quotation marks and alternations omitted)); *Free Stream Media Corp. v. Alphonso Inc.*, 996 F.3d 1355, 1363–64 (Fed. Cir. 2021) (finding claim directed to gathering, matching, and sending information ineligible in part because "the asserted claims do not at all describe how [the claimed] result is achieved."). The patentee had ideas about data compression, but rather than claim specific implementations of those ideas or provide new techniques to achieve the claimed results, the patentee sought and received claims on the ideas themselves. The patents claim abstract ideas without teaching how to implement those ideas. This is what § 101 jurisprudence prohibits.

IV. CONCLUSION

For the reasons stated above and in my prior opinion, D.I. 41, I find that all claims of the asserted patents are invalid under § 101 for lack of subject-matter eligibility. Accordingly, I will grant Defendants' Renewed Motion to Dismiss.

The Court will issue Orders consistent with this Memorandum Opinion.

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

Realtime Data LLC,

Plaintiff,

v.

Array Networks Inc., et al.,

Defendant.

Civil Action No. 17-0800-CFC
CONSOLIDATED

ORDER

At Wilmington this Twenty-third day of August in 2021:

For the reasons set forth in the Memorandum Opinion issued this day, **IT IS HEREBY ORDERED** that Defendants Renewed Motion to Dismiss (D.I. 78) is **GRANTED**.

CHIEF JUDGE

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

Realtime Data LLC,

Plaintiff,

v.

Spectra Logic Corp.,

Defendant.

Civil Action No. 17-0925-CFC

ORDER

At Wilmington this Twenty-third day of August in 2021:

For the reasons set forth in the Memorandum Opinion issued this day, **IT IS HEREBY ORDERED** that Defendant Spectra Logic Corporation Motion to Dismiss and Joinder in Defendants' Omnibus Motion to Dismiss Pursuant to Federal Rule of Civil Procedure 12(b)(6) For Lack of Patentable Subject Matter Under 35 U.S.C. § 101 (D.I. 68) is **GRANTED**.

CHIEF JUDGE

US007415530B2

(12) **United States Patent**
Fallon

(10) **Patent No.: US 7,415,530 B2**
(45) **Date of Patent: Aug. 19, 2008**

(54) **SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL**

(75) Inventor: **James J Fallon**, Armonk, NY (US)

(73) Assignee: **Realtime Data LLC**, New York, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/553,426**

(22) Filed: **Oct. 26, 2006**

(65) **Prior Publication Data**

US 2007/0067483 A1 Mar. 22, 2007

Related U.S. Application Data

(63) Continuation of application No. 10/628,795, filed on Jul. 28, 2003, now Pat. No. 7,130,913, which is a continuation of application No. 09/266,394, filed on Mar. 11, 1999, now Pat. No. 6,601,104.

(51) **Int. Cl.**
G06F 13/00 (2006.01)

(52) **U.S. Cl.** **709/231**

(58) **Field of Classification Search** 709/231, 709/233

See application file for complete search history.

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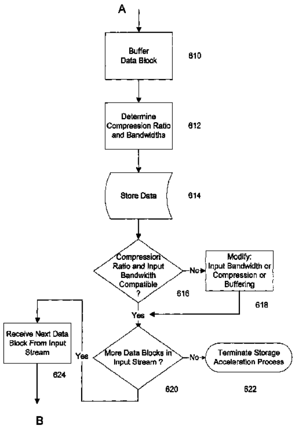
Primary Examiner—David Y Eng
(74) *Attorney, Agent, or Firm*—Ropes & Gray LLP

(57) **ABSTRACT**

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to simultaneously or sequentially losslessly compress data at a rate equivalent to or faster than the transmission rate of an input data stream. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to simultaneously or sequentially losslessly decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device. The data storage and retrieval accelerator method and system may employed: in a disk storage adapter to reduce the time required to store and retrieve data from computer to disk; in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory; in a display controller to reduce the time required to send display data to the display controller or processor; and/or in an input/output controller to reduce the time required to store, retrieve, or transmit data.

23 Claims, 20 Drawing Sheets



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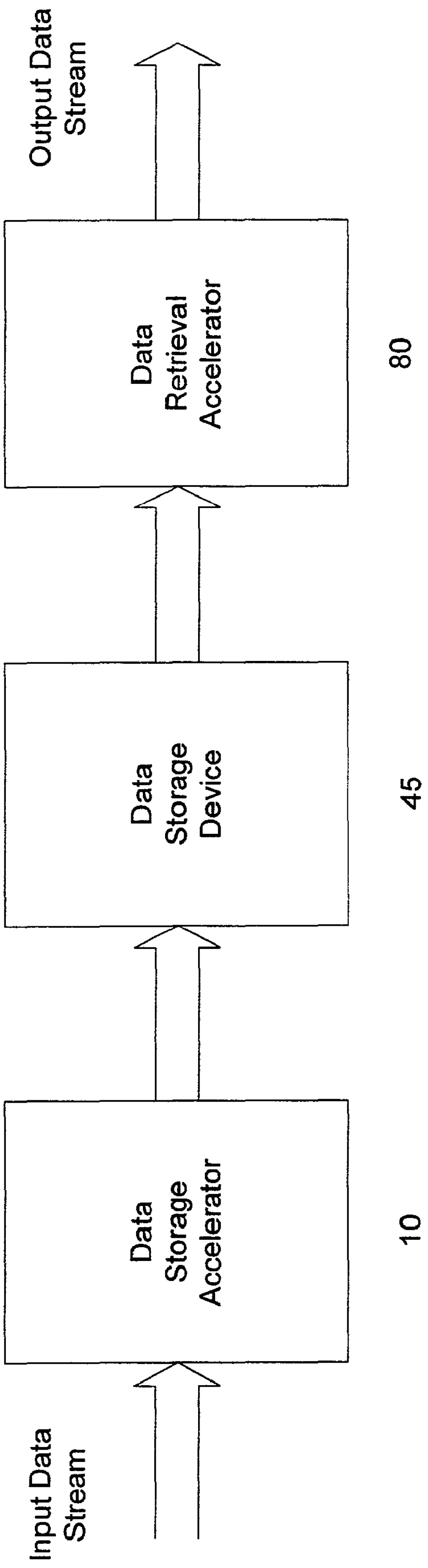
Input Data Stream
Data Storage Accelerator
10
Data Storage Device
45
Data Retrieval Accelerator
80
Output Data Stream

FIGURE 1

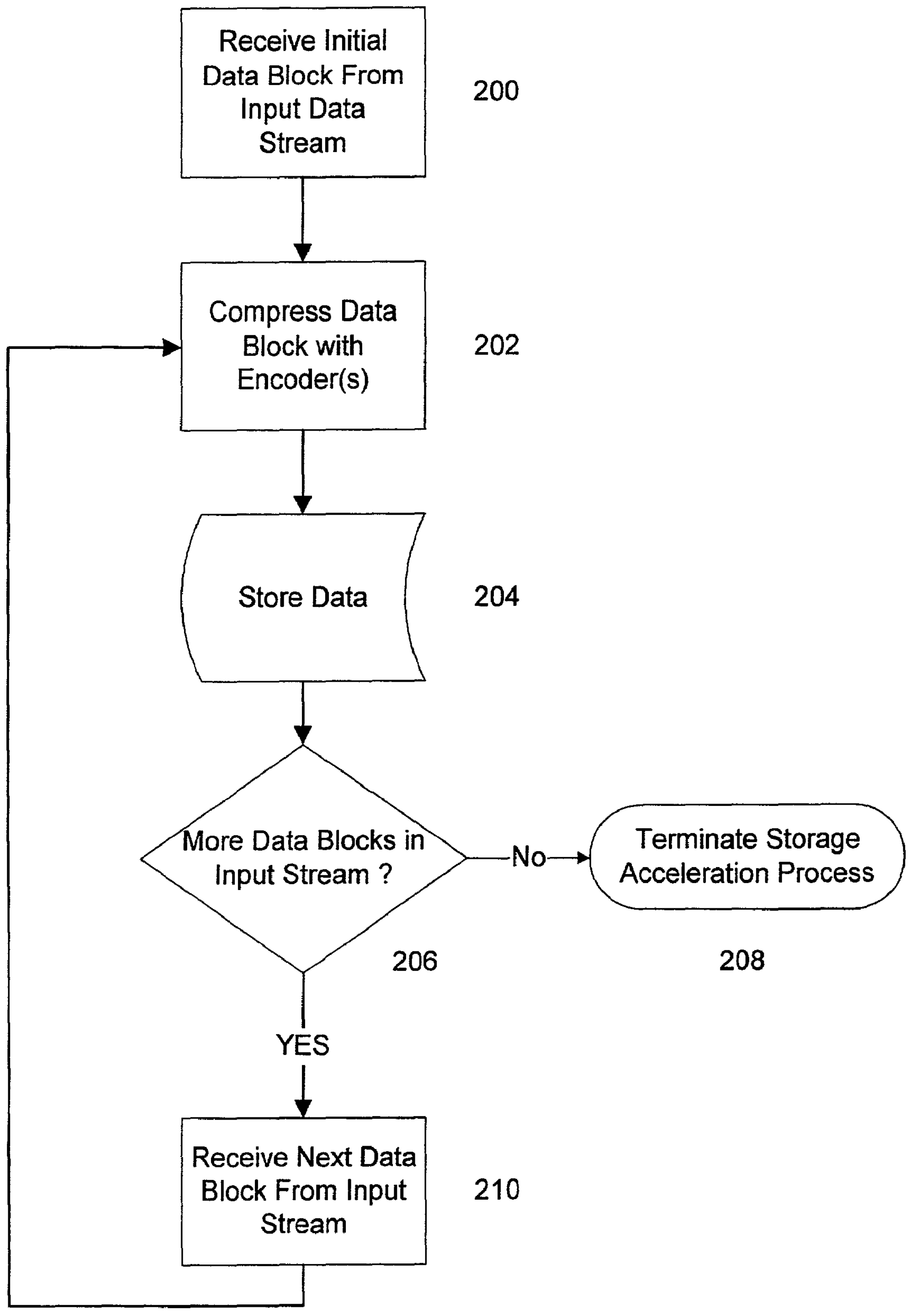
Receive Initial Data Block From Input Data Stream
200
Compress Data Block with Encoder(s)
202
Store Data
204
More Data Blocks in Input Stream ?
No
Terminate Storage Acceleration Process
206
208
YES
Receive Next Data Block From Input Stream
210

FIGURE 2

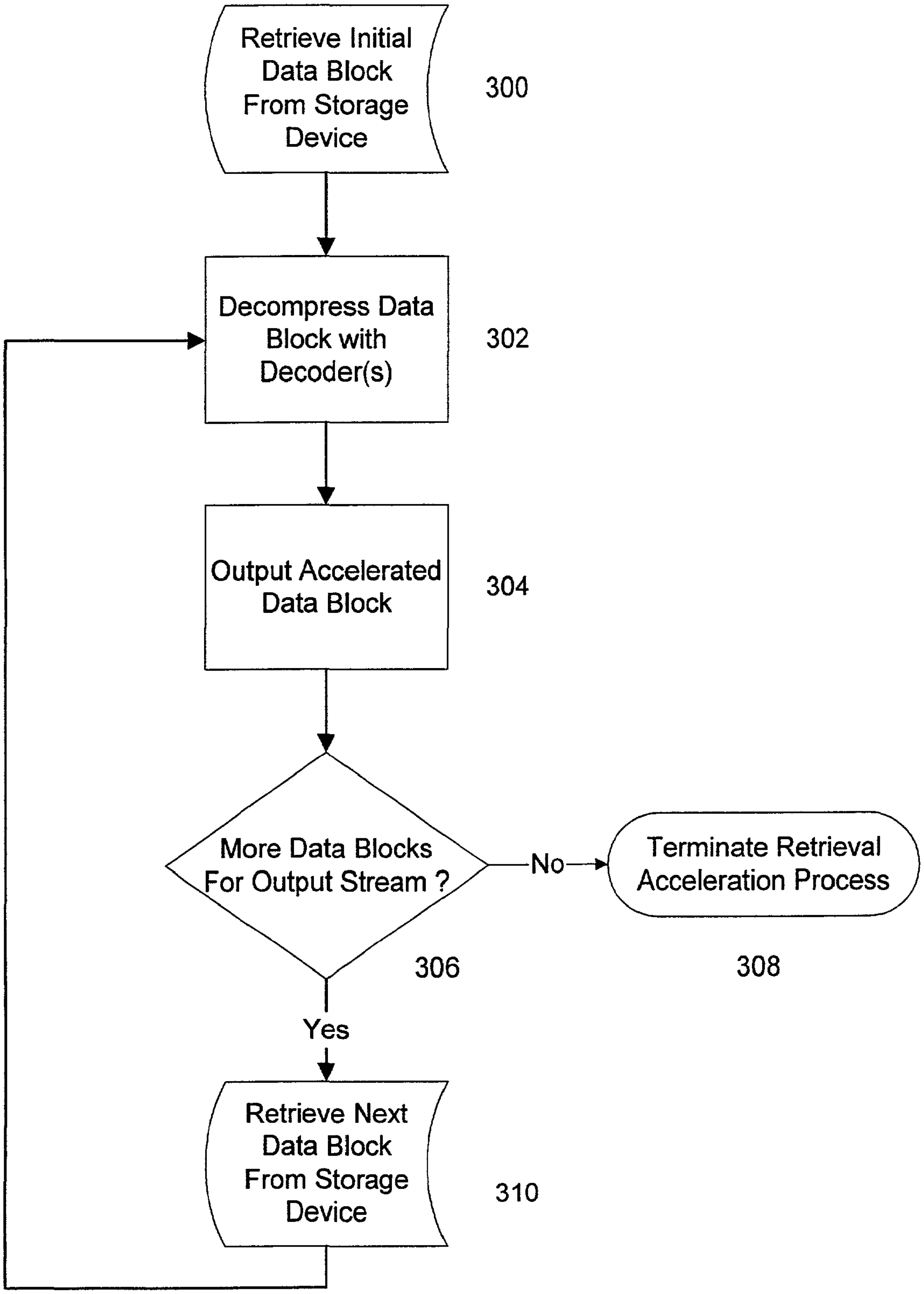
Retrieve Initial Data Block From Storage Device
300
Decompress Data Block with Decoder(s)
302
Output Accelerated Data Block
304
More Data Blocks For Output Stream ?
306
No
Terminate Retrieval Acceleration Process
308
Yes
Retrieve Next Data Block From Storage Device
310

FIGURE 3

Time Interval	T1	T2	T3	T4	Ti
Receive Data Block	Recieve Data Block 1	Receive Data Block 2	Receive Data Block 3	Receive Data Block 4	Receive Data Block i
<u>METHOD 1</u>					
Compress Data Block	Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block 4	Compress Data Block i
Store Encoded Data Block	Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block 3	Store Encoded Data Block 4	Store Encoded Data Block i
<u>METHOD 2</u>					
Compress Data Block		Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block (i-1)
Store Encoded Data Block			Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block (i-2)

FIGURE 4a

Time Interval	T(i+1)	T(i+2)		Tn	T(n+1)	T(n+2)
Receive Data Block	Recieve Data Block (i+1)	Receive Data Block (i+2)		Receive Data Block n		
METHOD 1						
Compress Data Block	Compress Data Block (i+1)	Compress Data Block (i+2)		Compress Data Block n		
Store Encoded Data Block	Store Encoded Data Block (i+1)	Store Encoded Data Block (i+2)		Store Encoded Data Block n		
METHOD 2						
Compress Data Block	Compress Data Block i	Compress Data Block (i+1)		Compress Data Block (n-1)	Compress Data Block n	
Store Encoded Data Block	Store Encoded Data Block (i-1)	Store Encoded Data Block i		Store Encoded Data Block (n-2)	Store Encoded Data Block (n-1)	Store Encoded Data Block n

FIGURE 4b

Time Interval	T1	T2	T3	T4	Ti
Retrieve Data Block	Retrieve Data Block 1	Retrieve Data Block 2	Retrieve Data Block 3	Retrieve Data Block 4	Retrieve Data Block i
<u>METHOD 1</u>					
Decompress Data Block	Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block 4	Decompress Data Block i
Output Decoded Data Block	Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block 3	Output Decoded Data Block 4	Output Decoded Data Block i
<u>METHOD 2</u>					
Decompress Data Block		Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block (i-1)
Output Decoded Data Block			Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block (i-2)

FIGURE 5a

Time Interval	T(i+1)	T(i+2)	Tn	T(n+1)	T(n+2)
Retrieve Data Block	Retrieve Data Block (i+1)	Retrieve Data Block (i+2)	Retrieve Data Block n		
<u>METHOD 1</u>					
Decompress Data Block	Decompress Data Block (i+1)	Decompress Data Block (i+2)	Decompress Data Block n		
Output Decoded Data Block	Output Decoded Data Block (i+1)	Output Decoded Data Block (i+2)	Output Decoded Data Block n		
<u>METHOD 2</u>					
Decompress Data Block	Decompress Data Block i	Decompress Data Block (i+1)	Decompress Data Block (n-1)	Decompress Data Block n	
Output Decoded Data Block	Output Decoded Data Block (i-1)	Output Decoded Data Block i	Output Decoded Data Block (n-2)	Output Decoded Data Block (n-1)	Output Decoded Data Block n

FIGURE 5b

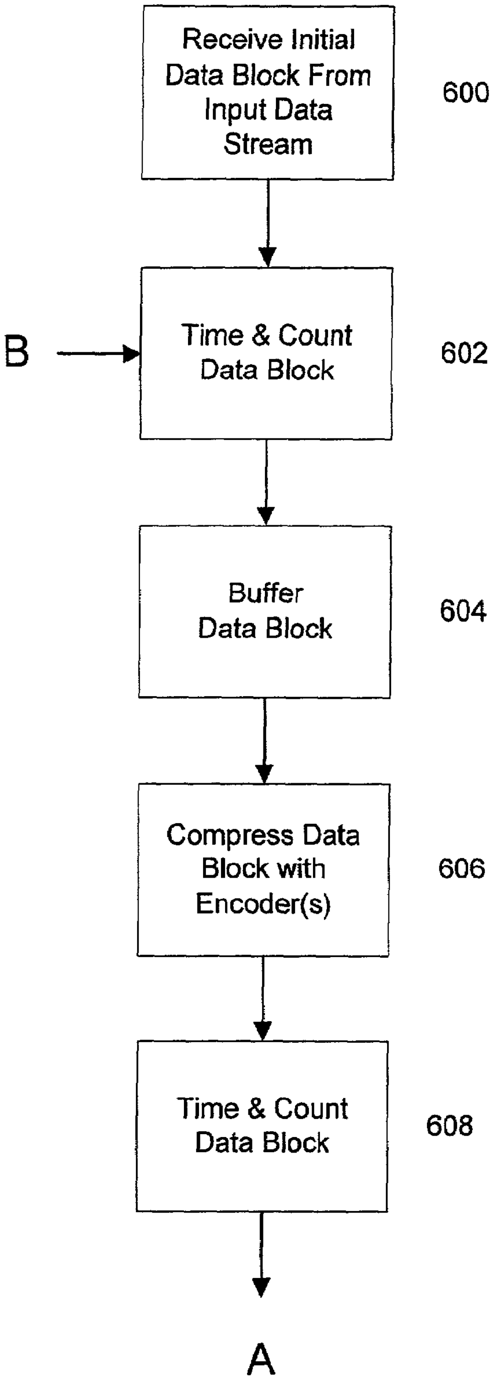
Receive Initial Data Block From Input Data Stream
600
B
Time & Count Data Block
602
Buffer Data Block
604
Compress Data Block with Encoder(s)
606
Time & Count Data Block
608
A

FIGURE 6a

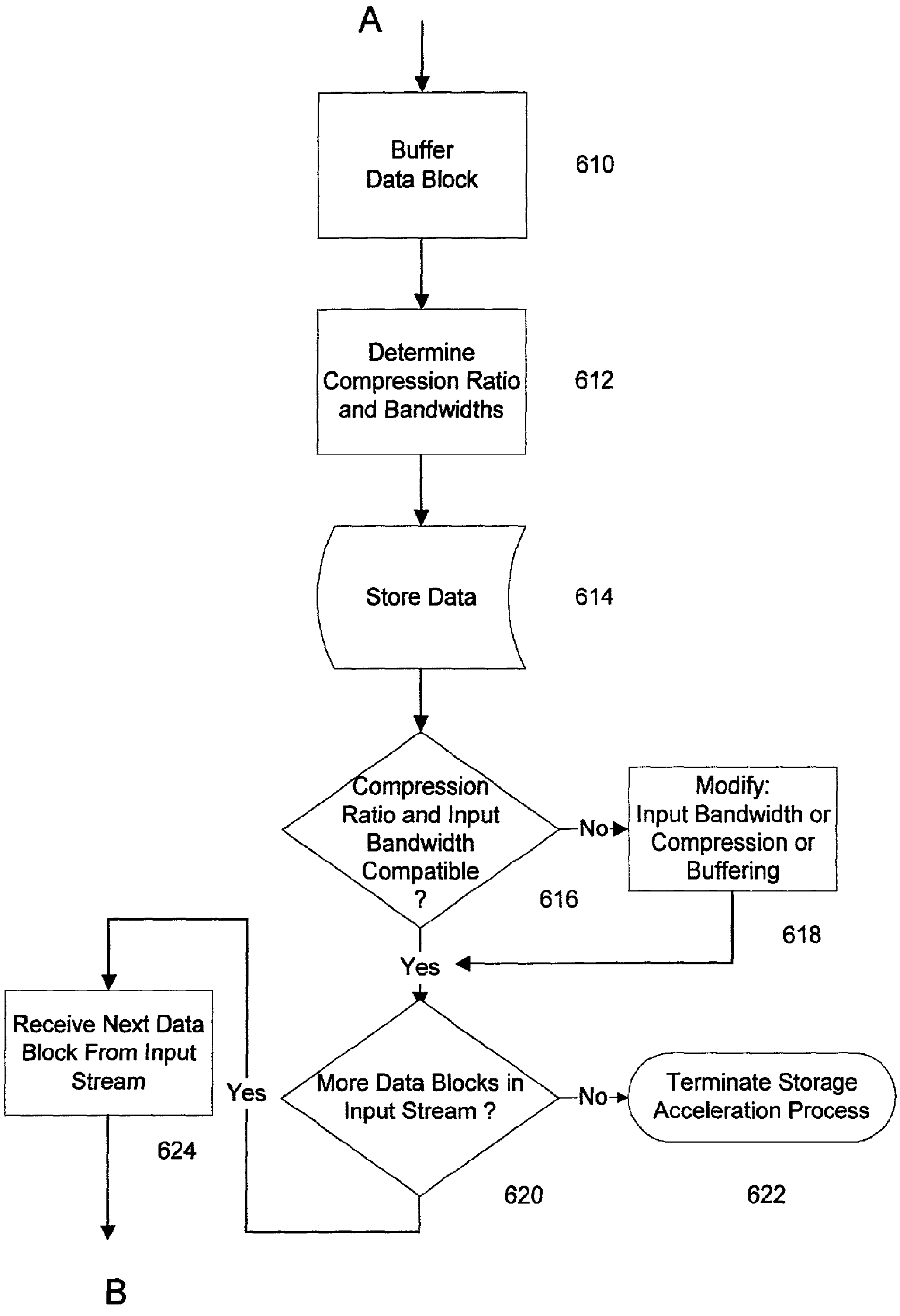
A
Buffer Data Block
610
Determine Compression Ratio and Bandwidths
612
Store Data
614
Compression Ratio and Input Bandwidth Compatible ?
616
No
Modify: Input Bandwidth or Compression or Buffering
618
Yes
More Data Blocks in Input Stream ?
620
No
Terminate Storage Acceleration Process
622
Yes
Receive Next Data Block From Input Stream
624
B

FIGURE 6b

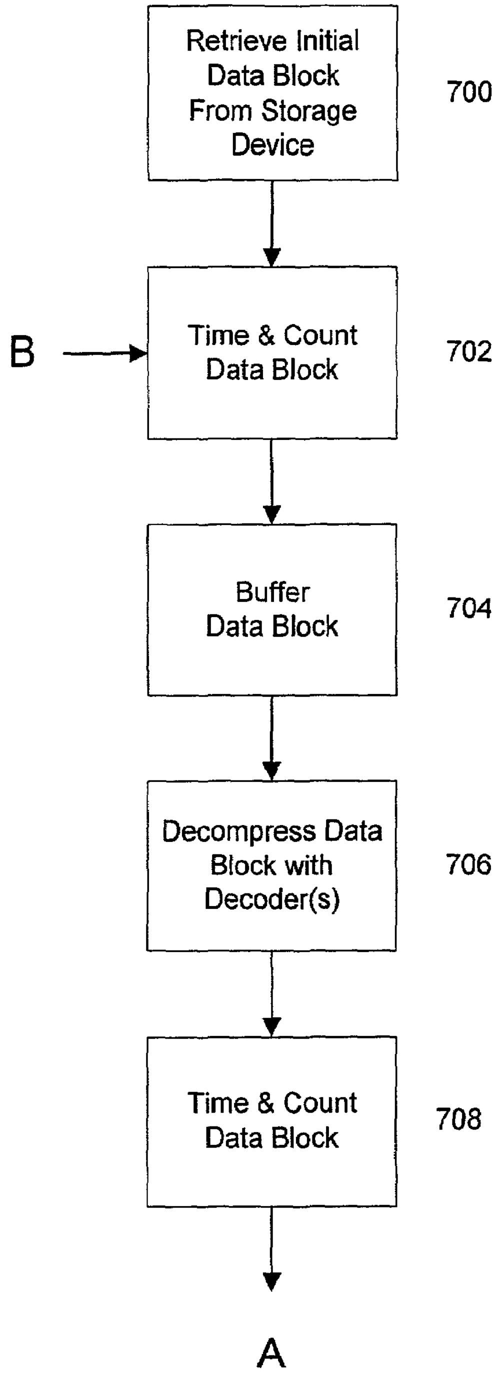
Retrieve Initial Data Block From Storage Device
700
B
Time & Count Data Block
702
Buffer Data Block
704
Decompress Data Block with Decoder(s)
706
Time & Count Data Block
708
A

FIGURE 7a

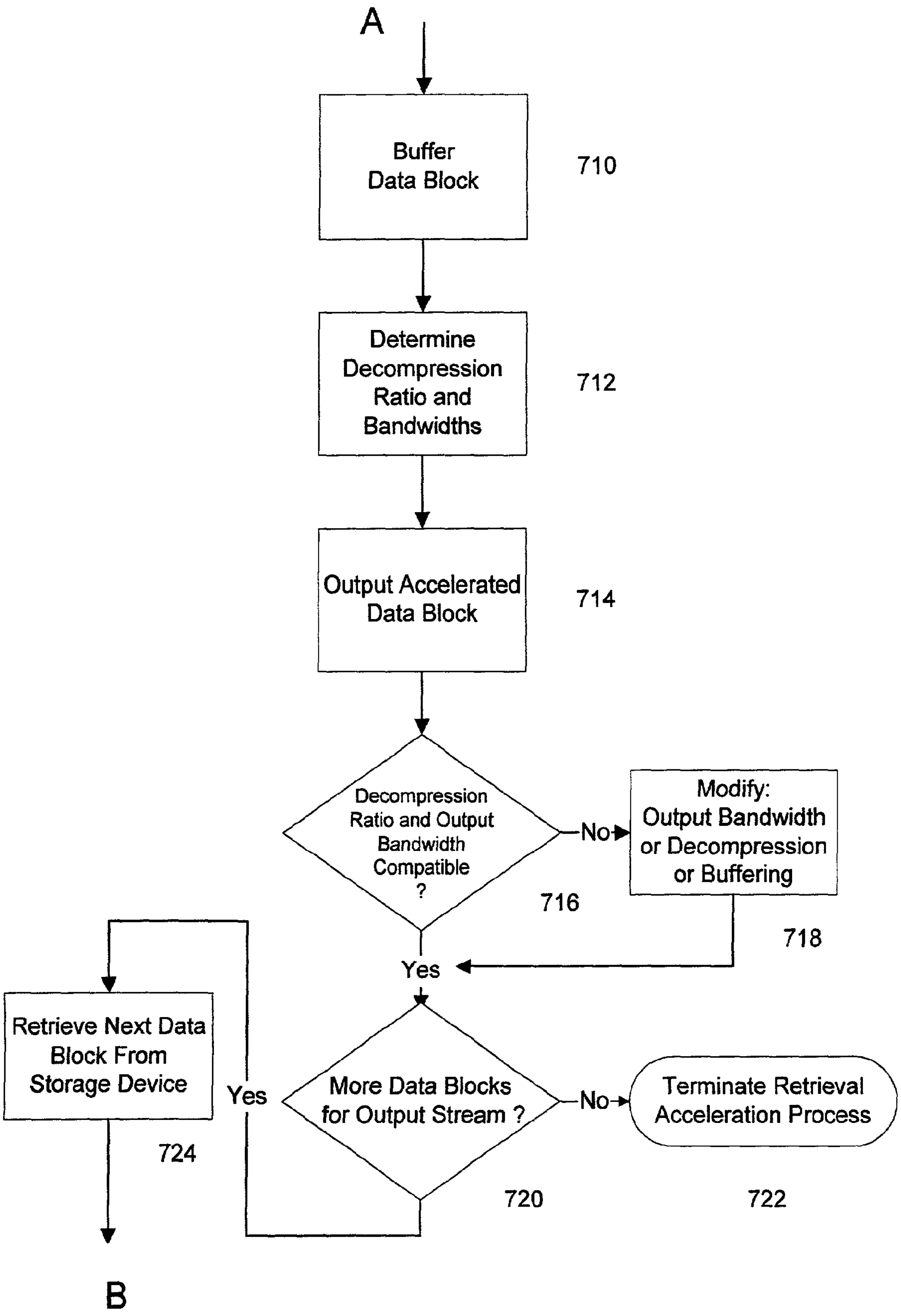
A
Buffer Data Block
710
Determine Decompression Ratio and Bandwidths
712
Output Accelerated Data Block
714
Decompression Ratio and Output Bandwidth Compatible ?
No
Modify: Output Bandwidth or Decompression or Buffering
716
718
Yes
Retrieve Next Data Block From Storage Device
Yes
More Data Blocks for Output Stream ?
No
Terminate Retrieval Acceleration Process
724
720
722
B

FIGURE 7b

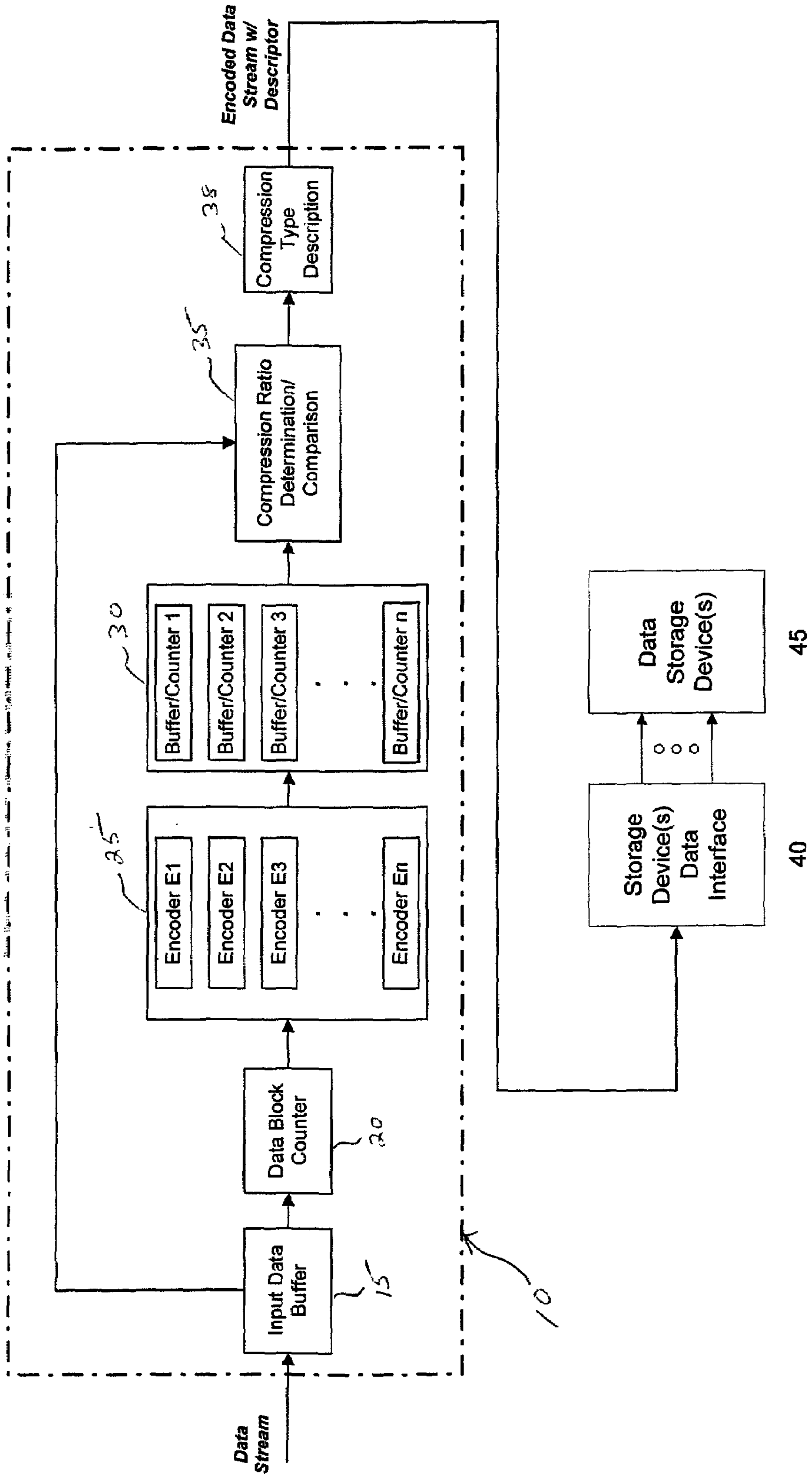
Data Stream
Input Data Buffer
15
Data Block Counter
20
Encoder E1
Encoder E2
Encoder E3
. . .
Encoder En
25
Buffer/Counter 1
Buffer/Counter 2
Buffer/Counter 3
. . .
Buffer/Counter n
30
Compression Ratio Determination/ Comparison
35
Compression Type Description
38
Encoded Data Stream w/ Descriptor
10
Storage Device(s) Data Interface
40
Data Storage Device(s)
45

FIGURE 8

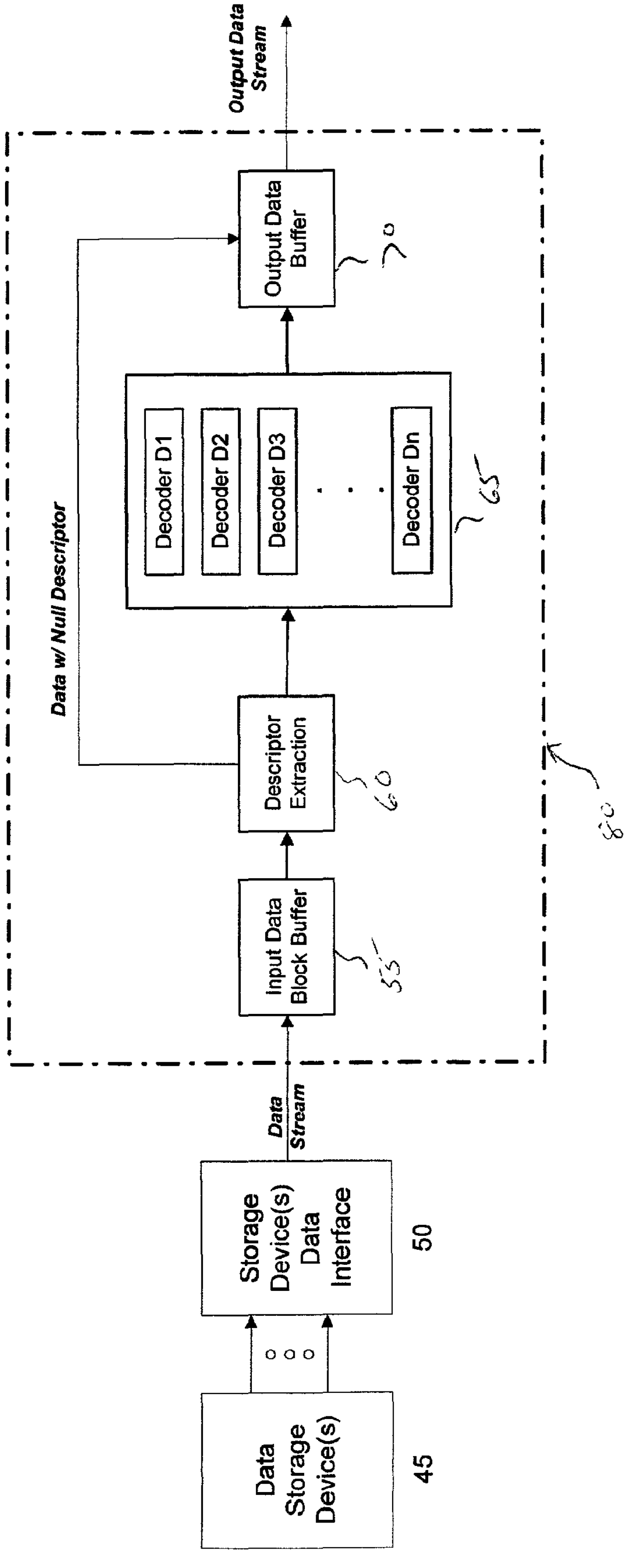
Data Storage Device(s)
45
Storage Device(s) Data Interface
50
Data Stream
Input Data Block Buffer
55
Descriptor Extraction
60
Data w/ Null Descriptor
Decoder D1
Decoder D2
Decoder D3
Decoder Dn
65
Output Data Buffer
70
Output Data Stream
80

FIG. 9

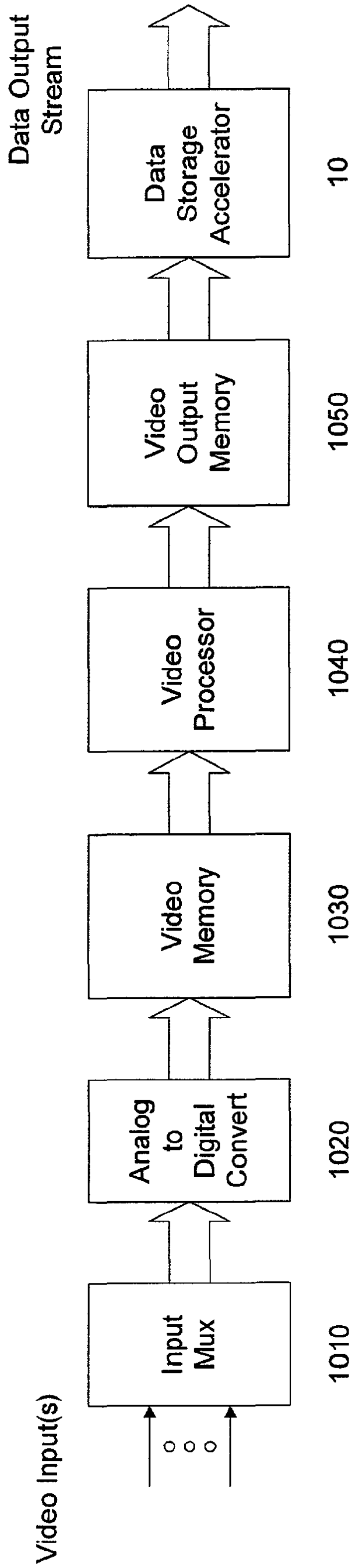
Video Input(s)
Input Mux
1010
Analog to Digital Convert
1020
Video Memory
1030
Video Processor
1040
Video Output Memory
1050
Data Storage Accelerator
10
Data Output Stream

FIGURE 10

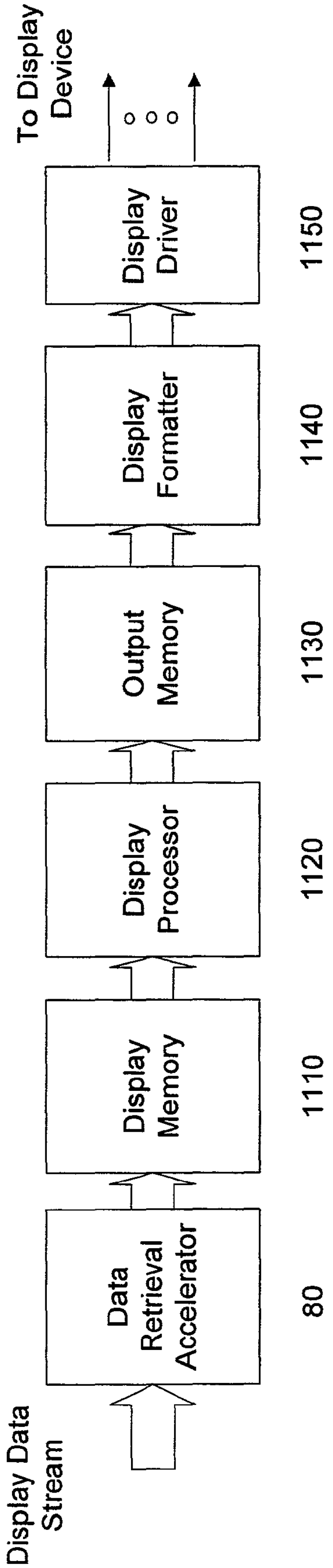
To Display Device
Display Driver
1150
Display Formatter
1140
Output Memory
1130
Display Processor
1120
Display Memory
1110
Data Retrieval Accelerator
80
Display Data Stream

FIGURE 11

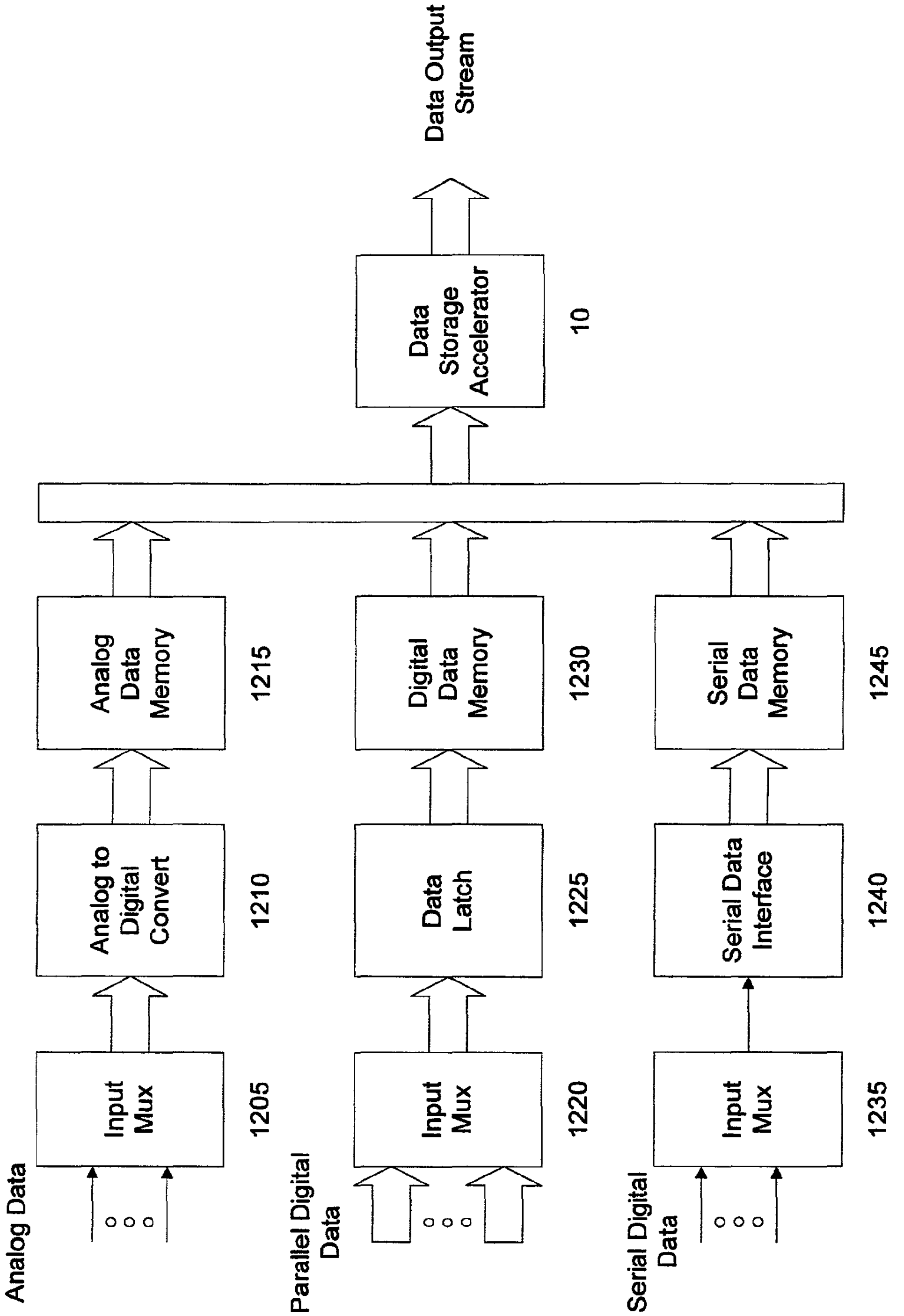
Analog Data
Input Mux
1205
Analog to Digital Convert
1210
Analog Data Memory
1215
Parallel Digital Data
Input Mux
1220
Data Latch
1225
Digital Data Memory
1230
Serial Digital Data
Input Mux
1235
Serial Data Interface
1240
Serial Data Memory
1245
Data Storage Accelerator
10
Data Output Stream

FIGURE 12

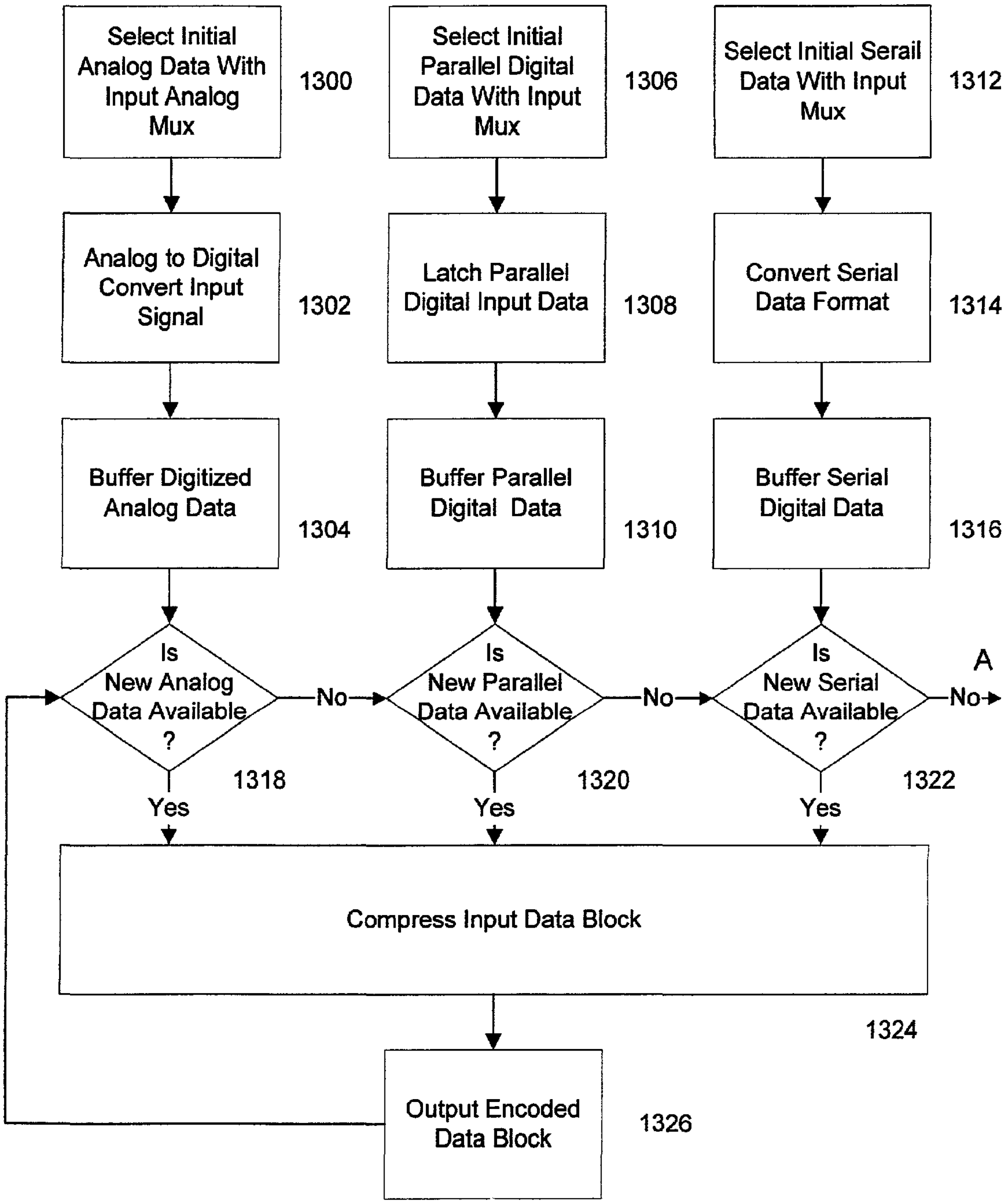
Select Initial Analog Data With Input Analog Mux
1300
Select Initial Parallel Digital Data With Input Mux
1306
Select Initial Serail Data With Input Mux
1312
Analog to Digital Convert Input Signal
1302
Latch Parallel Digital Input Data
1308
Convert Serial Data Format
1314
Buffer Digitized Analog Data
1304
Buffer Parallel Digital Data
1310
Buffer Serial Digital Data
1316
Is New Analog Data Available ?
No
Is New Parallel Data Available ?
No
Is New Serial Data Available ?
A
No
1318
1320
1322
Yes
Yes
Yes
Compress Input Data Block
1324
Output Encoded Data Block
1326

FIGURE 13

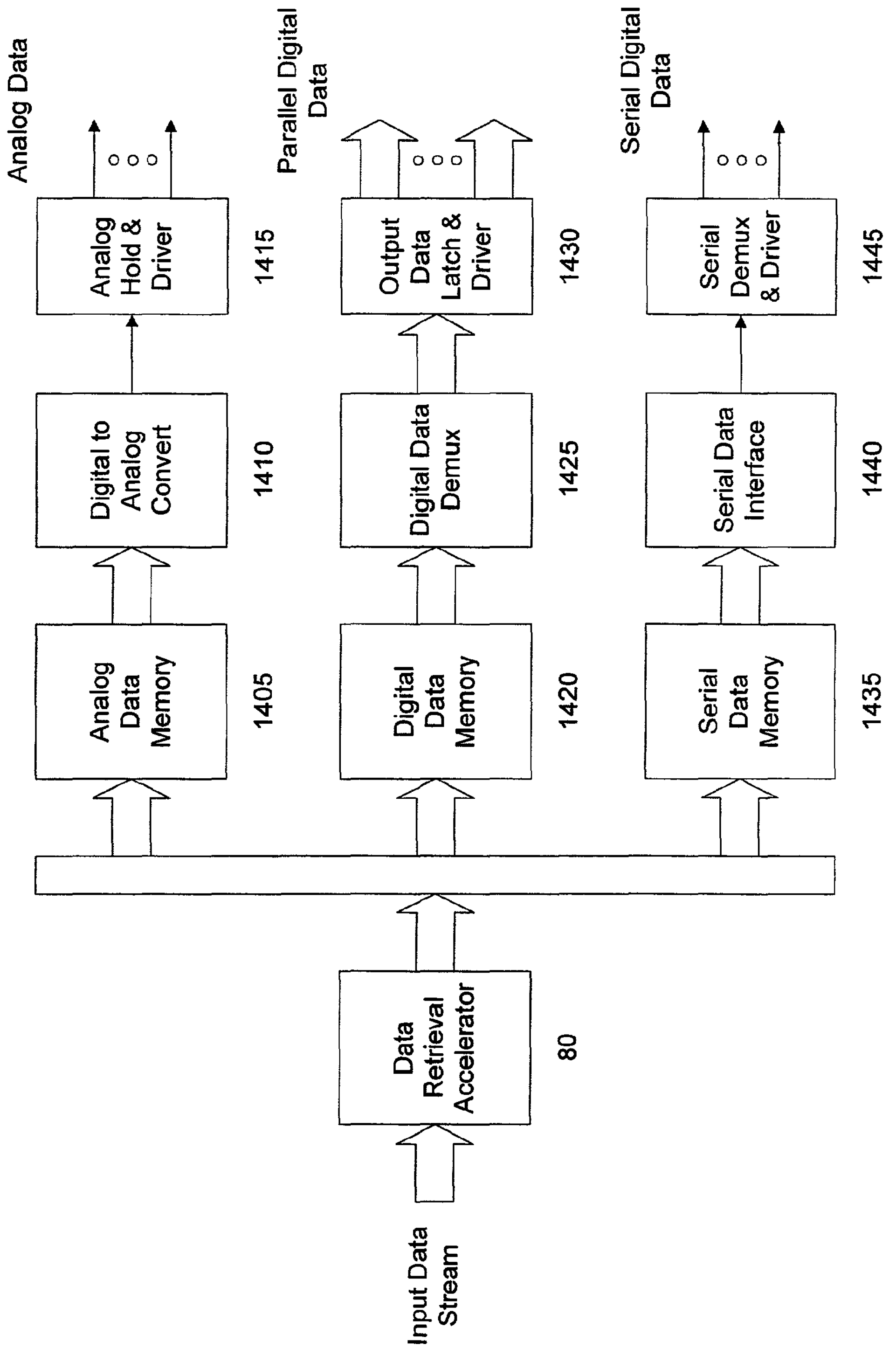
Input Data Stream
Data Retrieval Accelerator
80
Analog Data Memory
1405
Digital to Analog Convert
1410
Analog Hold & Driver
1415
Analog Data
Digital Data Memory
1420
Digital Data Demux
1425
Output Data Latch & Driver
1430
Parallel Digital Data
Serial Data Memory
1435
Serial Data Interface
1440
Serial Demux & Driver
1445
Serial Digital Data

FIGURE 14

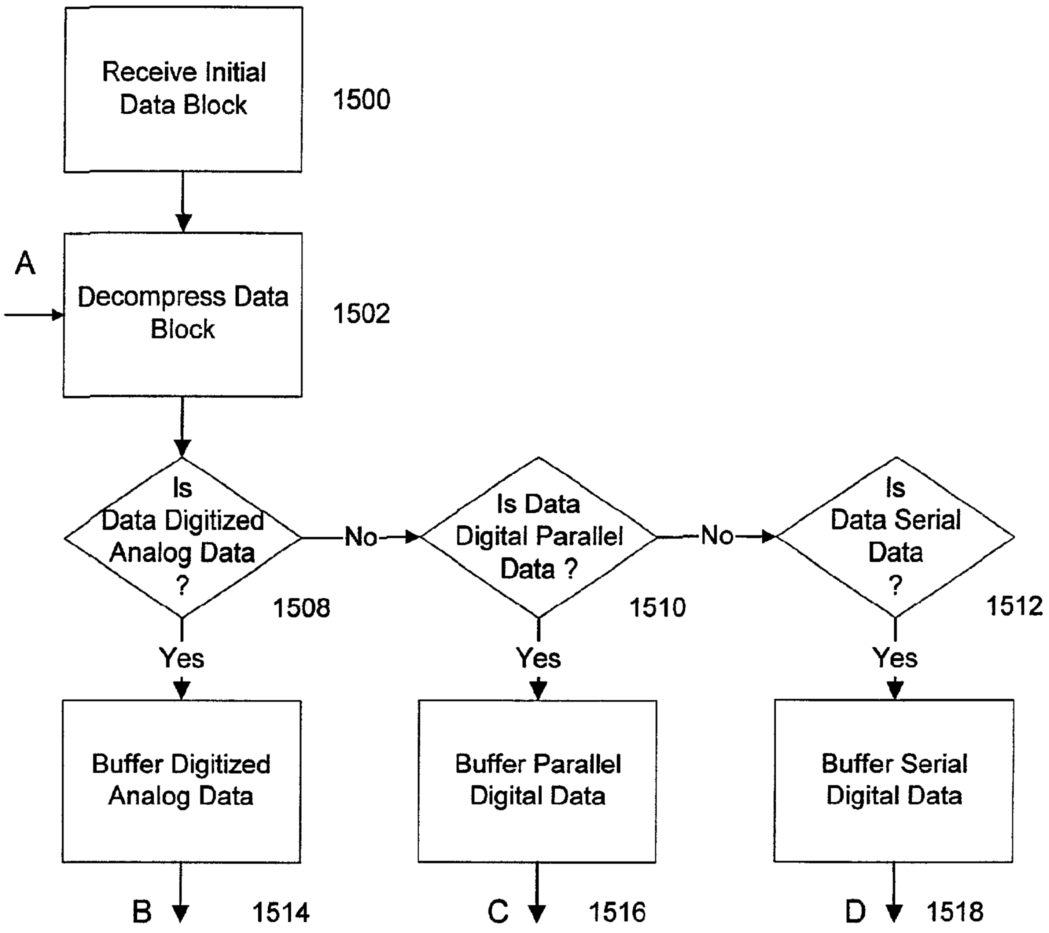
Receive Initial Data Block
1500
A
Decompress Data Block
1502
Is Data Digitized Analog Data ?
1508
No
Is Data Digital Parallel Data ?
1510
No
Is Data Serial Data ?
1512
Yes
Yes
Yes
Buffer Digitized Analog Data
Buffer Parallel Digital Data
Buffer Serial Digital Data
B
1514
C
1516
D
1518

FIGURE 15a

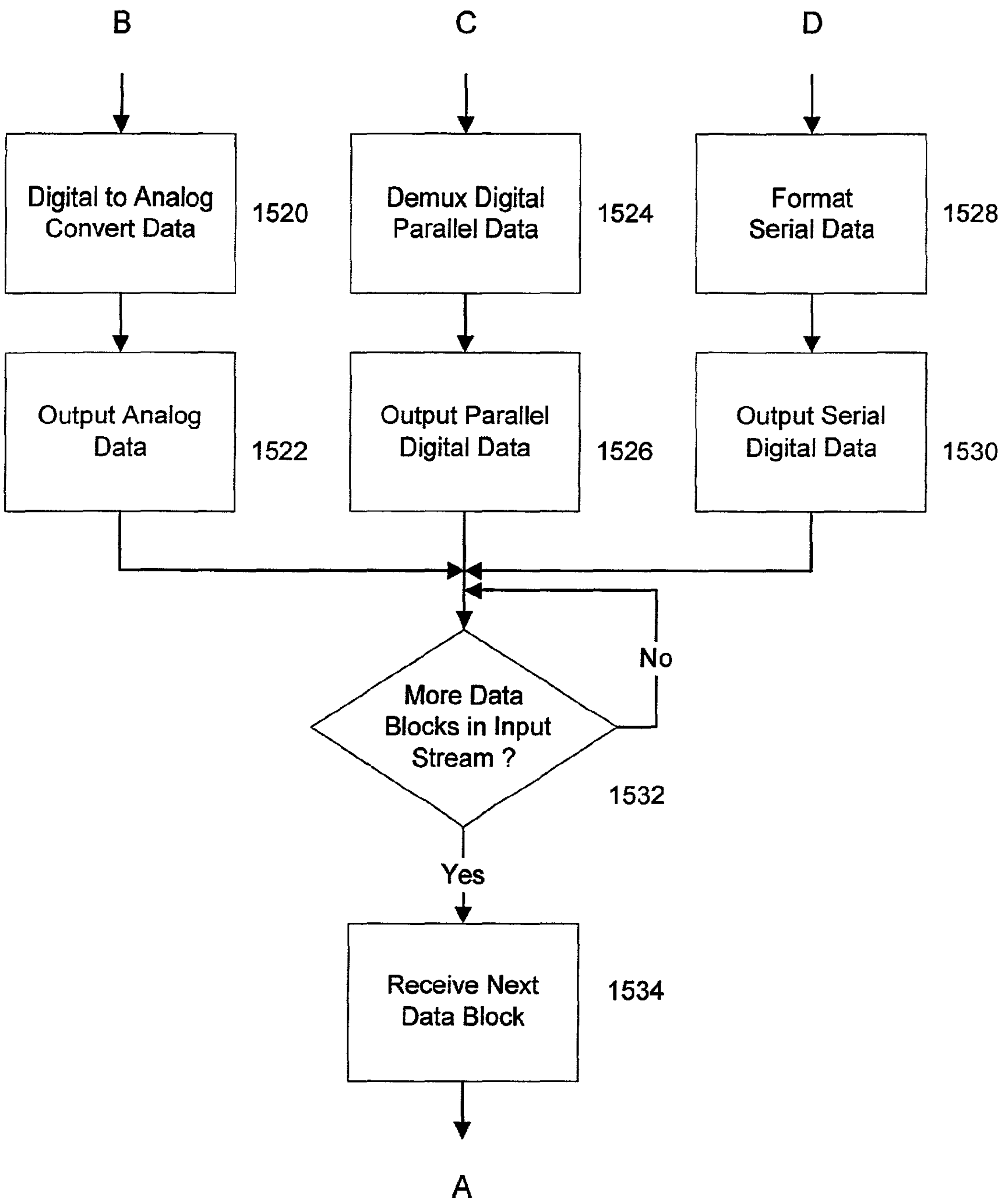
B
C
D
Digital to Analog Convert Data
1520
Demux Digital Parallel Data
1524
Format Serial Data
1528
Output Analog Data
1522
Output Parallel Digital Data
1526
Output Serial Digital Data
1530
No
More Data Blocks in Input Stream ?
1532
Yes
Receive Next Data Block
1534
A

FIGURE 15b

SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL

This application is a continuation of U.S. patent application Ser. No. 10/628,795, filed on Jul. 28, 2003, now U.S. Pat. No. 7,130,913, which is a continuation of U.S. patent application Ser. No. 09/266,394 filed on Mar 11, 1999, now U.S. Pat. No. 6,601,104, both of which are hereby incorporated by reference herein in their entirety.

BACKGROUND

1. Technical Field

The present invention relates generally to data storage and retrieval and, more particularly to systems and methods for improving data storage and retrieval bandwidth utilizing lossless data compression and decompression.

2. Description of the Related Art

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video frequently exists in the natural world as analog information. As is well-known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossy and lossless data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Negentropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than that dictated by the negentropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio of the target display device.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the negentropy of a given data set.

It is well known within the current art that data compression provides several unique benefits. First, data compression can reduce the time to transmit data by more efficiently utilizing low bandwidth data links. Second, data compression economizes on data storage and allows more information to be stored for a fixed memory size by representing information more efficiently.

One problem with the current art is that existing memory storage devices severely limit the performance of consumer, entertainment, office, workstation, servers, and mainframe computers for all disk and memory intensive operations. For example, magnetic disk mass storage devices currently employed in a variety of home, business, and scientific computing applications suffer from significant seek-time access delays along with profound read/write data rate limitations. Currently the fastest available (10,000) rpm disk drives support only a 17.1 Megabyte per second data rate (MB/sec). This is in stark contrast to the modern Personal Computer's Peripheral Component Interconnect (PCI) Bus's input/output capability of 264 MB/sec and internal local bus capability of 800 MB/sec.

Another problem within the current art is that emergent high performance disk interface standards such as the Small Computer Systems Interface (SCSI-3) and Fibre Channel offer only the promise of higher data transfer rates through intermediate data buffering in random access memory. These interconnect strategies do not address the fundamental problem that all modern magnetic disk storage devices for the personal computer marketplace are still limited by the same physical media restriction of 17.1 MB/sec. Faster disk access data rates are only achieved by the high cost solution of simultaneously accessing multiple disk drives with a technique known within the art as data striping.

Additional problems with bandwidth limitations similarly occur within the art by all other forms of sequential, pseudo-random, and random access mass storage devices. Typically mass storage devices include magnetic and optical tape, magnetic and optical disks, and various solid-state mass storage devices. It should be noted that the present invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing accelerated data storage and retrieval by utilizing lossless data compression and decompression. The present invention provides an effective increase of the data storage and retrieval bandwidth of a memory storage device. In one aspect of the present invention, a method for providing accelerated data storage and retrieval comprises the steps of:

receiving a data stream at an input data transmission rate which is greater than a data storage rate of a target storage device;

compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate;

storing the compressed data stream in the target storage device;

retrieving the compressed data stream from the target storage device at a rate equal to a data access rate of the target storage device; and

decompressing the compressed data at a decompression ratio to provide an output data stream having an output transmission rate which is greater than the data access rate of the target storage device.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a compression ratio that is at least equal to the ratio of the input data transmission rate to the data storage rate so as to provide continuous storage of the input data stream at the input data transmission rate.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a decompression ratio which is equal to or greater than the ratio of the data access rate to a maximum accepted output data transmission rate so as to provide a continuous and optimal data output transmission rate.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a disk storage adapter to reduce the time required to store and retrieve data from computer to a disk memory device.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory.

In another aspect of the present invention a data storage and retrieval accelerator method and system is employed in a video data storage system to reduce the time required to store digital video data.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a display controller to reduce the time required to send display data to the display controller or processor.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in an input/output controller to reduce the time required to store, retrieve, or transmit data various forms of data.

The present invention is realized due to recent improvements in processing speed, inclusive of dedicated analog and digital hardware circuits, central processing units, digital signal processors, dedicated finite state machines (and any hybrid combinations thereof), that, coupled with advanced data compression and decompression algorithms, are enabling of ultra high bandwidth data compression and decompression methods that enable improved data storage and retrieval bandwidth.

These and other aspects, features and advantages, of the present invention will become apparent from the following detailed description of preferred embodiments, that is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a system for accelerated data storage and retrieval according to one embodiment of the present invention;

FIG. **2** is a flow diagram of a method for accelerated data storage in accordance with one aspect of the present invention;

FIG. **3** is a flow diagram of a method for accelerated data retrieval in accordance with one aspect of the present invention;

FIGS. **4***a* and **4***b* are timing diagrams of methods for accelerated data storage according to the present invention;

FIGS. **5***a* and **5***b* are timing diagrams of methods for accelerated data retrieval according to the present invention;

FIGS. **6***a* and **6***b* comprise a flow diagram of a method for accelerated data storage in accordance with a further aspect of the present invention;

FIGS. **7***a* and **7***b* comprise a flow diagram of a method for accelerated data retrieval in accordance with a further aspect of the present invention;

FIG. **8** is a detailed block diagram of a system for accelerated data storage according to a preferred embodiment of the present invention;

FIG. **9** is a detailed block diagram of a system for accelerated data retrieval according to a preferred embodiment of the present invention;

FIG. **10** is a block diagram of a system for accelerated video storage according to one embodiment of the present invention;

FIG. **11** is a block diagram of a system for accelerated retrieval of video data according to one embodiment of the present invention;

FIG. **12** is a block diagram of an input/output controller system for accelerated storage of analog, digital, and serial data according to one embodiment of the present invention;

FIG. **13** is a flow diagram of a method for accelerated storage of analog, digital, and serial data according to one aspect of the present invention;

FIG. **14** is a block diagram of an input/output system for accelerated retrieval of analog, digital, and serial data according to one embodiment of the present invention; and

FIGS. **15***a* and **15***b* comprise a flow diagram of method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed to systems and methods for providing improved data storage and retrieval bandwidth utilizing lossless data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU) or digital signal processors (DSP), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform may also include an operating system, microinstruction code, and dedicated processing hardware utilizing combinatorial logic or finite state machines. The various processes and functions described herein may be either part of the hardware, microinstruction code or application programs that are executed via the operating system, or any combination thereof.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in that the systems are programmed. It is to be appreciated that special purpose microprocessors, digital signal processors, dedicated hardware, or and combination thereof may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **1**, a block diagram illustrates a system for accelerated data storage and retrieval in accordance with an embodiment of the present invention. The system includes a data storage accelerator **10**, operatively coupled to a data storage device **45**. The data storage accelerator operates to increase the effective data storage rate of the data storage device **45**. It is to be appreciated that the data storage device **45** may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The memory storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

The data storage accelerator **10** receives and processes data blocks from an input data stream. The data blocks may range in size from individual bits through complete files or collections of multiple files, and the data block size may be fixed or variable. In order to achieve continuous data storage acceleration, the data storage accelerator **10** must be configured to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Thus, to achieve optimum throughput, the rate that data blocks from the input data stream may be accepted by the data storage accelerator **10** is a function of the size of each input data block, the compression ratio achieved, and the bandwidth of the target storage device. For example, if the data storage device **45** (e.g., a typical target mass storage device) is capable of storing 20 megabytes per second and the data storage accelerator **10** is capable of providing an average compression ratio of 3:1, then 60 megabytes per second may be accepted as input and the data storage acceleration is precisely 3:1, equivalent to the average compression ratio.

It should be noted that it is not a requirement of the present invention to configure the storage accelerator **10** to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Indeed, if the storage accelerator **10** compresses data at a rate that is less than the input data rate, buffering may be applied to accept data from the input data stream for subsequent compression.

Additionally, it is not a requirement that the data storage accelerator **10** utilize data compression with a ratio that is at least the ratio of the input data stream to the data storage access rate of the data storage device **45**. Indeed, if the compression ratio is less than this ratio, the input data stream may be periodically halted to effectively reduce the rate of the input data stream. Alternatively, the input data stream or the output of the data accelerator **10** may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to reduce the input data rate to rate that is equal to or slower than the ratio of the input data rate to the data storage device access rate by signaling the data input source and requesting a slower data input rate, if possible.

Referring again to FIG. **1**, a data retrieval accelerator **80** is operatively connected to and receives data from the data storage device **45**. The data retrieval accelerator **80** receives and processes compressed data from data storage device **45** in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator **80** is configured to decompress each compressed data block which is received from the data storage device **45**. In order to achieve continuous accelerated data retrieval, the data retrieval accelerator must decompress a given input data block at a rate that is equal to or faster than receipt of the input data.

In a manner analogous to the data storage accelerator **10**, achieving optimum throughput with the data retrieval accelerator **80** is a function of the rate that compressed data blocks are retrieved from the data storage device **45**, the size of each data block, the decompression ratio achieved, and the limitation on the bandwidth of the output data stream, if any. For example, if the data storage device **45** is capable of continuously supplying 20 megabytes per second and the data retrieval accelerator **80** is capable of providing an average decompression ratio of 1:3, then a 60 megabytes per second output data stream is achieved, and the corresponding data retrieval acceleration is precisely 1:3, equivalent to the average decompression ratio.

It is to be understood that it is not required that the data retrieval accelerator **80** utilize data decompression with a ratio that is at most equal to the ratio of the retrieval rate of the data storage device **45** to the maximum rate data output stream. Indeed, if the decompression ratio is greater than this ratio, retrieving data from the data storage device may be periodically halted to effectively reduce the rate of the output data stream to be at or below its maximum. Alternatively, the compressed data retrieved from the data storage device **45** or the output of the data decompressor may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to increase the output data rate by signaling or otherwise requesting the data output device(s) receiving the output data stream to accept a higher bandwidth, if possible.

Referring now to FIG. **2**, a flow diagram of a method for accelerated data storage according to one aspect of the present invention illustrates the operation of the data storage acceleration shown in FIG. **1**. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream (step **200**) is input into and compressed by the data storage accelerator **10** (step **202**). Upon completion of the encoding of the input data block, the encoded data block is then stored in the data storage device **45** (step **204**). A check or other form of test is performed to see if there are additional data blocks available in the input stream (step **206**). If no more data blocks are available, the storage acceleration process is terminated (step **208**). If more data blocks are available in the input data stream, the next data block is received (step **210**) and the process repeats beginning with data compression (step **202**).

Referring now to FIG. **3**, a flow diagram of a method for accelerated data retrieval according to one aspect of the present invention illustrates the operation of the data retrieval accelerator **80** shown in FIG. **1**. Data decompression is also performed on a per data block basis. The initial compressed data block is retrieved from the storage device **45** (step **300**) and is decompressed by the data retrieval accelerator **80** (step **302**). Upon completion of the decoding of the initial data block, the decoded data block is then output for subsequent processing, storage, or transmittal (step **304**). A check or other form of test is performed to see if additional data blocks available from the data storage device (step **306**). If no more data blocks are available, the data retrieval acceleration process is terminated (step **308**). If more data blocks are available from the data storage device, the next data block is retrieved (step **310**) and the process repeats beginning with data decompression (step **302**).

Referring now to FIGS. **4***a* and **4***b*, a timing diagram illustrates methods for accelerated data storage utilizing data compression in accordance with the present invention. Successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** is received from an input stream of one or more data blocks. Similarly, data block **2** through data block n are received during time intervals T**2** through Tn, respectively. For the purposes of discussion, FIGS. **4***a* and **4***b* demonstrate one embodiment of the data storage utilizing a stream of n data blocks. As previously stated, the input data stream is comprised of one or more data blocks data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable.

In accordance with Method **1**, compression of data block **1** and subsequent storage of the encoded data block **1** occurs within time interval T**1**. Similarly, the compression and storage of each successive data block occurs within the time interval the data block is received. Specifically, data blocks **2** . . . n are compressed in time intervals T**2** . . . Tn, respectively, and the corresponding encoded data blocks **2** . . . n are stored during the time intervals T**2** . . . Tn, respectively. It is to be understood that Method **1** relies on data compression and encoding techniques that process data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data compression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of encoding data when received. Method **1** possesses the advantage of introducing a minimum delay in the time from receipt of input to storage of encoded data blocks.

Referring again to FIGS. **4***a* and **4***b*, Method **2** illustrates compressing and storing data utilizing pipelined data processing. For Method **2**, successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** is received from an input stream of one or more data blocks during time interval T**1**. Similarly, data block **2** through data block n are received during time intervals T**2** through Tn, respectively. Compression of data block **1** occurs during time interval T**2** and the storage of encoded data block **1** occurs during time interval T**3**. As shown by Method **2**, compression of each successive data block occurs within the next time interval after the data block is received and data storage of the corresponding encoded data block occur in the next time interval after completion of data compression.

The pipelining of Method **2**, as shown, utilizes successive single time interval delays for data compression and data storage. Within the current invention, it is permissible to have increased pipelining to facilitate additional data processing or storage delays. For example, data compression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data compressors to process successive data blocks, e.g., data compression processing of a single data block through three successive time intervals requires three data compressors, each processing a successive input data block. Due to the principle of causality, encoded data blocks are output only after compression encoding.

Method **2** provides for block oriented processing of the input data blocks. Within the current art, block oriented data compression techniques provide the opportunity for increased data compression ratios. The disadvantage of Method **2** is increased delay from receipt of input data block to storage of encoded data. Depending on factors such as the size of input data blocks, the rate that they are received, the time required for data compression processing, the data compression ratio achieved, the bandwidth of the data storage device, and the intended application, the delay may or may not be significant. For example, in a modern database system, recording data for archival purposes, the opportunity for increased data compression may far outweigh the need for minimum delay. Conversely, in systems such as a military real-time video targeting system, minimizing delay is often of the essence. It should be noted that Method **1** and Method **2** are not mutually exclusive, and may be utilized in any combination.

Referring now to FIGS. **5***a* and **5***b*, a timing diagram illustrates methods for accelerated data retrieval utilizing data decompression in accordance the present invention shown. Successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** is retrieved or otherwise accepted as input from one or more compressed data blocks retrieved from a data storage device. As shown, data block **2** through data block n are retrieved during time intervals T**2** through Tn, respectively. For the purposes of discussion, FIGS. **5***a* and **5***b* demonstrate one embodiment of the data retrieval accelerator utilizing a stream of n data blocks. Once again, the retrieved data stream is comprised of one or more data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the retrieved data block size may be fixed or variable.

In accordance with Method **1**, decompression of data block **1** and subsequent outputting of the decoded data block **1** occurs within time interval T**1**. Similarly, decompression and outputting of each successive data block occurs within the time intervals they are retrieved. In particular, data block **2** through data block n are decompressed and decoded data block **2** through decoded data block n are output during time intervals T**2** . . . Tn, respectively. It is to be understood that Method **1** relies on data decompression and decoding techniques that process compressed data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data decompression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of decoding data when received. Method **1** possesses the advantage of introducing a minimum delay in the time from retrieval of compressed data to output of decoded data blocks.

Referring again to FIGS. **5***a* and **5***b*, Method **2** involves decompressing and outputting data utilizing pipelined data processing. For Method **2**, successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** through data block n are retrieved or otherwise accepted as input from a data storage device during time intervals T**1** through Tn, respectively. Decompression of data block **1** occurs during time interval T**2** and the decoded data block **1** is output during time interval T**3**. Similarly, decompression of each successive data block occurs within the next time interval after the data block is retrieved and the outputting of the decoded data block occurs during the next time interval after completion of data decompression.

The pipelining of Method **2**, utilizes successive single time interval delays for data decompression and data output. Within the current invention, it is permissible to have increased pipelining to facilitate additional data retrieval or data decompression processing delays. For example, data decompression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data decompressors to process successive compressed data blocks, e.g., data decompression processing of a single data block through three successive time intervals requires three data decompressors, each processing a successive input data block. Due to the principle of causality, decoded data blocks are only output after decompression decoding.

As before, Method **2** provides for block oriented processing of the retrieved data blocks. Within the current art, block oriented data decompression techniques provide the opportunity to utilize data compression encoders that increase data compression ratios. The disadvantage of method **2** is increased delay from retrieval of compressed data block to output of decompressed data. As previously discussed for data storage acceleration, depending on the size of retrieved data blocks, the rate that they are retrieved, the time required for data decompression processing, the data decompression ratio achieved, the bandwidth of the data output, and the intended application, the delay may or may not be significant.

Referring now to FIGS. **6***a* and **6***b*, a flow diagram illustrates a method for accelerated data storage according to a further aspect of the present invention. With this method, the data compression rate of the storage accelerator **10** is not required to be equal to or greater than the ratio of the input data rate to the data storage access rate. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream is received (step **600**) and then timed and counted (step **602**). Timing and counting enables determination of the bandwidth of the input data stream. The input data block is then buffered (step **604**) and compressed by the data storage accelerator **10** (step **606**). During and after the encoding of the input data block, the encoded data block is then timed and counted (step **608**), thus enabling determination of the compression ratio and compression bandwidth. The compressed, timed and counted data block is then buffered (step **610**). The compression ratio and bandwidths of the input data stream and the encoder are then determined (step **612**). The compressed data block is then stored in the data storage device **45** (step **614**). Checks or other forms of testing are applied to ensure that the data bandwidths of the input data stream, data compressor, and data storage device are compatible (step **616**). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step **618**). For instance, the input bandwidth may be adjusted by either not accepting input data requests, lowering the duty cycle of input data requests, or by signaling one or more of the data sources that transmit the input data stream to request or mandate a lower data rate. In addition, the data compression ratio of the data storage accelerator **10** may be adjusted by applying a different type of encoding process such as employing a single encoder, multiple parallel or sequential encoders, or any combination thereof. Furthermore, additional temporary buffering of either the input data stream or the compressed data stream (or both) may be utilized.

By way of example, assuming the input data rate is 90 MB/sec and the data storage accelerator **10** provides a compression ration of 3:1, then the output of the data storage accelerator **10** would be 30 MB/sec. If the maximum data storage rate of the data storage device **45** is 20 MB/sec (which is less than the data rate output from the data storage accelerator **10**), data congestion and backup would occur at the output of the data storage accelerator **10**. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the compression ratio to provide a data output rate from the data storage accelerator **10** to be equal to the data storage rate of the data storage device **45**.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more of the system parameters), then a check or other form of test is performed to determine if there are additional data blocks available in the input stream (step **620**). If no more data blocks are available, the storage acceleration process is terminated (step **622**). If more data blocks are available in the input data stream, the next data block is received (step **624**) and the process repeats beginning with timing and counting of the input data block (step **602**).

Referring now to FIGS. **7***a* and **7***b*, a flow diagram illustrates a method for accelerated data retrieval according to one aspect of the present invention. With this method, the data decompression ratio is not required to be less than or equal to the ratio of the data retrieval access rate to the maximum output data rate. As previously stated above, data decompression is performed on a per data block basis. Accordingly, the initial input data block is retrieved from the storage device (step **700**) and is timed and counted (step **702**). Timing and counting enables determination of the bandwidth of data retrieval. The retrieved data block is then buffered (step **704**) and decompressed by the data retrieval accelerator **80** (step **706**). During and after the decoding of the input data block, the decoded data block is then timed and counted (step **708**), thus enabling determination of the decompression ratio and decompression bandwidth. The decompressed, timed and counted data block is then buffered (step **710**). The decompression ratio and bandwidths of the retrieved data and the decoder are then determined (step **712**). The decompressed data block is then output (step **714**). Checks or other forms of testing are applied to ensure that the data bandwidths of the retrieved data, data decompressor, and data output are compatible (step **716**). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step **718**). For instance, the data retrieval bandwidth may be adjusted either not accepting (continuously) data blocks retrieved from the data storage device or lowering the duty cycle of data blocks retrieved from the data storage device. In addition, one or more of the output data devices that receive the output data stream may be signaled or otherwise requested to accept a higher data rate. Moreover, a different type of decoding process may be applied to adjust the data decompression rate by applying, for example, a single decoder, multiple parallel or sequential decoders, or any combination thereof. Also, additional temporary buffering of either the retrieved or output data or both may be utilized.

By way of example, assuming the data storage device **45** has a data retrieval rate of 20 MB/sec and the data retrieval accelerator **80** provides a 1:4 decompression ratio, then the output of the data retrieval accelerator **80** would be 80 MB/sec. If the maximum output data transmission rate that can be accepted from the data retrieval accelerator **80** is 60 MB/sec (which is lower than the data output data rate of 80 MB/sec of the data retrieval accelerator **80**), data congestion and backup would occur at the output of the data retrieval accelerator **80**. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the decompression ratio to provide a data output rate from the data storage accelerator **80** to be equal to the maximum accepted output data transmission rate.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more system parameters), then a check or other form of test is performed to see if there are additional data blocks available from the data storage device (step **720**). If no more data blocks are available for output, the retrieval acceleration process is terminated (step

722). If more data blocks are available to be retrieved from the data storage device, the next data block is retrieved (step **724**) and the process repeats beginning with timing and counting of the retrieved data block (return to step **702**).

It is to be understood that any conventional compression/decompression system and method (which comply with the above mentioned constraints) may be employed in the data storage accelerator **10** and data retrieval accelerator **80** for providing accelerated data storage and retrieval in accordance with the present invention. Preferably, the present invention employs the data compression/decompression techniques disclosed in U.S. Ser. No. 09/210,491 entitled "Content Independent Data Compression Method and System," filed on Dec. 11, 1998, which is commonly assigned and which is fully incorporated herein by reference. It is to be appreciated that the compression and decompression systems and methods disclosed in U.S. Ser. No. 09/210,491 are suitable for compressing and decompressing data at rates which provide accelerated data storage and retrieval.

Referring now to FIG. **8**, a detailed block diagram illustrates a preferred system for accelerated data storage which employs a compression system as disclosed in the above-incorporated U.S. Ser. No. 09/210,491. In this embodiment, the data storage accelerator **10** accepts data blocks from an input data stream and stores the input data block in an input buffer or cache **15**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. A counter **20** counts or otherwise enumerates the size of input data block in any convenient units including bits, bytes, words, double words. It should be noted that the input buffer **15** and counter **20** are not required elements of the present invention. The input data buffer **15** may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold.

Data compression is performed by an encoder module **25** which may comprise a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" (where n may=1) of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **25** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **20**). Data compression is performed by the encoder module **25** wherein each of the encoders E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **25** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **30** is operatively connected to the encoder module **25** for buffering and counting the size of each of the encoded data blocks output from encoder module **25**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **35**, operatively connected to the output buffer/counter **30**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **35** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **38**, operatively coupled to the compression ratio module **35**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block. A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal. If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit, then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto. A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal.

The data storage acceleration device **10** is connected to a data storage device interface **40**. The function of the data storage interface **40** is to facilitate the formatting and transfer of data to one or more data storage devices **45**. The data storage interface may be any of the data interfaces known to those skilled in the art such as SCSI (Small Computer Systems Interface), Fibre Channel, "Firewire", IEEE P1394, SSA (Serial Storage Architecture), IDE (Integrated Disk

Electronics), and ATA/ATAPI interfaces. It should be noted that the storage device data interface **40** is not required for implementing the present invention. As before, the data storage device **45** may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The data storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory (RAM), magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices (e.g., ATA/ATAPI IDE disk). Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

Again, it is to be understood that the embodiment of the data storage accelerator **10** of FIG. **8** is exemplary of a preferred compression system which may be implemented in the present invention, and that other compression systems and methods known to those skilled in the art may be employed for providing accelerated data storage in accordance with the teachings herein. Indeed, in another embodiment of the compression system disclosed in the above-incorporated U.S. Ser. No. 09/210,491, a timer is included to measure the time elapsed during the encoding process against an a priori-specified time limit. When the time limit expires, only the data output from those encoders (in the encoder module **25**) that have completed the present encoding cycle are compared to determine the encoded data with the highest compression ratio. The time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved. In addition, the results from each encoder in the encoder module **25** may be buffered to allow additional encoders to be sequentially applied to the output of the previous encoder, yielding a more optimal lossless data compression ratio. Such techniques are discussed in greater detail in the above-incorporated U.S. Ser. No. 09/210,491.

Referring now to FIG. **9**, a detailed block diagram illustrates a preferred system for accelerated data retrieval employing a decompression system as disclosed in the above-incorporated U.S. Ser. No. 09/210,491. In this embodiment, the data retrieval accelerator **80** retrieves or otherwise accepts data blocks from one or more data storage devices **45** and inputs the data via a data storage interface **50**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. As stated above, the memory storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof. The data storage device interface **50** converts the input data from the storage device format to a format useful for data decompression.

The storage device data interface **50** is operatively connected to the data retrieval accelerator **80** which is utilized for decoding the stored (compressed) data, thus providing accelerated retrieval of stored data. In this embodiment, the data retrieval accelerator **80** comprises an input buffer **55** which receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **55** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **60** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **65** includes one or more decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source.

As with the data compression systems discussed in U.S. application Ser. No. 09/210,491, the decoder module **65** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time. The data retrieval accelerator **80** also includes an output data buffer or cache **70** for buffering the decoded data block output from the decoder module **65**. The output buffer **70** then provides data to the output data stream. It is to be appreciated by those skilled in the art that the data retrieval accelerator **80** may also include an input data counter and output data counter operatively coupled to the input and output, respectively, of the decoder module **65**. In this manner, the compressed and corresponding decompressed data block may be counted to ensure that sufficient decompression is obtained for the input data block.

Again, it is to be understood that the embodiment of the data retrieval accelerator **80** of FIG. **9** is exemplary of a preferred decompression system and method which may be implemented in the present invention, and that other data decompression systems and methods known to those skilled in the art may be employed for providing accelerated data retrieval in accordance with the teachings herein.

In accordance with another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in for increasing the storage rate of video data. In particular, referring now to FIG. **10**, a block diagram illustrates a system for providing accelerated video data storage in accordance with one embodiment of the present invention. The video data storage acceleration system accepts as input one or more video data streams that are analog, digital, or any combination thereof in nature. The input multiplexer **1010** selects the initial video data stream for data compression and acceleration. The input multiplexer **1010** is operatively connected to an analog to digital converter **1020** which converts analog video inputs to digital format of desired resolution. The analog to digital converter **1020** may also include functions to strip video data synchronization to perform other data formatting functions. It should be noted that the analog to digital conversion process is not required for digital video inputs. The analog to digital converter **1020** is operatively connected a video memory **1030** that is, in turn, operatively connected to a video processor **1040**. The video processor **1040** performs manipulation of the digital video data in accordance with any user desired processing functions. The video processor **1040** is operatively coupled to a video output memory **1050**, that is operatively connected to a data storage accelerator **10** which compresses the video data to provide accelerated video data to the output data stream for subsequent data processing, storage, or transmittal of the video data. This video data acceleration process is repeated for all data blocks in the input data stream. If more video data blocks are available in the input data stream, the video multiplexer selects the next block of video for accelerated processing. Again, it is to be understood that the data storage accelerator **10** may employ any compression system which is capable of compressing data at a rate suitable for providing accelerated video data storage in accordance with the teachings herein.

In accordance with another aspect of the present invention, the accelerated data storage and retrieval system may be employed in a display controller to reduce the time required to send display data to a display controller or processor. In particular, referring now to FIG. **11**, a block diagram illustrates a display accelerator system in accordance with one embodiment of the present invention. The video display accelerator accepts as input one or more digital display data blocks from an input display data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input video data block size may be fixed or variable. The input data blocks are processed by a data retrieval accelerator **80** which employs a data decompression system in accordance with the teachings herein. Upon completion of data decompression, the decompressed data block is then output to a display memory **1110** that provides data to a display processor **1120**. The display processor **1120** performs any user desired processing function. It is well known within the current art that display data is often provided in one or more symbolic formats such as Open Graphics Language (Open GL) or another display or image language. The display processor **1120** is operatively connected an output memory buffer **1130**. The output memory **1130** supplies data to a display formatter **1140** that converts the data to a format compatible with the output display device or devices. Data from the display formatter **1140** is provided to the display driver **1150** that outputs data in appropriate format and drive signal levels to one or more display devices. It should be noted that the display memory **1110**, display processor **1120**, output memory **1130**, display formatter **1140**, and display driver **1150** are not required elements of the present invention.

In accordance with yet another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in an I/O controller to reduce the time for storing, retrieving or transmitting parallel data streams. In particular, referring now to FIG. **12**, a block diagram illustrates a system for accelerated data storage of analog, digital, and serial data in accordance with one embodiment of the present invention. The data storage accelerator **10** is capable of accepting one or more simultaneous analog, parallel digital, and serial data inputs. An analog input multiplexer **1205** selects the initial analog data for data compression and acceleration. The analog input multiplexer **1205** is operatively connected to an analog to digital converter **1210** that converts the analog input signal to digital data of the desired resolution. The digitized data output of the analog to digital converter **1210** is stored in an analog data memory buffer **1215** for subsequent data storage acceleration. Similarly, a parallel digital data input multiplexer **1220** selects the initial parallel digital data for data compression and acceleration. The parallel digital data input multiplexer **1220** is operatively connected to an input data latch **1225** that holds the input parallel digital data. The parallel digital data is then stored in digital data memory buffer **1245** for subsequent data storage acceleration. In addition, a serial digital data input multiplexer **1235** selects the initial serial digital data for data compression and acceleration. The serial digital data input multiplexer **1235** is operatively connected to a serial data interface **1240** that converts the serial data stream to a format useful for data acceleration. The formatted serial digital data is then stored in serial data memory buffer **1245** for subsequent data acceleration. The analog data memory **1215**, parallel digital data memory **1230**, and serial data memory **1245** are operatively connected to the data storage accelerator device **10**. Data is selected from each data memory subsystem based upon a user defined algorithm or other selection criteria. It should be noted that the analog input multiplexer **1205**, analog to digital converter **1210**, analog data memory **1215**, parallel data input multiplexer **1220**, data latch **1225**, digital data memory **1230**, serial data input multiplexer **1235**, serial data interface **1240**, serial data memory **1245**, and counter **20** are not required elements of the present invention. As stated above, the data storage accelerator **10** employs any of the data compression methods disclosed in the above-incorporated U.S. Ser. No. 09/210,491, or any conventional data compression method suitable for compressing data at a rate necessary for obtaining accelerated data storage. The data storage accelerator supplies accelerated data to the output data stream for subsequent data processing, storage, or transmittal.

Referring now to FIG. **13**, a flow diagram illustrates a method for accelerated data storage of analog, digital, and serial data according to one aspect of the present invention. The analog input multiplexer selects the initial analog data for data compression and acceleration (step **1300**). The analog input multiplexer provides analog data to the analog to digital converter that converts the analog input signal to digital data of the desired resolution (step **1302**). The digitized data output of the analog to digital converter is then buffered in the analog data memory buffer (step **1304**) for subsequent data acceleration. Similarly, the parallel digital data multiplexer selects the initial parallel digital data for data compression and acceleration (step **1306**). The parallel digital data multiplexer provides data to the input data latch that then holds the input parallel digital data (step **1308**). The parallel digital data is then stored in digital data memory buffer for subsequent data acceleration (step **1310**). The serial digital data input multiplexer selects the initial serial digital data for data compression and acceleration (step **1312**). The serial digital data input multiplexer provides serial data to the serial data interface that converts the serial data stream to a format useful for data acceleration (step **1314**). The formatted serial digital data is then stored in the serial data memory buffer for subsequent data acceleration (step **1316**). A test or other check is performed to see if new analog data is available (step **1318**). If no new analog data is available a second check is performed to see if new parallel data is available (step **1320**). If no new parallel data is available, a third test is performed to see if new serial data is available (step **1322**). If no new serial data is available (step **1322**) the test sequence repeats with the test for new analog data (step **1318**). If new analog data block is available (step **1318**), or if new parallel data block is available (step **1320**), or if new serial data block is available (step **1322**), the input data block is compressed by the data storage accelerator (step **1324**) utilizing any compression method suitable for providing accelerated data storage in accordance with the teachings herein. After data compression is complete, the compressed data block is then output subsequent accelerated data processing, storage, or transmittal (step **1326**). After outputting data the process repeats beginning with a test for new analog data (return to step **1318**).

Referring now to FIG. **14**, a block diagram illustrates a system for accelerated retrieval of analog, digital, and serial data in accordance with one embodiment of the present invention. A data retrieval accelerator **80** receives data from an input data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator **80** decompresses the input data utilizing any of the decompression methods suitable for providing accelerated data retrieval in accordance with the teachings herein. The data retrieval accelerator **80** is operatively connected to analog data memory **1405**, digital data memory **1420**, and serial data memory **1435**. Dependent upon the type of input data block, the decoded data block is stored in the appropriate analog **1405**, digital **1420**, or serial **1435** data memory.

The analog data memory **1405** is operatively connected to a digital to analog converter **1410** that converts the decompressed digital data block into an analog signal. The digital to analog converter **1410** is further operatively connected to an analog hold and output driver **1415**. The analog hold and output driver **1415** demultiplexes the analog signal output from the digital to analog converter **1410**, samples and holds the analog data, and buffers the output analog data.

In a similar manner, the digital data memory **1420** is operatively connected to a digital data demultiplexer **1425** that routes the decompressed parallel digital data to the output data latch and driver **1430**. The output latch and driver **1430** holds the digital data and buffers the parallel digital output.

Likewise, the serial data memory **1435** is operatively connected to a serial data interface **1440** that converts the decompressed data block to an output serial data stream. The serial data interface **1440** is further operatively connected to the serial demultiplexer and driver **1445** that routes the serial digital data to the appropriate output and buffers the serial data output.

Referring now to FIGS. **15***a* and **15***b*, a flow diagram illustrates a method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention. An initial data block is received (step **1500**) and then decompressed by the data storage retrieval accelerator (step **1502**). Upon completion of data decompression, a test or other check is performed to see if the data block is digitized analog data (step **1508**). If the data block is not digitized analog data, a second check is performed to see if the data block is parallel digital data (step **1510**). If the data block is not parallel digital data, a third test is performed to see if the data block serial data (step **1512**). The result of at least one of the three tests will be affirmative.

If the data block is comprised of digitized analog data, the decoded data block is buffered in an “analog” digital data memory (step **1514**). The decoded data block is then converted to an analog signal by a digital to analog converter (step **1520**). The analog signal is then output (step **1522**).

If the data block is comprised of parallel digital data, the decoded data block is buffered in a “parallel” digital data memory (step **1516**). The decoded data block is then demultiplexed (step **1524**) and routed to the appropriate the output data latch and driver. The output latch and driver then holds the digital data and buffers the parallel digital output (step **1526**).

If the data block is comprised of serial data, the decoded data block is buffered in “serial” digital data memory (step **1518**). The decoded data is then formatted to a serial data format (step **1528**). The serial data is then demultiplexed, routed to the appropriate output, and output to a buffer (step **1530**).

Upon output of analog data (step **1522**), parallel digital data (step **1526**), or serial digital data (step **1530**), a test or other form of check is performed for more data blocks in the input stream (step **1532**). If no more data blocks are available, the test repeats (return to step **1532**). If a data block is available, the next data block is received (step **1534**) and the process repeats beginning with step **1502**.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A system comprising:

a memory device; and

a data accelerator, wherein said data accelerator is coupled to said memory device, a data stream is received by said data accelerator in received form, said data stream includes a first data block and a second data block, said data stream is compressed by said data accelerator to provide a compressed data stream by compressing said first data block with a first compression technique and said second data block with a second compression technique, said first and second compression techniques are different, said compressed data stream is stored on said memory device, said compression and storage occurs faster than said data stream is able to be stored on said memory device in said received form, a first data descriptor is stored on said memory device indicative of said first compression technique, and said first descriptor is utilized to decompress the portion of said compressed data stream associated with said first data block.

2. The system of claim **1**, wherein said data accelerator stores said first descriptor to said memory device.

3. The system of claim **1**, wherein said data accelerator retrieves said first descriptor and said compressed data stream from said memory device.

4. The system of claim **1**, wherein said data accelerator retrieves said compressed data stream from said memory device.

5. The system of claim **1**, wherein said data accelerator retrieves said compressed data stream from said memory device and said decompression of the portion of said compressed data stream associated with said first data block is performed by said data accelerator.

6. The system of claim **1**, wherein said data accelerator is coupled to said memory device via a small computer systems interface.

7. The system of claim **1**, wherein said data accelerator is coupled to said memory device via a fibre channel.

8. The system of claim **1**, wherein said data accelerator is coupled to said memory device via a serial storage architecture.

9. The system of claim **1**, wherein said memory device is a magnetic memory device.

10. The system of claim **1**, wherein said memory device is an optical memory device.

11. The system of claim **1**, wherein said memory device is a random access memory.

12. The system of claim **1**, wherein said memory device is a solid-state mass storage device.

13. The system of claim **1**, wherein said first compression technique includes compressing with Huffman encoding.

14. The system of claim **1**, wherein said first compression technique includes compressing with Lempel-Ziv encoding.

15. The system of claim **1**, wherein said first compression technique includes compressing with a plurality of encoders in a serial configuration.

16. The system of claim **1**, wherein said first compression technique includes compressing with a plurality of encoders in a parallel configuration.

17. The system of claim **1**, wherein said first compression technique includes compressing with a plurality of encoders in a parallel configuration and each one of said plurality of encoders is an identical type of encoder.

18. The system of claim **1**, wherein said first compression technique comprises compressing with a first encoder.

19. The system of claim **1**, wherein said data stream comprises a collection of multiple files.

20. The system of claim **1**, wherein said data stream includes a third data block and a fourth data block.

21. The system of claim **1**, wherein said data stream includes a third data block and a fourth data block and said compressed data stream is provided by compressing said third data block with a third compression technique and compressing said fourth data block with a fourth compression technique.

22. The system of claim **1**, wherein said data stream is an analog video data stream.

23. The system of claim **1**, wherein said data stream is a digital video data stream.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,415,530 B2
APPLICATION NO. : 11/553426
DATED : August 19, 2008
INVENTOR(S) : James J. Fallon

Page 1 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Cover page, item (57), --be-- should be inserted after “may”.

Cover page, item (56), Other Publications, Smith, T.B., et al., “Vo.45” should be --Vol.45--.

In the Drawings
Figure 13, Box 1312, “Serail” should be --Serial--.

Column 3, line 45, first occurrence of “data” should be deleted.

Column 4, line 66, “that” should be --which--.

Column 5, line 1, “and” should be --any--.

Column 5, line 60, --a-- should be inserted before second occurrence of “rate”.

Column 6, line 64, --are-- should be inserted after “blocks”.

Column 7, line 14, second occurrence of “data blocks” should be deleted.

Column 7, line 47, “occur” should be --occurs--.

Column 8, line 15, --with-- should be inserted after “accordance”.

Column 9, line 57, “ration” should be --ratio--.

Column 14, line 51, “for” should be deleted.

Column 14, line 67, --to-- should be inserted after “connected”.

Column 15, line 40, --to-- should be inserted after “connected”.

Column 17, line 1, --to-- should be inserted after “subsequent”.

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APPLICATION NO. : 11/553426
DATED : August 19, 2008
INVENTOR(S) : James J. Fallon

Page 2 of 2

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 17, line 52, --is-- should be inserted after "block".

Column 17, line 64, "the" after "appropriate" should be deleted.

Signed and Sealed this

Second Day of December, 2008

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

US007415530C1

(12) INTER PARTES REEXAMINATION CERTIFICATE (671st)

United States Patent

Fallon

(10) **Number: US 7,415,530 C1**

(45) **Certificate Issued: Aug. 16, 2013**

(54) **SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL**

(75) Inventor: **James J Fallon**, Armonk, NY (US)

(73) Assignee: **Realtime Data LLC**, New York, NY (US)

Reexamination Request:

No. 95/001,927, Mar. 2, 2012

Reexamination Certificate for:

Patent No.:	**7,415,530**
Issued:	**Aug. 19, 2008**
Appl. No.:	**11/553,426**
Filed:	**Oct. 26, 2006**

Certificate of Correction issued Dec. 2, 2008

Related U.S. Application Data

(63) Continuation of application No. 10/628,795, filed on Jul. 28, 2003, now Pat. No. 7,130,913, which is a continuation of application No. 09/266,394, filed on Mar. 11, 1999, now Pat. No. 6,601,104.

(51) **Int. Cl.**
G06F 15/16 (2006.01)

(52) **U.S. Cl.**
USPC **709/231**

(58) **Field of Classification Search**
None
See application file for complete search history.

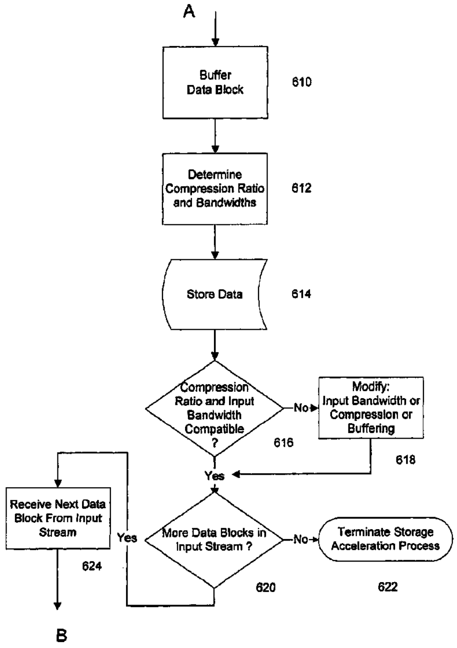
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 95/001,927, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — Mark Sager

(57) **ABSTRACT**

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to simultaneously or sequentially losslessly compress data at a rate equivalent to or faster than the transmission rate of an input data stream. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to simultaneously or sequentially losslessly decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device. The data storage and retrieval accelerator method and system may employed: in a disk storage adapter to reduce the time required to store and retrieve data from computer to disk; in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory; in a display controller to reduce the time required to send display data to the display controller or processor; and/or in an input/output controller to reduce the time required to store, retrieve, or transmit data.



INTER PARTES REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 316

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1**, **2**, **16-21** and **23** is confirmed.

New claims **24-26** are added and determined to be patentable.

Claims **3-15** and **22** were not reexamined.

24. A system comprising:

a memory device; and

a data accelerator, wherein said data accelerator is coupled to said memory device, a data stream is received by said data accelerator in received form, wherein a bandwidth of the received data stream is determined, said data stream includes a first data block and a second data block, said data stream is compressed by said data accelerator to provide a compressed data stream by compressing said first data block with a first compression technique and said second data block with a second compression technique, said first and second compression techniques are different, wherein a data rate of the compressed data stream is adjusted, by modifying a system parameter, to make a bandwidth of the compressed data stream compatible with a bandwidth of the memory device, said compressed data stream is stored on said memory device, said compression and storage occurs faster than said data stream is able to be stored on said memory device in said received form, a first data descriptor is stored on said memory device indicative of said first compression technique, and said first descriptor is utilized to decompress the portion of said compressed data stream associated with said first data block.

25. The system of claim 1, wherein the data accelerator is configured to append a type descriptor to the first and second compressed data blocks in the compressed data stream, and wherein the type descriptor includes values corresponding to a plurality of encoding techniques that were applied to the compressed data stream.

26. The system of claim 1, wherein the data accelerator is configured to adjust the data rate of the compressed data stream by adjusting a compression ratio of a lossless encoder.

* * * * *

US009116908B2

(12) **United States Patent**
Fallon

(10) **Patent No.: US 9,116,908 B2**
(45) **Date of Patent: *Aug. 25, 2015**

(54) **SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL**

(71) Applicant: **Realtime Data LLC**, Armonk, NY (US)

(72) Inventor: **James J. Fallon**, Armonk, NY (US)

(73) Assignee: **Realtime Data LLC**, Armonk, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/303,276**

(22) Filed: **Jun. 12, 2014**

(65) **Prior Publication Data**

US 2015/0012507 A1 Jan. 8, 2015

Related U.S. Application Data

(63) Continuation of application No. 11/553,419, filed on Oct. 26, 2006, now Pat. No. 8,756,332, which is a continuation of application No. 10/628,795, filed on Jul. 28, 2003, now Pat. No. 7,130,913, which is a continuation of application No. 09/266,394, filed on Mar. 11, 1999, now Pat. No. 6,601,104.

(51) **Int. Cl.**

G06F 15/16	(2006.01)
G06F 17/30	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***G06F 17/30153*** (2013.01); ***G06F 17/30371*** (2013.01); ***H04L 69/04*** (2013.01);
(Continued)

(58) **Field of Classification Search**
USPC 709/231, 247
See application file for complete search history.

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(Continued)

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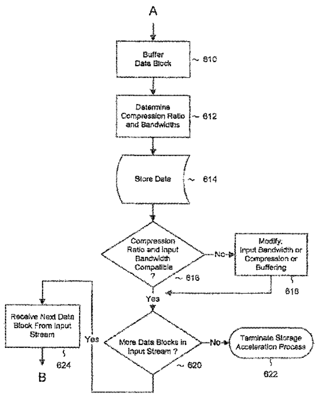
(57) **ABSTRACT**

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to compress data. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device.

30 Claims, 20 Drawing Sheets



(51) **Int. Cl.**

H04N 9/804	(2006.01)
H04L 29/06	(2006.01)
H04N 19/176	(2014.01)
H04N 19/15	(2014.01)
H04N 19/115	(2014.01)
H04N 19/152	(2014.01)
H04N 5/781	(2006.01)
H04N 5/84	(2006.01)
H04N 5/85	(2006.01)
H04N 5/907	(2006.01)
H04N 9/82	(2006.01)

(52) **U.S. Cl.**

CPC ***H04N 9/8042*** (2013.01); ***H04N 19/115*** (2014.01); ***H04N 19/15*** (2014.01); ***H04N 19/152*** (2014.01); ***H04N 19/176*** (2014.01); *H04N 5/781* (2013.01); *H04N 5/843* (2013.01); *H04N 5/85* (2013.01); *H04N 5/907* (2013.01); *H04N 9/8227* (2013.01)

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Exhibit 65, Prior Art Chart for U.S. Pat. No. 7,777,651, 313 pages, *Realtime Data, LLC D/B/A IXO* v. *Morgan Stanley, et al.*, 6:09-cv-326-LED-JDL, 6:10-cv-248-LED-JDL, 6:10-cv-426-LED-JDL, *Realtime Data, LLC D/B/A IXO* v. *CME Group Inc., et al.*, 6:09-cv-327-LED-JDL, 6:10-cv-246-LED-JDL, 6:10-cv-424-LED-JDL, *Realtime Data, LLC D/B/A IXO* v. *Thomson Reuters Corp., et al.*, 6:09-cv-333-LED-JDL, 6:10-cv-247-LED-JDL, 6:10-cv-425-LED-JDL, United States District Court for the Eastern District of Texas Tyler Division, Feb. 4, 2011, citing Telekurs Ticker—"Telekurs Ticker Service: Programmer's Reference," Telekurs (North America), Inc. (Jan. 11, 1993); C. Helck. "Encapsulated Ticker: Ver. 1.0," Telekurs NA, 1-22 (Jul. 14, 1993); A-T Financial Offers Manipulation, Redistribution of Ticker III, Micro Ticker Report, v 4, n 14 (Sep. 5, 1989); V. Kulkosky, "Upping the Ante" Wall Street & Technology, v11 n5 pp. 8-11 (Oct. 1993); "Telekurs to Launch New Int's Feed/Internet Server," Wall Street & Technology, v15 n1 pp. 14 (Jan. 1997); I. Schmerken, "Time running out for old technologies", Wall Street Computer Review, v47 n7 p. 14(7) (Apr. 1990); Scrolling News, Inside Market Data, v 10, n 11 (Feb. 27, 1995); Telekurs Buys S&P Trading Systems and Its Debut 128 KPS Ticker by Year's End, Inside Market Data, v 9, n 21 (Jul. 18, 1994); Telekurs Now Carries All Dow Jones' News on 56-KBPS Ticker, Inside Market Data, v9, N7 (Dec. 20, 1993); Telekurs Sells No. American Division in Mgmt. Buyout, Inside Market Data, v11, n.3 (Oct. 23, 1995).

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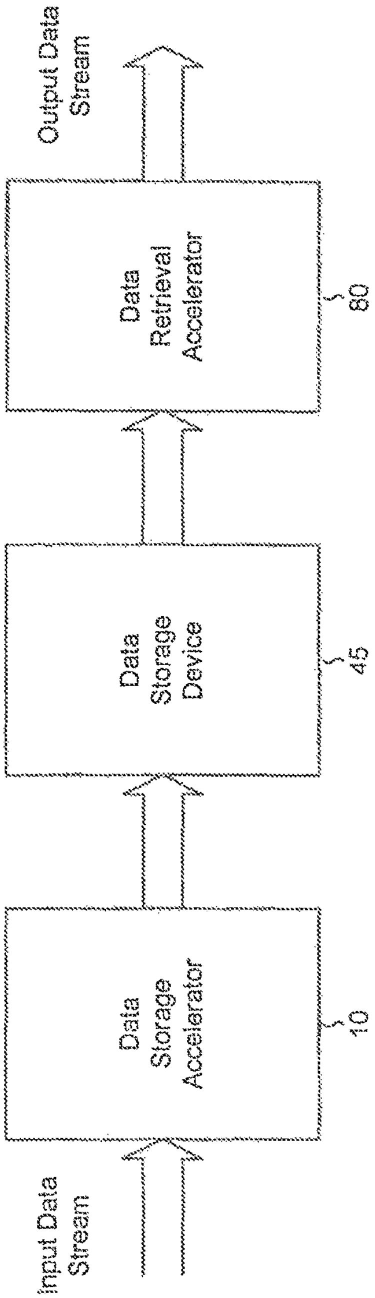
Input Data Stream
Data Storage Accelerator
10
Data Storage Device
45
Data Retrieval Accelerator
80
Output Data Stream

FIGURE 1

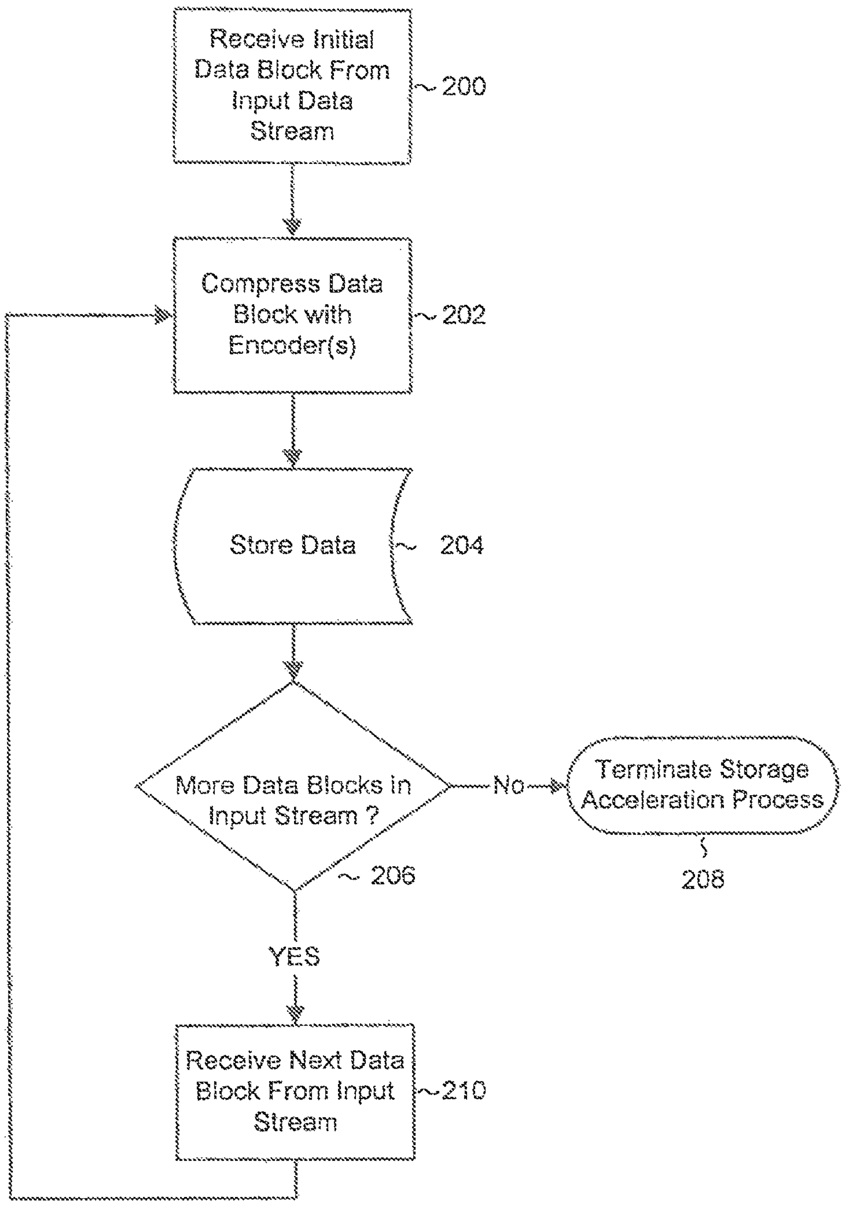
Receive Initial Data Block From Input Data Stream
200
Compress Data Block with Encoder(s)
202
Store Data
204
More Data Blocks in Input Stream ?
206
No
Terminate Storage Acceleration Process
208
YES
Receive Next Data Block From Input Stream
210

FIGURE 2

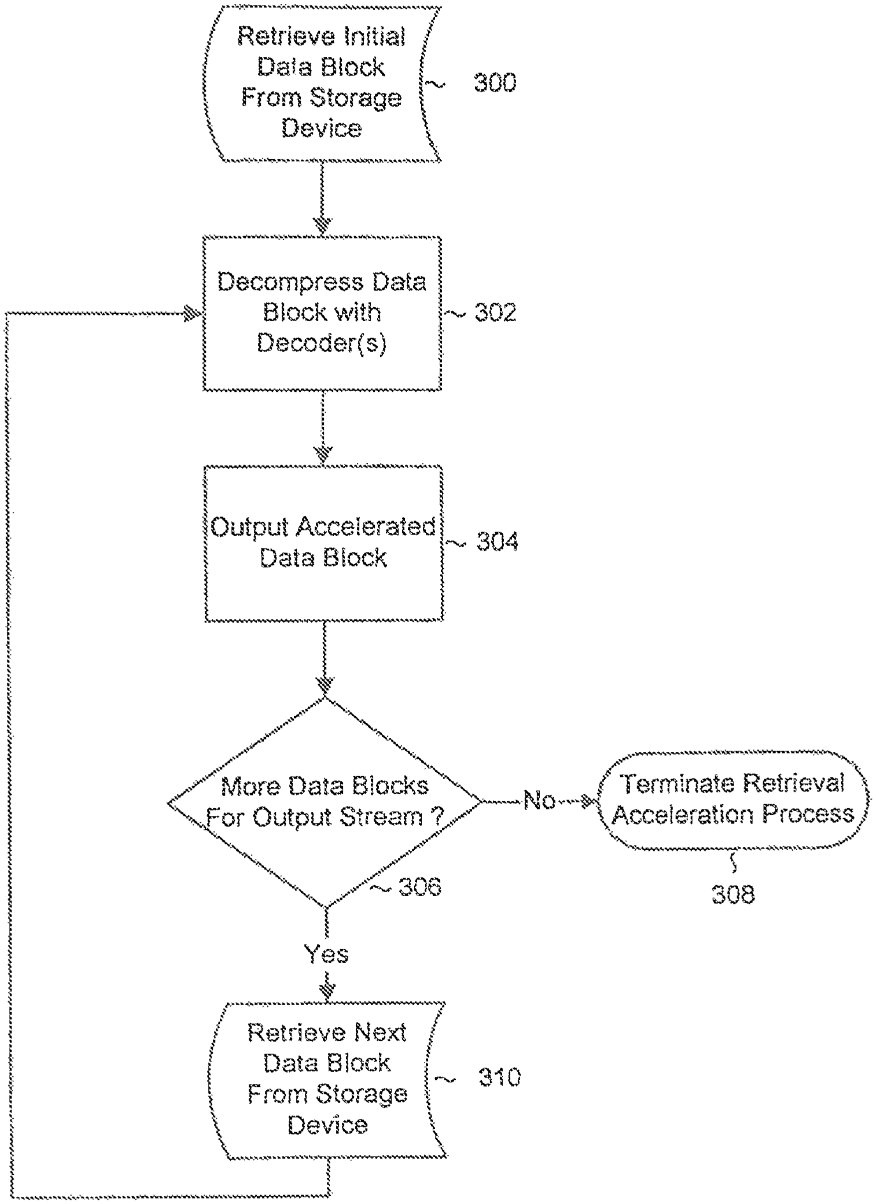
Retrieve Initial Data Block From Storage Device
300
Decompress Data Block with Decoder(s)
302
Output Accelerated Data Block
304
More Data Blocks For Output Stream ?
306
No
Terminate Retrieval Acceleration Process
308
Yes
Retrieve Next Data Block From Storage Device
310

FIGURE 3

Time Interval	T1	T2	T3	T4	Ti
Receive Data Block	Receive Data Block 1	Receive Data Block 2	Receive Data Block 3	Receive Data Block 4	Receive Data Block i
METHOD 1					
Compress Data Block	Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block 4	Compress Data Block i
Store Encoded Data Block	Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block 3	Store Encoded Data Block 4	Store Encoded Data Block i
METHOD 2					
Compress Data Block		Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block (i-1)
Store Encoded Data Block			Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block (i-2)

FIGURE 4a

Time interval	T(i+1)	T(i+2)	Tn	T(n+1)	T(n+2)
Receive Data Block	Receive Data Block (i+1)	Receive Data Block (i+2)	Receive Data Block n		
<u>METHOD 1</u>					
Compress Data Block	Compress Data Block (i+1)	Compress Data Block (i+2)	Compress Data Block n		
Store Encoded Data Block	Store Encoded Data Block (i+1)	Store Encoded Data Block (i+2)	Store Encoded Data Block n		
<u>METHOD 2</u>					
Compress Data Block	Compress Data Block i	Compress Data Block (i+1)	Compress Data Block (n-1)	Compress Data Block n	
Store Encoded Data Block	Store Encoded Data Block (i-1)	Store Encoded Data Block i	Store Encoded Data Block (n-2)	Store Encoded Data Block (n-1)	Store Encoded Data Block n

FIGURE 4b

Time Interval	T1	T2	T3	T4	Ti
Retrieve Data Block	Retrieve Data Block 1	Retrieve Data Block 2	Retrieve Data Block 3	Retrieve Data Block 4	Retrieve Data Block i
METHOD 1					
Decompress Data Block	Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block 4	Decompress Data Block i
Output Decoded Data Block	Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block 3	Output Decoded Data Block 4	Output Decoded Data Block i
METHOD 2					
Decompress Data Block		Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block (i-1)
Output Decoded Data Block			Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block (i-2)

FIGURE 5a

Time Interval	T(i+1)	T(i+2)	Tn	T(n+1)	T(n+2)
Retrieve Data Block	Retrieve Data Block (i+1)	Retrieve Data Block (i+2)	Retrieve Data Block n		
METHOD 1					
Decompress Data Block	Decompress Data Block (i+1)	Decompress Data Block (i+2)	Decompress Data Block n		
Output Decoded Data Block	Output Decoded Data Block (i+1)	Output Decoded Data Block (i+2)	Output Decoded Data Block n		
METHOD 2					
Decompress Data Block	Decompress Data Block i	Decompress Data Block (i+1)	Decompress Data Block (n-1)	Decompress Data Block n	
Output Decoded Data Block	Output Decoded Data Block (i-1)	Output Decoded Data Block i	Output Decoded Data Block (n-2)	Output Decoded Data Block (n-1)	Output Decoded Data Block n

FIGURE 5b

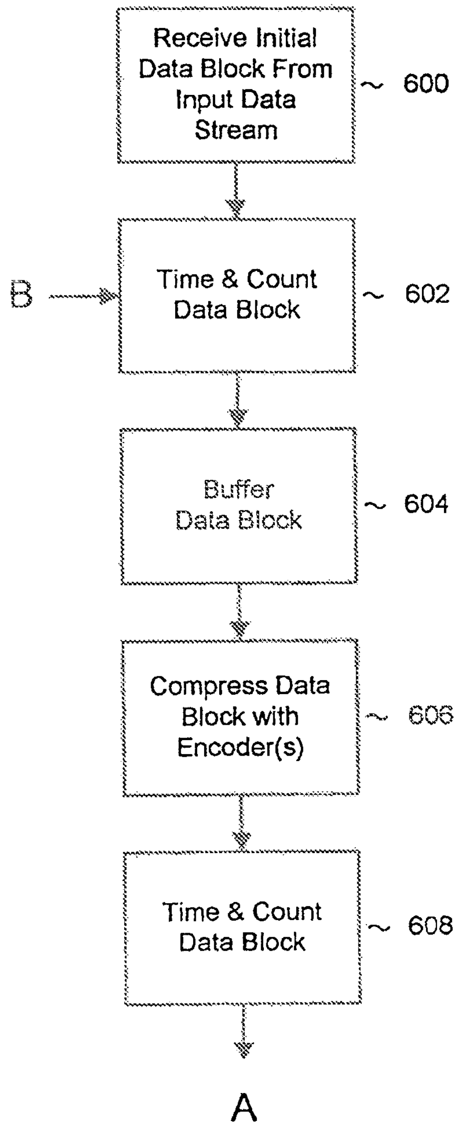
Receive Initial Data Block From Input Data Stream
600
B
Time & Count Data Block
602
Buffer Data Block
604
Compress Data Block with Encoder(s)
606
Time & Count Data Block
608
A

FIGURE 6a

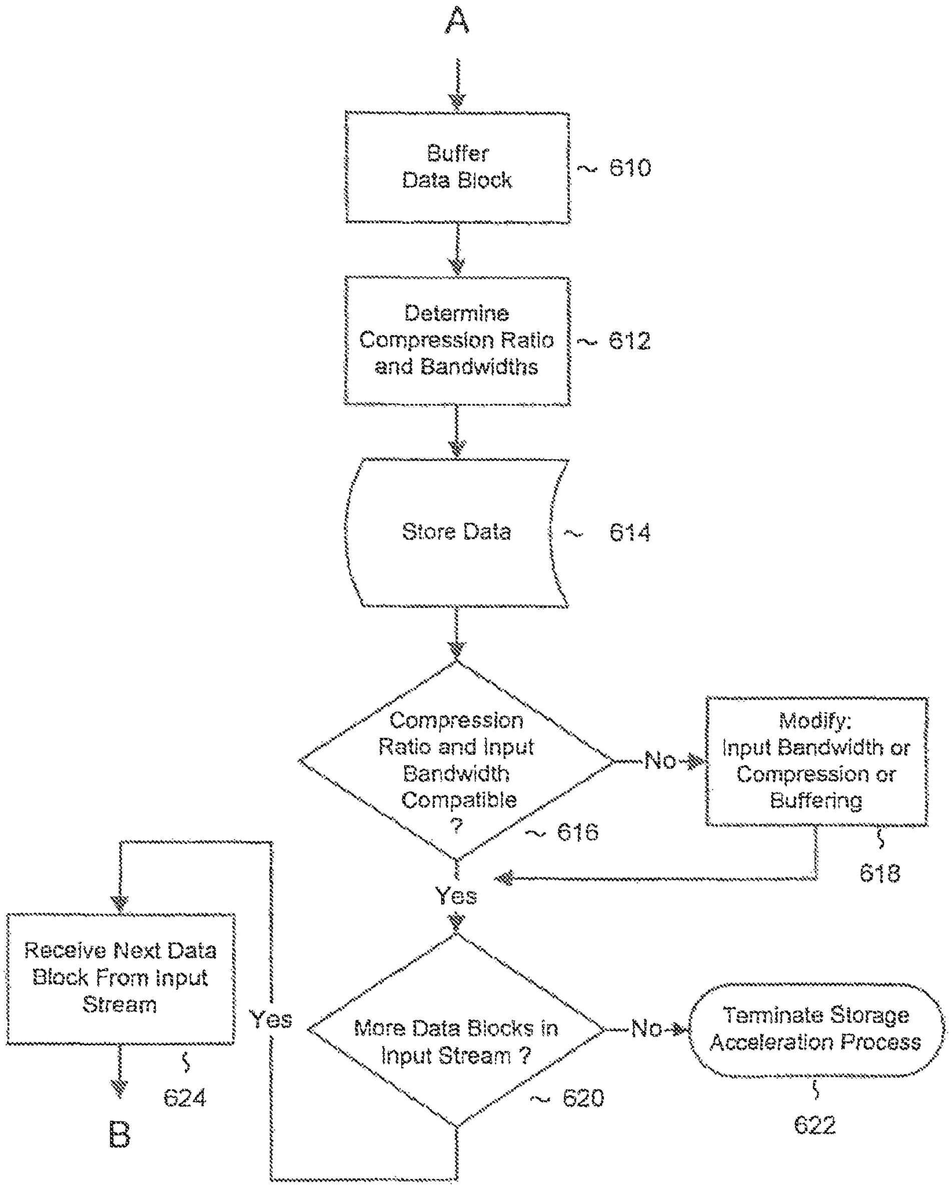
A
Buffer Data Block
610
Determine Compression Ratio and Bandwidths
612
Store Data
614
Compression Ratio and Input Bandwidth Compatible ?
616
No
Modify: Input Bandwidth or Compression or Buffering
618
Yes
Receive Next Data Block From Input Stream
624
B
Yes
More Data Blocks in Input Stream ?
620
No
Terminate Storage Acceleration Process
622

FIGURE 6b

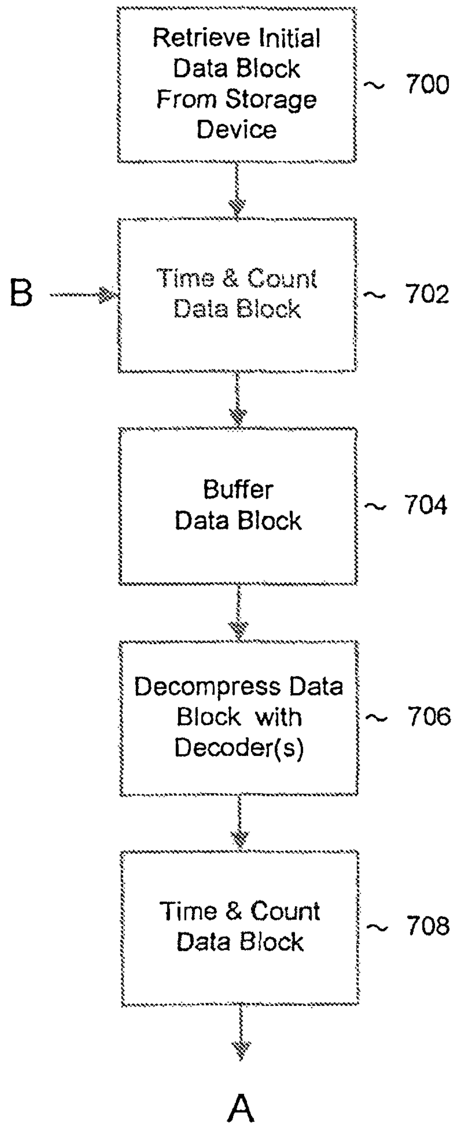
Retrieve Initial Data Block From Storage Device
700
B
Time & Count Data Block
702
Buffer Data Block
704
Decompress Data Block with Decoder(s)
706
Time & Count Data Block
708
A

FIGURE 7a

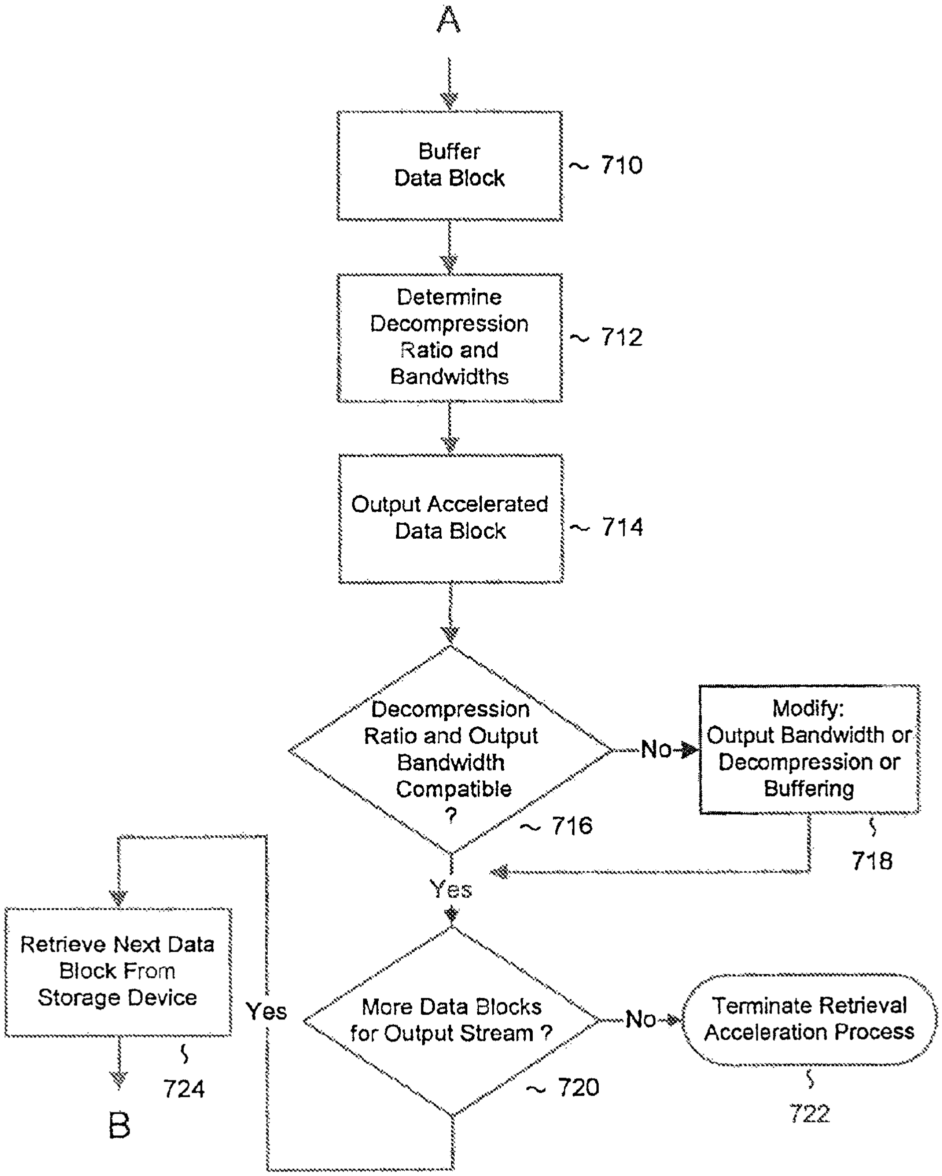
A
Buffer Data Block
710
Determine Decompression Ratio and Bandwidths
712
Output Accelerated Data Block
714
Decompression Ratio and Output Bandwidth Compatible ?
716
No
Modify: Output Bandwidth or Decompression or Buffering
718
Yes
More Data Blocks for Output Stream ?
720
No
Terminate Retrieval Acceleration Process
722
Yes
Retrieve Next Data Block From Storage Device
724
B

FIGURE 7b

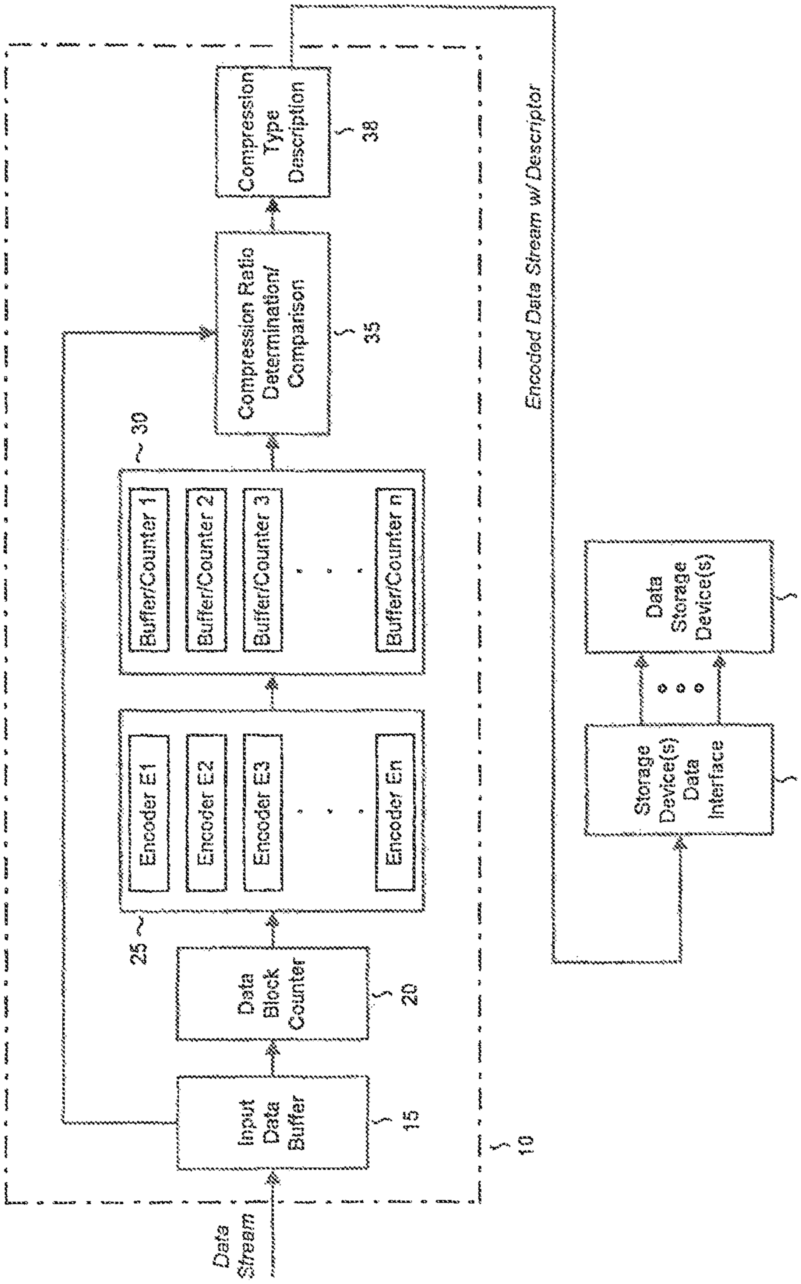
Data Stream
Input Data Buffer
15
Data Block Counter
20
25
Encoder E1
Encoder E2
Encoder E3
. . .
Encoder En
Buffer/Counter 1
Buffer/Counter 2
Buffer/Counter 3
. . .
Buffer/Counter n
30
Compression Ratio Determination/ Comparison
35
Compression Type Description
38
10
Encoded Data Stream w/ Descriptor
Storage Device(s) Data Interface
40
Data Storage Device(s)
45

FIGURE 8

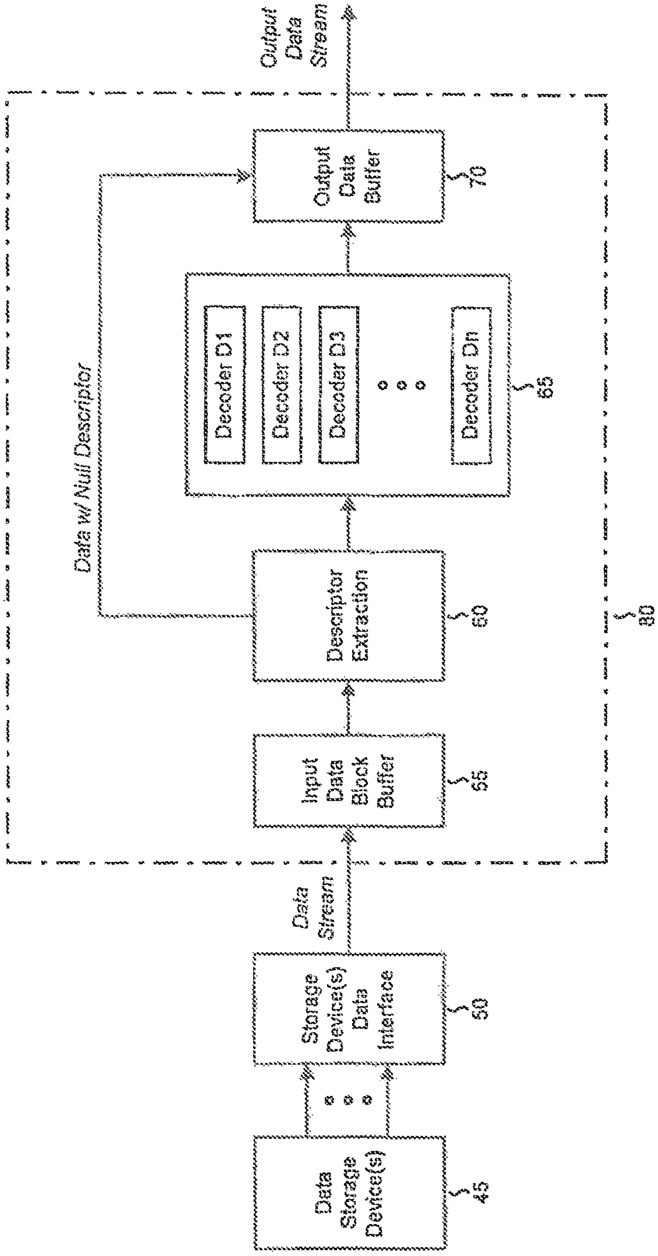
Data Storage Device(s)
45
Storage Device(s) Data Interface
50
Data Stream
Input Data Block Buffer
55
Descriptor Extraction
60
Data w/ Null Descriptor
Decoder D1
Decoder D2
Decoder D3
Decoder Dn
65
Output Data Buffer
70
Output Data Stream
80

FIGURE 9

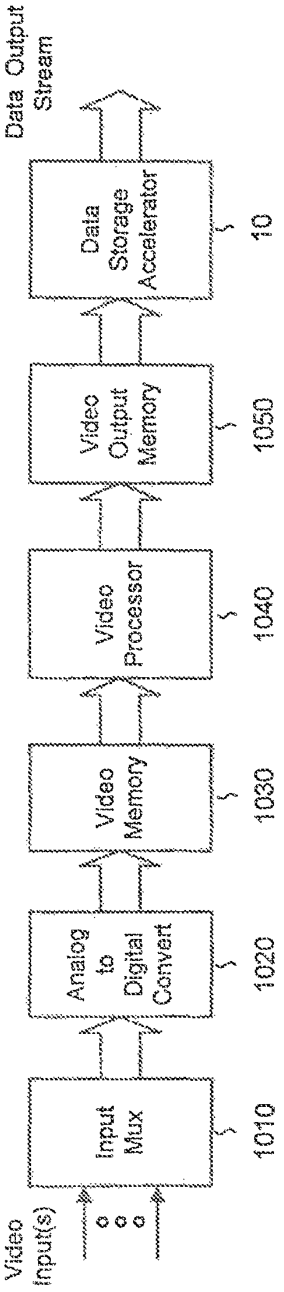
Video Input(s)
Input Mux
1010
Analog to Digital Convert
1020
Video Memory
1030
Video Processor
1040
Video Output Memory
1050
Data Storage Accelerator
10
Data Output Stream

FIGURE 10

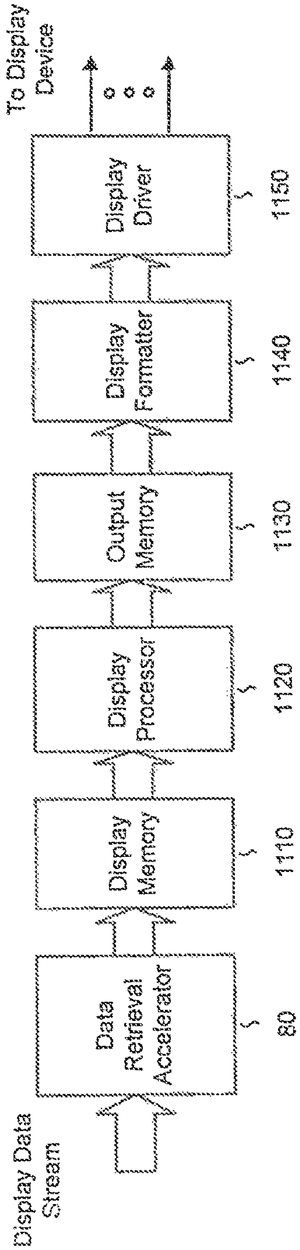
Display Data Stream
Data Retrieval Accelerator
80
Display Memory
1110
Display Processor
1120
Output Memory
1130
Display Formatter
1140
Display Driver
1150
To Display Device

FIGURE 11

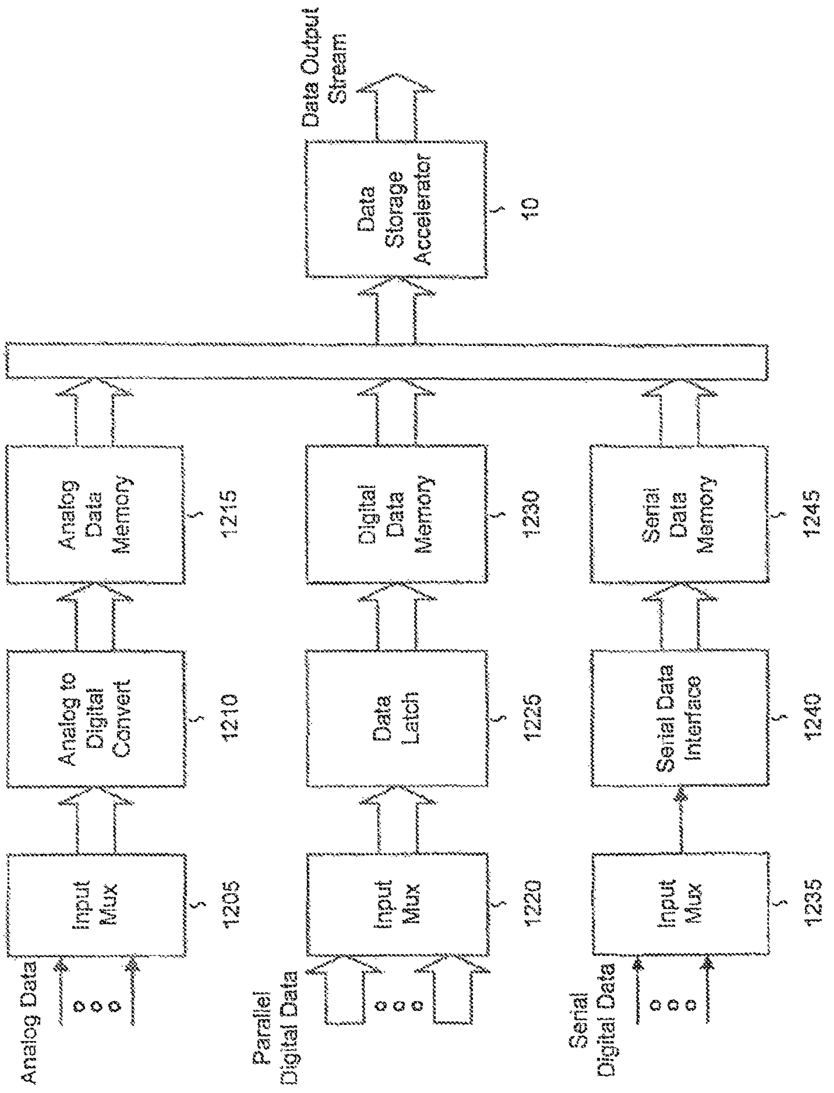
Data Output Stream
Data Storage Accelerator
10
Analog Data
Input Mux
1205
Analog to Digital Convert
1210
Analog Data Memory
1215
Parallel Digital Data
Input Mux
1220
Data Latch
1225
Digital Data Memory
1230
Serial Digital Data
Input Mux
1235
Serial Data Interface
1240
Serial Data Memory
1245

FIGURE 12

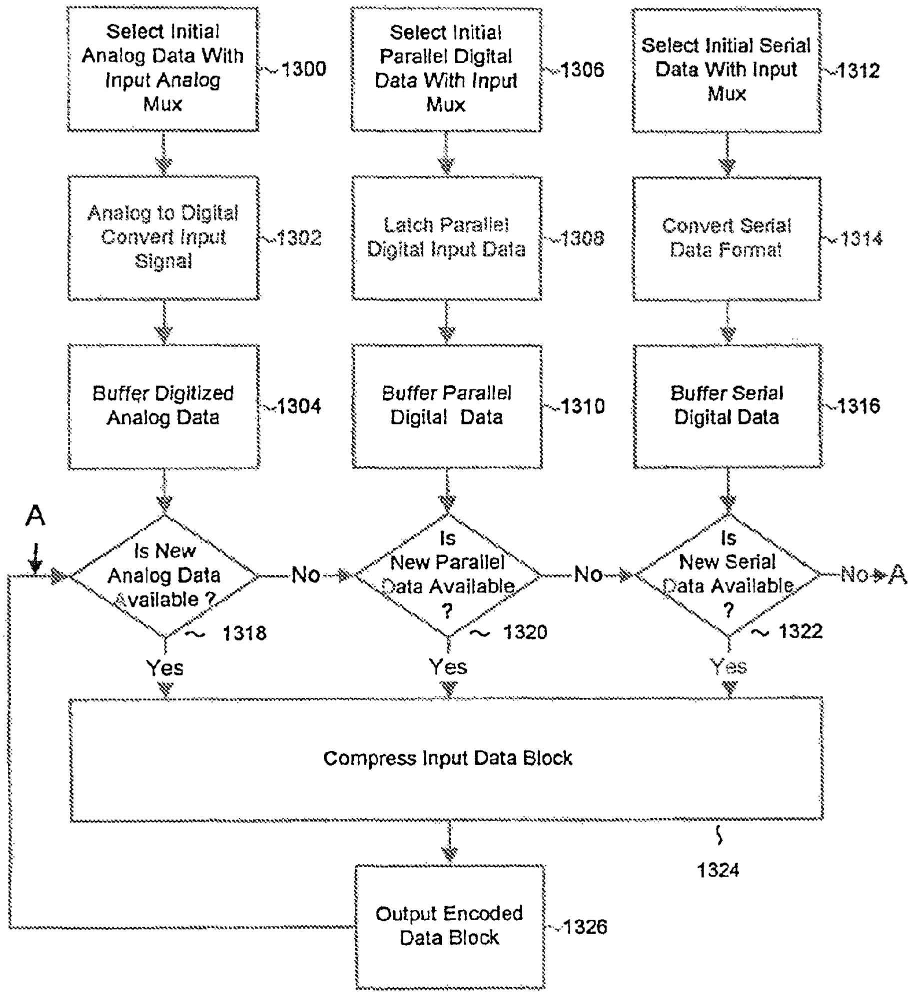
Select Initial Analog Data With Input Analog Mux
1300
Select Initial Parallel Digital Data With Input Mux
1306
Select Initial Serial Data With Input Mux
1312
Analog to Digital Convert Input Signal
1302
Latch Parallel Digital Input Data
1308
Convert Serial Data Format
1314
Buffer Digitized Analog Data
1304
Buffer Parallel Digital Data
1310
Buffer Serial Digital Data
1316
A
Is New Analog Data Available ?
1318
No
Is New Parallel Data Available ?
1320
No
Is New Serial Data Available ?
1322
No
A
Yes
Yes
Yes
Compress Input Data Block
1324
Output Encoded Data Block
1326

FIGURE 13

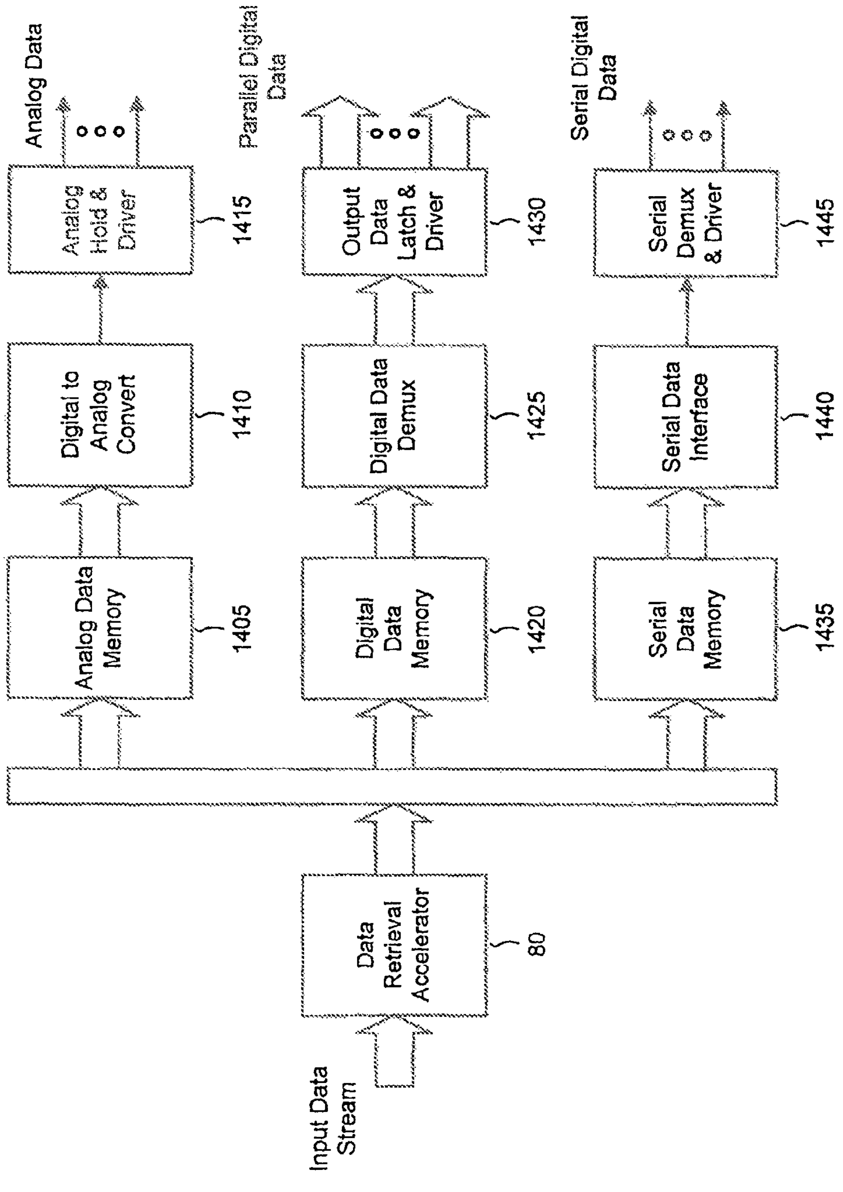
Input Data Stream
Data Retrieval Accelerator
80
Analog Data Memory
1405
Digital to Analog Convert
1410
Analog Hold & Driver
1415
Analog Data
Digital Data Memory
1420
Digital Data Demux
1425
Output Data Latch & Driver
1430
Parallel Digital Data
Serial Data Memory
1435
Serial Data Interface
1440
Serial Demux & Driver
1445
Serial Digital Data

FIGURE 14

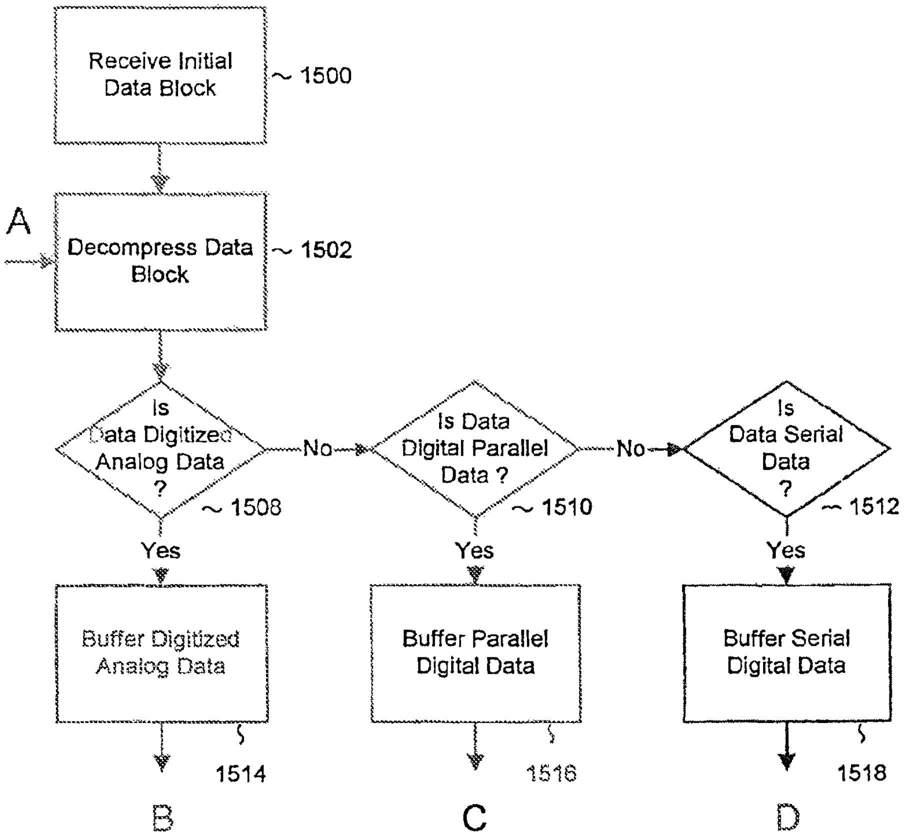
Receive Initial Data Block
1500
A
Decompress Data Block
1502
Is Data Digitized Analog Data ?
1508
No
Is Data Digital Parallel Data ?
1510
No
Is Data Serial Data ?
1512
Yes
Yes
Yes
Buffer Digitized Analog Data
Buffer Parallel Digital Data
Buffer Serial Digital Data
1514
1516
1518
B
C
D

FIGURE 15a

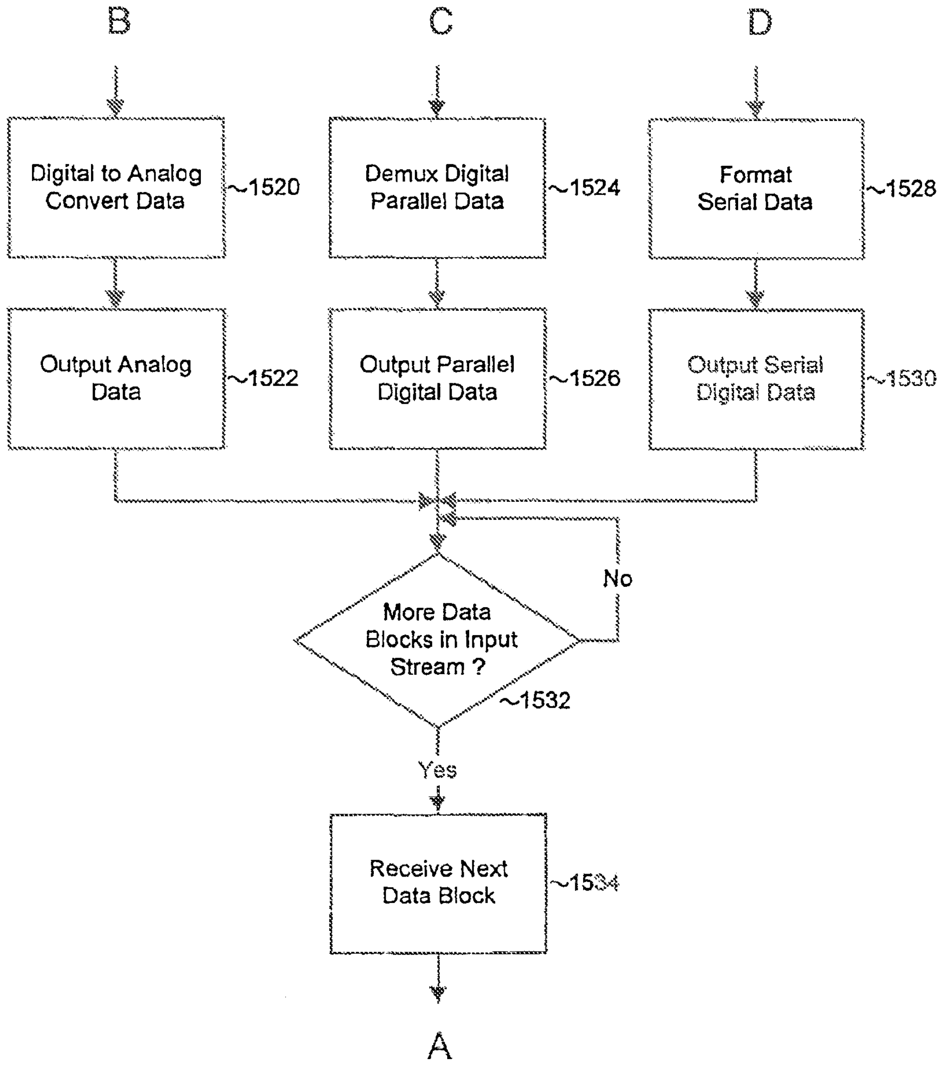
B
C
D
Digital to Analog Convert Data
1520
Demux Digital Parallel Data
1524
Format Serial Data
1528
Output Analog Data
1522
Output Parallel Digital Data
1526
Output Serial Digital Data
1530
No
More Data Blocks in Input Stream ?
1532
Yes
Receive Next Data Block
1534
A

FIGURE 15b

SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL

This application is a continuation of U.S. patent application Ser. No. 11/553,419, filed on Oct. 26, 2006, which is a continuation of U.S. patent application Ser. No. 10/628,795, filed on Jul. 28, 2003, now U.S. Pat. No. 7,130,913, which is a continuation of U.S. patent application Ser. No. 09/266,394 filed on Mar. 11, 1999, now U.S. Pat. No. 6,601,104, all of which are incorporated by reference in their entirety.

BACKGROUND

The present invention relates generally to data storage and retrieval and, more particularly to systems and methods for improving data storage and retrieval bandwidth utilizing lossless data compression and decompression.

DESCRIPTION OF THE RELATED ART

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video frequently exists in the natural world as analog information. As is well-known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossy and lossless data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Negentropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than that dictated by the negentropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise

imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio of the target display device.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the negentropy of a given data set.

It is well known within the current art that data compression provides several unique benefits. First, data compression can reduce the time to transmit data by more efficiently utilizing low bandwidth data links. Second, data compression economizes on data storage and allows more information to be stored for a fixed memory size by representing information more efficiently.

One problem with the current art is that existing memory storage devices severely limit the performance of consumer, entertainment, office, workstation, servers, and mainframe computers for all disk and memory intensive operations. For example, magnetic disk mass storage devices currently employed in a variety of home, business, and scientific computing applications suffer from significant seek-time access delays along with profound read/write data rate limitations. Currently the fastest available (10,000) rpm disk drives support only a 17.1 Megabyte per second data rate (MB/sec). This is in stark contrast to the modern Personal Computer's Peripheral Component Interconnect (PCI) Bus's input/output capability of 264 MB/sec and internal local bus capability of 800 MB/sec.

Another problem within the current art is that emergent high performance disk interface standards such as the Small Computer Systems Interface (SCSI-3) and Fibre Channel offer only the promise of higher data transfer rates through intermediate data buffering in random access memory. These interconnect strategies do not address the fundamental problem that all modern magnetic disk storage devices for the personal computer marketplace are still limited by the same physical media restriction of 17.1 MB/sec. Faster disk access data rates are only achieved by the high cost solution of simultaneously accessing multiple disk drives with a technique known within the art as data striping.

Additional problems with bandwidth limitations similarly occur within the art by all other forms of sequential, pseudo-random, and random access mass storage devices. Typically mass storage devices include magnetic and optical tape, magnetic and optical disks, and various solid-state mass storage devices. It should be noted that the present invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing accelerated data storage and retrieval by utilizing lossless data compression and decompression. The present invention provides an effective increase of the data storage and retrieval bandwidth of a memory storage device. In one aspect of the present invention, a method for providing accelerated data storage and retrieval comprises the steps of:

receiving a data stream at an input data transmission rate which is greater than a data storage rate of a target storage device;

compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate;

storing the compressed data stream in the target storage device;

retrieving the compressed data stream from the target storage device at a rate equal to a data access rate of the target storage device; and

decompressing the compressed data at a decompression ratio to provide an output data stream having an output transmission rate which is greater than the data access rate of the target storage device.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a compression ratio that is at least equal to the ratio of the input data transmission rate to the data storage rate so as to provide continuous storage of the input data stream at the input data transmission rate.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a decompression ratio which is equal to or greater than the ratio of the data access rate to a maximum accepted output data transmission rate so as to provide a continuous and optimal data output transmission rate.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a disk storage adapter to reduce the time required to store and retrieve data from computer to a disk memory device.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory.

In another aspect of the present invention a data storage and retrieval accelerator method and system is employed in a video data storage system to reduce the time required to store digital video data.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a display controller to reduce the time required to send display data to the display controller or processor.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in an input/output controller to reduce the time required to store, retrieve, or transmit data various forms of data.

The present invention is realized due to recent improvements in processing speed, inclusive of dedicated analog and digital hardware circuits, central processing units, digital signal processors, dedicated finite state machines (and any hybrid combinations thereof), that, coupled with advanced data compression and decompression algorithms, are enabling of ultra high bandwidth data compression and decompression methods that enable improved data storage and retrieval bandwidth.

These and other aspects, features and advantages, of the present invention will become apparent from the following detailed description of preferred embodiments, that is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a system for accelerated data storage and retrieval according to one embodiment of the present invention;

FIG. **2** is a flow diagram of a method for accelerated data storage in accordance with one aspect of the present invention;

FIG. **3** is a flow diagram of a method for accelerated data retrieval in accordance with one aspect of the present invention;

FIGS. **4***a* and **4***b* are timing diagrams of methods for accelerated data storage according to the present invention;

FIGS. **5***a* and **5***b* are timing diagrams of methods for accelerated data retrieval according to the present invention;

FIGS. **6***a* and **6***b* comprise a flow diagram of a method for accelerated data storage in accordance with a further aspect of the present invention;

FIGS. **7***a* and **7***b* comprise a flow diagram of a method for accelerated data retrieval in accordance with a further aspect of the present invention;

FIG. **8** is a detailed block diagram of a system for accelerated data storage according to a preferred embodiment of the present invention;

FIG. **9** is a detailed block diagram of a system for accelerated data retrieval according to a preferred embodiment of the present invention;

FIG. **10** is a block diagram of a system for accelerated video storage according to one embodiment of the present invention;

FIG. **11** is a block diagram of a system for accelerated retrieval of video data according to one embodiment of the present invention;

FIG. **12** is a block diagram of an input/output controller system for accelerated storage of analog, digital, and serial data according to one embodiment of the present invention;

FIG. **13** is a flow diagram of a method for accelerated storage of analog, digital, and serial data according to one aspect of the present invention;

FIG. **14** is a block diagram of an input/output system for accelerated retrieval of analog, digital, and serial data according to one embodiment of the present invention; and

FIGS. **15***a* and **15***b* comprise a flow diagram of method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed to systems and methods for providing improved data storage and retrieval bandwidth utilizing lossless data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU) or digital signal processors (DSP), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform may also include an operating system, microinstruction code, and dedicated processing hardware utilizing combinatorial logic or finite state machines. The various processes and functions described herein may be either part of the hardware, microinstruction code or application programs that are executed via the operating system, or any combination thereof.

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to simultaneously or sequentially losslessly compress data at a rate equivalent to or faster than the transmission rate of an input data stream. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to simultaneously or sequentially losslessly decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device. The data storage and retrieval accelerator method and system may employed: in a disk storage adapter to reduce the time required to store and retrieve data from computer to disk; in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory; in a display controller to reduce the time required to send display data to the display controller or processor; and/or in an input/output controller to reduce the time required to store, retrieve, or transmit data.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in that the systems are programmed. It is to be appreciated that special purpose microprocessors, digital signal processors, dedicated hardware, or and combination thereof may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **1**, a block diagram illustrates a system for accelerated data storage and retrieval in accordance with an embodiment of the present invention. The system includes a data storage accelerator **10**, operatively coupled to a data storage device **45**. The data storage accelerator operates to increase the effective data storage rate of the data storage device **45**. It is to be appreciated that the data storage device **45** may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The memory storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

The data storage accelerator **10** receives and processes data blocks from an input data stream. The data blocks may range in size from individual bits through complete files or collections of multiple files, and the data block size may be fixed or variable. In order to achieve continuous data storage acceleration, the data storage accelerator **10** must be configured to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Thus, to achieve optimum throughput, the rate that data blocks from the input data stream may be accepted by the data storage accelerator **10** is a function of the size of each input data block, the compression ratio achieved, and the bandwidth of the target storage device. For example, if the data storage device **45** (e.g., a typical target mass storage device) is capable of storing 20 megabytes per second and the data storage accelerator **10** is capable of providing an average compression ratio of 3:1, then 60 megabytes per second may be accepted as input and the data storage acceleration is precisely 3:1, equivalent to the average compression ratio.

It should be noted that it is not a requirement of the present invention to configure the storage accelerator **10** to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Indeed, if the storage accelerator **10** compresses data at a rate that is less than the input data rate, buffering may be applied to accept data from the input data stream for subsequent compression.

Additionally, it is not a requirement that the data storage accelerator **10** utilize data compression with a ratio that is at least the ratio of the input data stream to the data storage access rate of the data storage device **45**. Indeed, if the compression ratio is less than this ratio, the input data stream may be periodically halted to effectively reduce the rate of the input data stream. Alternatively, the input data stream or the output of the data accelerator **10** may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to reduce the input data rate to rate that is equal to or slower than the ratio of the input data rate to the data storage device access rate by signaling the data input source and requesting a slower data input rate, if possible.

Referring again to FIG. **1**, a data retrieval accelerator **80** is operatively connected to and receives data from the data storage device **45**. The data retrieval accelerator **80** receives and processes compressed data from data storage device **45** in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator **80** is configured to decompress each compressed data block which is received from the data storage device **45**. In order to achieve continuous accelerated data retrieval, the data retrieval accelerator must decompress a given input data block at a rate that is equal to or faster than receipt of the input data.

In a manner analogous to the data storage accelerator **10**, achieving optimum throughput with the data retrieval accelerator **80** is a function of the rate that compressed data blocks are retrieved from the data storage device **45**, the size of each data block, the decompression ratio achieved, and the limitation on the bandwidth of the output data stream, if any. For example, if the data storage device **45** is capable of continuously supplying 20 megabytes per second and the data retrieval accelerator **80** is capable of providing an average decompression ratio of 1:3, then a 60 megabytes per second output data stream is achieved, and the corresponding data retrieval acceleration is precisely 1:3, equivalent to the average decompression ratio.

It is to be understood that it is not required that the data retrieval accelerator **80** utilize data decompression with a ratio that is at most equal to the ratio of the retrieval rate of the data storage device **45** to the maximum rate data output stream. Indeed, if the decompression ratio is greater than this ratio, retrieving data from the data storage device may be periodically halted to effectively reduce the rate of the output data stream to be at or below its maximum. Alternatively, the compressed data retrieved from the data storage device **45** or the output of the data decompressor may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to increase the output data rate by signaling or otherwise requesting the data output device(s) receiving the output data stream to accept a higher bandwidth, if possible.

Referring now to FIG. **2**, a flow diagram of a method for accelerated data storage according to one aspect of the present invention illustrates the operation of the data storage acceleration shown in FIG. **1**. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream (step **200**) is input into and compressed by the data storage accelerator **10** (step **202**). Upon completion of the encoding of the input data block, the encoded data block is then stored in the data storage device **45** (step **204**). A check or other form of test is performed to see if there are additional data blocks available in the input stream (step **206**). If no more data blocks are available, the storage acceleration process is terminated (step **208**). If more data blocks are available in the input data stream, the next data block is received (step **210**) and the process repeats beginning with data compression (step **202**).

Referring now to FIG. **3**, a flow diagram of a method for accelerated data retrieval according to one aspect of the present invention illustrates the operation of the data retrieval accelerator **80** shown in FIG. **1**. Data decompression is also performed on a per data block basis. The initial compressed data block is retrieved from the storage device **45** (step **300**) and is decompressed by the data retrieval accelerator **80** (step **302**). Upon completion of the decoding of the initial data block, the decoded data block is then output for subsequent processing, storage, or transmittal (step **304**). A check or other form of test is performed to see if additional data blocks available from the data storage device (step **306**). If no more data blocks are available, the data retrieval acceleration process is terminated (step **308**). If more data blocks are available from the data storage device, the next data block is retrieved (step **310**) and the process repeats beginning with data decompression (step **302**).

Referring now to FIGS. **4***a* and **4***b*, a timing diagram illustrates methods for accelerated data storage utilizing data compression in accordance with the present invention. Successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 is received from an input stream of one or more data blocks. Similarly, data block 2 through data block n are received during time intervals T2 through Tn, respectively. For the purposes of discussion, FIGS. **4***a* and **4***b* demonstrate one embodiment of the data storage utilizing a stream of n data blocks. As previously stated, the input data stream is comprised of one or more data blocks data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable.

In accordance with Method 1, compression of data block 1 and subsequent storage of the encoded data block 1 occurs within time interval T1. Similarly, the compression and storage of each successive data block occurs within the time interval the data block is received. Specifically, data blocks 2 . . . n are compressed in time intervals T2 . . . Tn, respectively, and the corresponding encoded data blocks 2 . . . n are stored during the time intervals T2 . . . Tn, respectively. It is to be understood that Method 1 relies on data compression and encoding techniques that process data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data compression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of encoding data when received. Method 1 possesses the advantage of introducing a minimum delay in the time from receipt of input to storage of encoded data blocks.

Referring again to FIGS. **4***a* and **4***b*, Method 2 illustrates compressing and storing data utilizing pipelined data processing. For Method 2, successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 is received from an input stream of one or more data blocks during time interval T1. Similarly, data block 2 through data block n are received during time intervals T2 through Tn, respectively. Compression of data block 1 occurs during time interval T2 and the storage of encoded data block 1 occurs during time interval T3. As shown by Method 2, compression of each successive data block occurs within the next time interval after the data block is received and data storage of the corresponding encoded data block occur in the next time interval after completion of data compression.

The pipelining of Method 2, as shown, utilizes successive single time interval delays for data compression and data storage. Within the current invention, it is permissible to have increased pipelining to facilitate additional data processing or storage delays. For example, data compression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data compressors to process successive data blocks, e.g., data compression processing of a single data block through three successive time intervals requires three data compressors, each processing a successive input data block. Due to the principle of causality, encoded data blocks are output only after compression encoding.

Method 2 provides for block oriented processing of the input data blocks. Within the current art, block oriented data compression techniques provide the opportunity for increased data compression ratios. The disadvantage of Method 2 is increased delay from receipt of input data block to storage of encoded data. Depending on factors such as the size of input data blocks, the rate that they are received, the time required for data compression processing, the data compression ratio achieved, the bandwidth of the data storage device, and the intended application, the delay may or may not be significant. For example, in a modern database system, recording data for archival purposes, the opportunity for increased data compression may far outweigh the need for minimum delay. Conversely, in systems such as a military real-time video targeting system, minimizing delay is often of the essence. It should be noted that Method 1 and Method 2 are not mutually exclusive, and may be utilized in any combination.

Referring now to FIGS. **5***a* and **5***b*, a timing diagram illustrates methods for accelerated data retrieval utilizing data decompression in accordance the present invention shown. Successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 is retrieved or otherwise accepted as input from one or more compressed data blocks retrieved from a data storage device. As shown, data block 2 through data block n are retrieved during time intervals T2 through Tn, respectively. For the purposes of discussion, FIGS. **5***a* and **5***b* demonstrate one embodiment of the data retrieval accelerator utilizing a stream of n data blocks. Once again, the retrieved data stream is comprised of one or more data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the retrieved data block size may be fixed or variable.

In accordance with Method 1, decompression of data block 1 and subsequent outputting of the decoded data block 1 occurs within time interval T1. Similarly, decompression and outputting of each successive data block occurs within the time intervals they are retrieved. In particular, data block 2 through data block n are decompressed and decoded data block 2 through decoded data block n are output during time intervals T2 . . . Tn, respectively. It is to be understood that Method 1 relies on data decompression and decoding techniques that process compressed data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data decompression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of decoding data when received. Method 1 possesses the advantage of introducing a minimum delay in the time from retrieval of compressed data to output of decoded data blocks.

Referring again to FIGS. **5***a* and **5***b*, Method 2 involves decompressing and outputting data utilizing pipelined data processing. For Method 2, successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 through data block n are retrieved or otherwise accepted as input from a data storage device during time intervals T1 through Tn, respectively. Decompression of data block 1 occurs during time interval T2 and the decoded data block 1 is output during time interval T3. Similarly, decompression of each successive data block occurs within the next time interval after the data block is retrieved and the outputting of the decoded data block occurs during the next time interval after completion of data decompression.

The pipelining of Method 2, utilizes successive single time interval delays for data decompression and data output. Within the current invention, it is permissible to have increased pipelining to facilitate additional data retrieval or data decompression processing delays. For example, data decompression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data decompressors to process successive compressed data blocks, e.g., data decompression processing of a single data block through three successive time intervals requires three data decompressors, each processing a successive input data block. Due to the principle of causality, decoded data blocks are only output after decompression decoding.

As before, Method 2 provides for block oriented processing of the retrieved data blocks. Within the current art, block oriented data decompression techniques provide the opportunity to utilize data compression encoders that increase data compression ratios. The disadvantage of method 2 is increased delay from retrieval of compressed data block to output of decompressed data. As previously discussed for data storage acceleration, depending on the size of retrieved data blocks, the rate that they are retrieved, the time required for data decompression processing, the data decompression ratio achieved, the bandwidth of the data output, and the intended application, the delay may or may not be significant.

Referring now to FIGS. **6***a* and **6***b*, a flow diagram illustrates a method for accelerated data storage according to a further aspect of the present invention. With this method, the data compression rate of the storage accelerator **10** is not required to be equal to or greater than the ratio of the input data rate to the data storage access rate. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream is received (step **600**) and then timed and counted (step **602**). Timing and counting enables determination of the bandwidth of the input data stream. The input data block is then buffered (step **604**) and compressed by the data storage accelerator **10** (step **606**). During and after the encoding of the input data block, the encoded data block is then timed and counted (step **608**), thus enabling determination of the compression ratio and compression bandwidth. The compressed, timed and counted data block is then buffered (step **610**). The compression ratio and bandwidths of the input data stream and the encoder are then determined (step **612**). The compressed data block is then stored in the data storage device **45** (step **614**). Checks or other forms of testing are applied to ensure that the data bandwidths of the input data stream, data compressor, and data storage device are compatible (step **616**). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step **618**). For instance, the input bandwidth may be adjusted by either not accepting input data requests, lowering the duty cycle of input data requests, or by signaling one or more of the data sources that transmit the input data stream to request or mandate a lower data rate. In addition, the data compression ratio of the data storage accelerator **10** may be adjusted by applying a different type of encoding process such as employing a single encoder, multiple parallel or sequential encoders, or any combination thereof. Furthermore, additional temporary buffering of either the input data stream or the compressed data stream (or both) may be utilized.

By way of example, assuming the input data rate is 90 MB/sec and the data storage accelerator **10** provides a compression ratio of 3:1, then the output of the data storage accelerator **10** would be 30 MB/sec. If the maximum data storage rate of the data storage device **45** is 20 MB/sec (which is less than the data rate output from the data storage accelerator **10**), data congestion and backup would occur at the output of the data storage accelerator **10**. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the compression ratio to provide a data output rate from the data storage accelerator **10** to be equal to the data storage rate of the data storage device **45**.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more of the system parameters), then a check or other form of test is performed to determine if there are additional data blocks available in the input stream (step **620**). If no more data blocks are available, the storage acceleration process is terminated (step **622**). If more data blocks are available in the input data stream, the next data block is received (step **624**) and the process repeats beginning with timing and counting of the input data block (step **602**).

Referring now to FIGS. **7***a* and **7***b*, a flow diagram illustrates a method for accelerated data retrieval according to one aspect of the present invention. With this method, the data decompression ratio is not required to be less than or equal to the ratio of the data retrieval access rate to the maximum output data rate. As previously stated above, data decompression is performed on a per data block basis. Accordingly, the initial input data block is retrieved from the storage device (step **700**) and is timed and counted (step **702**). Timing and counting enables determination of the bandwidth of data retrieval. The retrieved data block is then buffered (step **704**) and decompressed by the data retrieval accelerator **80** (step **706**). During and after the decoding of the input data block, the decoded data block is then timed and counted (step **708**), thus enabling determination of the decompression ratio and decompression bandwidth. The decompressed, timed and counted data block is then buffered (step **710**). The decompression ratio and bandwidths of the retrieved data and the decoder are then determined (step **712**). The decompressed data block is then output (step **714**). Checks or other forms of testing are applied to ensure that the data bandwidths of the retrieved data, data decompressor, and data output are compatible (step **716**). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step **718**). For instance, the data retrieval bandwidth may be adjusted either not accepting (continuously) data blocks retrieved from the data storage device or lowering the duty cycle of data blocks retrieved from the data storage device. In addition, one or more of the output data devices that receive the output data stream may be signaled or otherwise requested to accept a higher data rate.

Moreover, a different type of decoding process may be applied to adjust the data decompression rate by applying, for example, a single decoder, multiple parallel or sequential decoders, or any combination thereof. Also, additional temporary buffering of either the retrieved or output data or both may be utilized.

By way of example, assuming the data storage device **45** has a data retrieval rate of 20 MB/sec and the data retrieval accelerator **80** provides a 1:4 decompression ratio, then the output of the data retrieval accelerator **80** would be 80 MB/sec. If the maximum output data transmission rate that can be accepted from the data retrieval accelerator **80** is 60 MB/sec (which is lower than the data output data rate of 80 MB/sec of the data retrieval accelerator **80**), data congestion and backup would occur at the output of the data retrieval accelerator **80**. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the decompression ratio to provide a data output rate from the data storage accelerator **80** to be equal to the maximum accepted output data transmission rate.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more system parameters), then a check or other form of test is performed to see if there are additional data blocks available from the data storage device (step **720**). If no more data blocks are available for output, the retrieval acceleration process is terminated (step **722**). If more data blocks are available to be retrieved from the data storage device, the next data block is retrieved (step **724**) and the process repeats beginning with timing and counting of the retrieved data block (return to step **702**).

It is to be understood that any conventional compression/decompression system and method (which comply with the above mentioned constraints) may be employed in the data storage accelerator **10** and data retrieval accelerator **80** for providing accelerated data storage and retrieval in accordance with the present invention. Preferably, the present invention employs the data compression/decompression techniques disclosed in U.S. Ser. No. 09/210,491 entitled "Content Independent Data Compression Method and System," filed on Dec. 11, 1998, which is commonly assigned and which is fully incorporated herein by reference. It is to be appreciated that the compression and decompression systems and methods disclosed in U.S. Ser. No. 09/210,491 are suitable for compressing and decompressing data at rates which provide accelerated data storage and retrieval.

Referring now to FIG. **8**, a detailed block diagram illustrates a preferred system for accelerated data storage which employs a compression system as disclosed in the above-incorporated U.S. Ser. No. 09/210,491. In this embodiment, the data storage accelerator **10** accepts data blocks from an input data stream and stores the input data block in an input buffer or cache **15**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. A counter **20** counts or otherwise enumerates the size of input data block in any convenient units including bits, bytes, words, double words. It should be noted that the input buffer **15** and counter **20** are not required elements of the present invention. The input data buffer **15** may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold.

Data compression is performed by an encoder module **25** which may comprise a set of encoders E1, E2, E3 . . . En. The encoder set E1, E2, E3 . . . En may include any number "n" (where n may=1) of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **25** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **20**). Data compression is performed by the encoder module **25** wherein each of the encoders E1 . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E1 . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoders E1 through En of encoder module **25** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E1 through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E1 may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **30** is operatively connected to the encoder module **25** for buffering and counting the size of each of the encoded data blocks output from encoder module **25**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC1, BC2, BC3 . . . BCn, each operatively associated with a corresponding one of the encoders E1 . . . En. A compression ratio module **35**, operatively connected to the output buffer/counter **30**, determines the compression ratio obtained for each of the enabled encoders E1 . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC1 . . . BCn. In addition, the compression ratio module **35** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E1 . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **38**, operatively coupled to the compression ratio module **35**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block. A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal. If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit, then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto. A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal.

The data storage acceleration device **10** is connected to a data storage device interface **40**. The function of the data storage interface **40** is to facilitate the formatting and transfer of data to one or more data storage devices **45**. The data storage interface may be any of the data interfaces known to those skilled in the art such as SCSI (Small Computer Systems Interface), Fibre Channel, "Firewire", IEEE P1394, SSA (Serial Storage Architecture), IDE (Integrated Disk Electronics), and ATA/ATAPI interfaces. It should be noted that the storage device data interface **40** is not required for implementing the present invention. As before, the data storage device **45** may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The data storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory (RAM), magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices (e.g., ATA/ATAPI IDE disk). Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

Again, it is to be understood that the embodiment of the data storage accelerator **10** of FIG. **8** is exemplary of a preferred compression system which may be implemented in the present invention, and that other compression systems and methods known to those skilled in the art may be employed for providing accelerated data storage in accordance with the teachings herein. Indeed, in another embodiment of the compression system disclosed in the above-incorporated U.S. Ser. No. 09/210,491, a timer is included to measure the time elapsed during the encoding process against an a priori-specified time limit. When the time limit expires, only the data output from those encoders (in the encoder module **25**) that have completed the present encoding cycle are compared to determine the encoded data with the highest compression ratio. The time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved. In addition, the results from each encoder in the encoder module **25** may be buffered to allow additional encoders to be sequentially applied to the output of the previous encoder, yielding a more optimal lossless data compression ratio. Such techniques are discussed in greater detail in the above-incorporated U.S. Ser. No. 09/210,491.

Referring now to FIG. **9**, a detailed block diagram illustrates a preferred system for accelerated data retrieval employing a decompression system as disclosed in the above-incorporated U.S. Ser. No. 09/210,491. In this embodiment, the data retrieval accelerator **80** retrieves or otherwise accepts data blocks from one or more data storage devices **45** and inputs the data via a data storage interface **50**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. As stated above, the memory storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof. The data storage device interface **50** converts the input data from the storage device format to a format useful for data decompression.

The storage device data interface **50** is operatively connected to the data retrieval accelerator **80** which is utilized for decoding the stored (compressed) data, thus providing accelerated retrieval of stored data. In this embodiment, the data retrieval accelerator **80** comprises an input buffer **55** which receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **55** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **60** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **65** includes one or more decoders D1 . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D1 . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source.

As with the data compression systems discussed in U.S. application Ser. No. 09/210,491, the decoder module **65** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time. The data retrieval accelerator **80** also includes an output data buffer or cache **70** for buffering the decoded data block output from the decoder module **65**. The output buffer **70** then provides data to the output data stream. It is to be appreciated by those skilled in the art that the data retrieval accelerator **80** may also include an input data counter and output data counter operatively coupled to the input and output, respectively, of the decoder module **65**. In this manner, the compressed and corresponding decompressed data block may be counted to ensure that sufficient decompression is obtained for the input data block.

Again, it is to be understood that the embodiment of the data retrieval accelerator **80** of FIG. **9** is exemplary of a preferred decompression system and method which may be implemented in the present invention, and that other data decompression systems and methods known to those skilled in the art may be employed for providing accelerated data retrieval in accordance with the teachings herein.

In accordance with another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in for increasing the storage rate of video data. In particular, referring now to FIG. **10**, a block diagram illustrates a system for providing accelerated video data storage in accordance with one embodiment of the present invention. The video data storage acceleration system accepts as input one or more video data streams that are analog, digital, or any combination thereof in nature. The input multiplexer **1010** selects the initial video data stream for data compression and acceleration. The input multiplexer **1010** is operatively connected to an analog to digital converter **1020** which converts analog video inputs to digital format of desired resolution. The analog to digital converter **1020** may also include functions to strip video data synchronization to perform other data formatting functions. It should be noted that the analog to digital conversion process is not required for digital video inputs. The analog to digital converter **1020** is operatively connected a video memory **1030** that is, in turn, operatively connected to a video processor **1040**. The video processor **1040** performs manipulation of the digital video data in accordance with any user desired processing functions. The video processor **1040** is operatively coupled to a video output memory **1050**, that is operatively connected to a data storage accelerator **10** which compresses the video data to provide accelerated video data to the output data stream for subsequent data processing, storage, or transmittal of the video data. This video data acceleration process is repeated for all data blocks in the input data stream. If more video data blocks are available in the input data stream, the video multiplexer selects the next block of video for accelerated processing. Again, it is to be understood that the data storage accelerator **10** may employ any compression system which is capable of compressing data at a rate suitable for providing accelerated video data storage in accordance with the teachings herein.

In accordance with another aspect of the present invention, the accelerated data storage and retrieval system may be employed in a display controller to reduce the time required to send display data to a display controller or processor. In particular, referring now to FIG. **11**, a block diagram illustrates a display accelerator system in accordance with one embodiment of the present invention. The video display accelerator accepts as input one or more digital display data blocks from an input display data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input video data block size may be fixed or variable. The input data blocks are processed by a data retrieval accelerator **80** which employs a data decompression system in accordance with the teachings herein. Upon completion of data decompression, the decompressed data block is then output to a display memory **1110** that provides data to a display processor **1120**. The display processor **1120** performs any user desired processing function. It is well known within the current art that display data is often provided in one or more symbolic formats such as Open Graphics Language (Open GL) or another display or image language. The display processor **1120** is operatively connected an output memory buffer **1130**. The output memory **1130** supplies data to a display formatter **1140** that converts the data to a format compatible with the output display device or devices. Data from the display formatter **1140** is provided to the display driver **1150** that outputs data in appropriate format and drive signal levels to one or more display devices. It should be noted that the display memory **1110**, display processor **1120**, output memory **1130**, display formatter **1140**, and display driver **1150** are not required elements of the present invention.

In accordance with yet another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in an I/O controller to reduce the time for storing, retrieving or transmitting parallel data streams. In particular, referring now to FIG. **12**, a block diagram illustrates a system for accelerated data storage of analog, digital, and serial data in accordance with one embodiment of the present invention. The data storage accelerator **10** is capable of accepting one or more simultaneous analog, parallel digital, and serial data inputs. An analog input multiplexer **1205** selects the initial analog data for data compression and acceleration. The analog input multiplexer **1205** is operatively connected to an analog to digital converter **1210** that converts the analog input signal to digital data of the desired resolution. The digitized data output of the analog to digital converter **1210** is stored in an analog data memory buffer **1215** for subsequent data storage acceleration. Similarly, a parallel digital data input multiplexer **1220** selects the initial parallel digital data for data compression and acceleration. The parallel digital data input multiplexer **1220** is operatively connected to an input data latch **1225** that holds the input parallel digital data. The parallel digital data is then stored in digital data memory buffer **1245** for subsequent data storage acceleration. In addition, a serial digital data input multiplexer **1235** selects the initial serial digital data for data compression and acceleration. The serial digital data input multiplexer **1235** is operatively connected to a serial data interface **1240** that converts the serial data stream to a format useful for data acceleration. The formatted serial digital data is then stored in serial data memory buffer **1245** for subsequent data acceleration. The analog data memory **1215**, parallel digital data memory **1230**, and serial data memory **1245** are operatively connected to the data storage accelerator device **10**. Data is selected from each data memory subsystem based upon a user defined algorithm or other selection criteria. It should be noted that the analog input multiplexer **1205**, analog to digital converter **1210**, analog data memory **1215**, parallel data input multiplexer **1220**, data latch **1225**, digital data memory **1230**, serial data input multiplexer **1235**, serial data interface **1240**, serial data memory **1245**, and counter **20** are not required elements of the present invention. As stated above, the data storage accelerator **10** employs any of the data compression methods disclosed in the above-incorporated U.S. Ser. No. 09/210,491, or any conventional data compression method suitable for compressing data at a rate necessary for obtaining accelerated data storage. The data storage accelerator supplies accelerated data to the output data stream for subsequent data processing, storage, or transmittal.

Referring now to FIG. **13**, a flow diagram illustrates a method for accelerated data storage of analog, digital, and serial data according to one aspect of the present invention. The analog input multiplexer selects the initial analog data for data compression and acceleration (step **1300**). The analog input multiplexer provides analog data to the analog to digital converter that converts the analog input signal to digital data of the desired resolution (step **1302**). The digitized data output of the analog to digital converter is then buffered in the analog data memory buffer (step **1304**) for subsequent data acceleration. Similarly, the parallel digital data multiplexer selects the initial parallel digital data for data compression and acceleration (step **1306**). The parallel digital data multiplexer provides data to the input data latch that then holds the input parallel digital data (step **1308**). The parallel digital data is then stored in digital data memory buffer for subsequent data acceleration (step **1310**). The serial digital data input multiplexer selects the initial serial digital data for data compression and acceleration (step **1312**). The serial digital data input multiplexer provides serial data to the serial data interface that converts the serial data stream to a format useful for data acceleration (step **1314**). The formatted serial digital data is then stored in the serial data memory buffer for subsequent data acceleration (step **1316**). A test or other check is performed to see if new analog data is available (step **1318**). If no new analog data is available a second check is performed to see if new parallel data is available (step **1320**). If no new parallel data is available, a third test is performed to see if new serial data is available (step **1322**). If no new serial data is available (step **1322**) the test sequence repeats with the test for new analog data (step **1318**). If new analog data block is available (step **1318**), or if new parallel data block is available (step **1320**), or if new serial data block is available (step **1322**), the input data block is compressed by the data storage accelerator (step **1324**) utilizing any compression method suitable for providing accelerated data storage in accordance with the teachings herein. After data compression is complete, the compressed data block is then output subsequent accelerated data processing, storage, or transmittal (step **1326**). After outputting data the process repeats beginning with a test for new analog data (return to step **1318**).

Referring now to FIG. **14**, a block diagram illustrates a system for accelerated retrieval of analog, digital, and serial data in accordance with one embodiment of the present invention. A data retrieval accelerator **80** receives data from an input data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator **80** decompresses the input data utilizing any of the decompression methods suitable for providing accelerated data retrieval in accordance with the teachings herein. The data retrieval accelerator **80** is operatively connected to analog data memory **1405**, digital data memory **1420**, and serial data memory **1435**. Dependent upon the type of input data block, the decoded data block is stored in the appropriate analog **1405**, digital **1420**, or serial **1435** data memory.

The analog data memory **1405** is operatively connected to a digital to analog converter **1410** that converts the decompressed digital data block into an analog signal. The digital to analog converter **1410** is further operatively connected to an analog hold and output driver **1415**. The analog hold and output driver **1415** demultiplexes the analog signal output from the digital to analog converter **1410**, samples and holds the analog data, and buffers the output analog data.

In a similar manner, the digital data memory **1420** is operatively connected to a digital data demultiplexer **1425** that routes the decompressed parallel digital data to the output data latch and driver **1430**. The output latch and driver **1430** holds the digital data and buffers the parallel digital output.

Likewise, the serial data memory **1435** is operatively connected to a serial data interface **1440** that converts the decompressed data block to an output serial data stream. The serial data interface **1440** is further operatively connected to the serial demultiplexer and driver **1445** that routes the serial digital data to the appropriate output and buffers the serial data output.

Referring now to FIGS. **15***a* and **15***b*, a flow diagram illustrates a method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention. An initial data block is received (step **1500**) and then decompressed by the data storage retrieval accelerator (step **1502**). Upon completion of data decompression, a test or other check is performed to see if the data block is digitized analog data (step **1508**). If the data block is not digitized analog data, a second check is performed to see if the data block is parallel digital data (step **1510**). If the data block is not parallel digital data, a third test is performed to see if the data block serial data (step **1512**). The result of at least one of the three tests will be affirmative.

If the data block is comprised of digitized analog data, the decoded data block is buffered in an "analog" digital data memory (step **1514**). The decoded data block is then converted to an analog signal by a digital to analog converter (step **1520**). The analog signal is then output (step **1522**).

If the data block is comprised of parallel digital data, the decoded data block is buffered in a "parallel" digital data memory (step **1516**). The decoded data block is then demultiplexed (step **1524**) and routed to the appropriate the output data latch and driver. The output latch and driver then holds the digital data and buffers the parallel digital output (step **1526**).

If the data block is comprised of serial data, the decoded data block is buffered in "serial" digital data memory (step **1518**). The decoded data is then formatted to a serial data format (step **1528**). The serial data is then demultiplexed, routed to the appropriate output, and output to a buffer (step **1530**).

Upon output of analog data (step **1522**), parallel digital data (step **1526**), or serial digital data (step **1530**), a test or other form of check is performed for more data blocks in the input stream (step **1532**). If no more data blocks are available, the test repeats (return to step **1532**). If a data block is available, the next data block is received (step **1534**) and the process repeats beginning with step **1502**.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A system comprising:

a memory device; and

a data accelerator configured to compress: (i) a first data block with a first compression technique to provide a first compressed data block; and (ii) a second data block with a second compression technique, different from the first compression technique, to provide a second compressed data block;

wherein the compressed first and second data blocks are stored on the memory device, and the compression and storage occurs faster than the first and second data blocks are able to be stored on the memory device in uncompressed form.

2. The system of claim **1**, wherein the data accelerator stores a first data descriptor on the memory device indicative of the first compression technique such that the first descriptor is capable of being utilized to decompress at least a portion of the first data block.

3. The system of claim **2**, wherein the data accelerator stores a second data descriptor on the memory device indicative of the second compression technique such that the second descriptor is capable of being utilized to decompress at least a portion of the second data block.

4. The system of claim **2**, wherein the data accelerator retrieves the first descriptor and the first compressed data block from the memory device.

5. The system of claim **1**, wherein the data accelerator retrieves the first compressed and second data blocks from the memory device.

6. The system of claim **1**, wherein the data accelerator retrieves the first compressed data block from the memory device and decompresses the first compressed data block.

7. The system of claim **6**, wherein the retrieval of the first compressed data block from the memory device and the decompression occurs faster than the first data block is able to be retrieved from the memory device in uncompressed form.

8. The system of claim **1**, wherein the data accelerator is coupled to the memory device via an industry standard disk interface.

9. The system of claim **1**, wherein the first compression technique applied to the first data block is a fonn of dictionary compression and the second compression technique applied to the second data block is a form of Lempel-Ziv compression.

10. The system of claim **1**, wherein the first compression technique includes compressing with Lempel-Ziv encoding.

11. The system of claim **1**, wherein the first compression technique includes compressing with a form of dictionary encoding.

12. The system of claim **1**, wherein the first compression technique includes compressing with a plurality of encoders in a serial configuration.

13. The system of claim **1**, wherein the first compression technique includes compressing with a plurality of encoders in a parallel configuration, each of the plurality of encoders having an identical type.

14. The system of claim **1**, wherein the data accelerator is configured to compress a third data block with a third compression technique to provide a third compressed data block.

15. The system of claim **14** wherein the first compression technique is content dependent, the second compression technique is a form of dictionary compression, and the third compression technique is a different form of dictionary compression.

16. The system of claim **15**, wherein the third data block is compressed by the third compression technique in real-time.

17. The system of claim **15**, wherein the third data block is compressed by the third compression technique not in real-time.

18. The system of claim **1**, wherein the first and second data blocks comprise audio or video information.

19. The system of claim **1**, wherein the first and second data blocks are received over a communications channel.

20. The system of claim **1** wherein the first compression technique is content dependent and the second compression technique is a form of dictionary compression.

21. A method for accelerated data storage of data, comprising:

compressing a first data block with a first data compression technique to provide a first compressed data block; and

compressing a second data block with a second data compression technique to provide a second compressed data block, wherein the first data compression technique and the second data compression technique are different;

storing the first and second data compressed blocks on a memory device wherein the compression and storage occurs faster than the first and second data blocks are able to be stored on the memory device in uncompressed form.

22. The method of claim **21**, further comprising:

storing, on the memory device, a first data descriptor indicative of the first compression technique such that the first descriptor is capable of being utilized to decompress the first compressed data block.

23. The method of claim **21**, wherein retrieval of the first compressed data block from the memory device and decompression of the first compressed data block occurs faster than the first data block is able to be retrieved from the memory device in uncompressed form.

24. The system of claim **21**, wherein the first compression technique applied to the first data block is a form of dictionary compression and the second compression technique applied to the second data block is a form of Lempel-Ziv compression.

25. A method for accelerated storage of data, comprising:

receiving a first and a second data block over a communications channel;

compressing the first data block with a first data compression technique to provide a first compressed data block;

compressing the second data block with a second data compression technique to provide a second compressed data block, wherein the first data compression technique and the second data compression technique are different; and

storing the first and second data compressed blocks on a memory device wherein the compression and storage occurs faster than the first and second data blocks are able to be stored on the memory device in uncompressed form.

26. The method of claim **25**, further comprising:

determining a bandwidth at which the first and the second data blocks are received; and

adjusting a system parameter to make a bandwidth of the first and compressed second data blocks compatible with a bandwidth of the memory device.

27. The method of claim **25**, wherein a data token is associated with the first and second compressed data blocks, and wherein the token includes values corresponding to a one or more encoding techniques that were applied to either or both of the first and second compressed data blocks.

28. The method of claim **25**, wherein retrieval of compressed first data block from the memory device and decompression occurs faster than the first data block is able to be retrieved from the memory device in uncompressed form.

29. A method for accelerated retrieval of data comprising:

retrieving a first compressed data block and a second compressed data block from a memory device; and

decompressing the first compressed data block and the second compressed data block, wherein the retrieval and decompression occurs faster than the first data block is able to be retrieved from the memory device in uncompressed form;

wherein the first compressed data block was compressed with a first data compression technique to provide a first compressed data block;

wherein the second compressed data block was compressed with a second data compression technique to provide a second compressed data block, wherein the first data compression technique and the second data compression techniques are different; and wherein the first and second data compression blocks were stored on the memory device.

30. The method of claim **29**, wherein the first compression technique applied to the first data block was a form of dictionary compression and the second compression technique applied to the second data block was a form of Lempel-Ziv compression.

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US010019458B2

(12) **United States Patent**
Fallon

(10) **Patent No.: US 10,019,458 B2**
(45) **Date of Patent: *Jul. 10, 2018**

(54) **SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/794,201**

(22) Filed: **Jul. 8, 2015**

(65) **Prior Publication Data**

US 2016/0162505 A1 Jun. 9, 2016

Related U.S. Application Data

(63) Continuation of application No. 14/303,276, filed on Jun. 12, 2014, now Pat. No. 9,116,908, which is a
(Continued)

(51) **Int. Cl.**
G06F 15/16 (2006.01)
G06F 17/30 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .. ***G06F 17/30153*** (2013.01); ***G06F 17/30371*** (2013.01); ***H04L 69/04*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G06F 17/30153; G06F 17/30371; H04L 69/04; H04N 19/15
(Continued)

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Realtime's Response in Opposition to the Defendants' Joint Objections to Report and Recommendation of Magistrate Regarding Motion for Partial Summary Judgment of Invalidity for Indefiniteness, in *Realtime Data, LLC d/b/a/IXO* v. *Packeteer, Inc. et al.*, Civil Action No. 6:08-cv-00144-LED; U.S. District Court for the Eastern District of Texas, dated Jul. 27, 2009, 15 pages.

(Continued)

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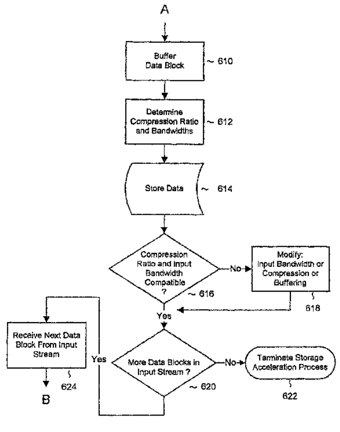
(57) **ABSTRACT**

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to compress data. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device.

22 Claims, 20 Drawing Sheets



Related U.S. Application Data

continuation of application No. 11/553,419, filed on Oct. 26, 2006, now Pat. No. 8,756,332, which is a continuation of application No. 10/628,795, filed on Jul. 28, 2003, now Pat. No. 7,130,913, which is a continuation of application No. 09/266,394, filed on Mar. 11, 1999, now Pat. No. 6,601,104.

(51) **Int. Cl.**

H04N 9/804	(2006.01)
H04L 29/06	(2006.01)
H04N 19/176	(2014.01)
H04N 19/15	(2014.01)
H04N 19/115	(2014.01)
H04N 19/152	(2014.01)
H04N 5/781	(2006.01)
H04N 5/84	(2006.01)
H04N 5/85	(2006.01)
H04N 5/907	(2006.01)
H04N 9/82	(2006.01)

(52) **U.S. Cl.**

CPC ***H04N 9/8042*** (2013.01); ***H04N 19/115*** (2014.11); ***H04N 19/15*** (2014.11); ***H04N 19/152*** (2014.11); ***H04N 19/176*** (2014.11); *H04N 5/781* (2013.01); *H04N 5/843* (2013.01); *H04N 5/85* (2013.01); *H04N 5/907* (2013.01); *H04N 9/8227* (2013.01)

(58) **Field of Classification Search**

USPC 709/231, 247

See application file for complete search history.

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Realtime Data LLC d/b/a IXO v. *Acronis, Inc.*, No. 1:17-cv-11279 (D. Mass.), Preliminary Invalidity Contentions Dec. 4, 2017.

Realtime Data LLC d/b/a IXO v. *DISH Network Corporation et al.*, No. 6:17-cv-00421 (E.D. Texas), Final Judgement Case Dismissed Nov. 8, 2017.

Realtime Data LLC d/b/a IXO v. *Sling TV LLC et al.*, No. 1:17-cv-02097 (D. Colorado), Answer to Counterclaims Apr. 10, 2018.

Realtime Adaptive Streaming LLC v. *Amazon.com et al.*, No. 6:17-cv-00549 (E.D. Texas), Answer to Amended Complaint Dec. 15, 2017.

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Realtime Adaptive Streaming LLC v. *Cisco Systems, Inc.*, No. 6:17-cv-00591 (E.D. Texas), Amended Complaint Nov. 30, 2017.

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Realtime Data LLC d/b/a IXO v. *Egnyte, Inc.*, No. 1:17-cv-01750 (D. Delaware), Answer and Counterclaims Jan. 30, 2018.

Realtime Data LLC d/b/a IXO v. *IXSystems Inc.*, No. 1:17-cv-01769 (D. Delaware), filed Dec. 5, 2017.

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Realtime Adaptive Streaming LLC v. *Samsung Electronics Co., Ltd. et al*., 6:18-cv-00113 (E.D. Texas), filed Mar. 9, 2018.

Realtime Adaptive Streaming LLC v. *Wowza Media Systems LLC*, 1:18-cv-00927 (D. Colorado), filed Apr. 20, 2018.

Defendants Dish Technologies L.L.C. and Dish Network L.L.C.'s Answer, Affirmative Defenses, Counterclaims, and Jury Demand to Plaintiff Realtime Adaptive Streaming L.L.C's Second Amended Complaint, filed in *Realtime Adaptive Streaming, LLC* v. *Sling TV L.L.C. et al*., Case No. 1:17-cv-02097 (D. Colorado), filed Mar. 21, 2018; 26 pages.

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Defendant Synacor, Inc.'s Responsive Claim Construction Brief, filed in *Realtime Data LLC d/b/a IXO* v. *Synacor, Inc*., Case No. 6: 17-cv-00126 (E.D. Texas), filed Mar. 15, 2018; 13 pages.

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Final Written Decision, filed in *Apple, Inc*. v. *Realtime Data LLC*, Case No. IPR2016-01739 (P.T.A.B.), filed Mar. 13, 2018; 48 pages.

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Decision Denying Institution of *Inter Partes* Review, filed in *Unified Patents, Inc*. v. *Realtime Data LLC*, Case No. IPR2017-02129 (P.T.A.B.), filed Mar. 27, 2018; 20 pages.

Decision Denying Institution of *Inter Partes* Review, filed in *Commvault Systems, Inc*. v. *Realtime Data LLC*, Case No. IPR2017-02128 (P.T.A.B.), filed Apr. 10, 2018; 16 pages.

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Declaration of Dr. Iain Richardson in Support Petition for *Inter Partes* Review, filed in *Unified Patents Inc*. v. *Realtime Adaptive Streaming, LLC*, Case No. IPR2018-00883 (P.T.A.B.), filed Apr. 6, 2018; 79 pages.

ITU-T: Transmission of Non-Telephone Signals, "Information Technology—Generic Coding of Moving Pictures and Associated Audio Information: Video," Document H.262, Jul. 10, 1995; 211 pages.

International Organization for Standardisation, "MPEG Press Release," London, Nov. 6, 1992; 5 pages.

ITU-T: Line Transmission of Non-Telephone Signals, Video Codec for Audiovisual Sewices At *p* x 64 kbits, Document H.261, Mar. 1-12, 1993; 29 pages.

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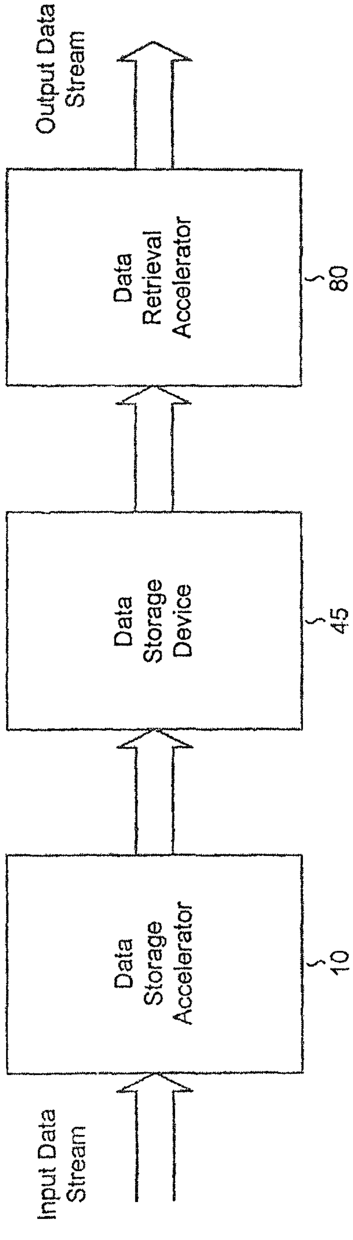
Input Data Stream
Data Storage Accelerator
10
Data Storage Device
45
Data Retrieval Accelerator
80
Output Data Stream

FIGURE 1

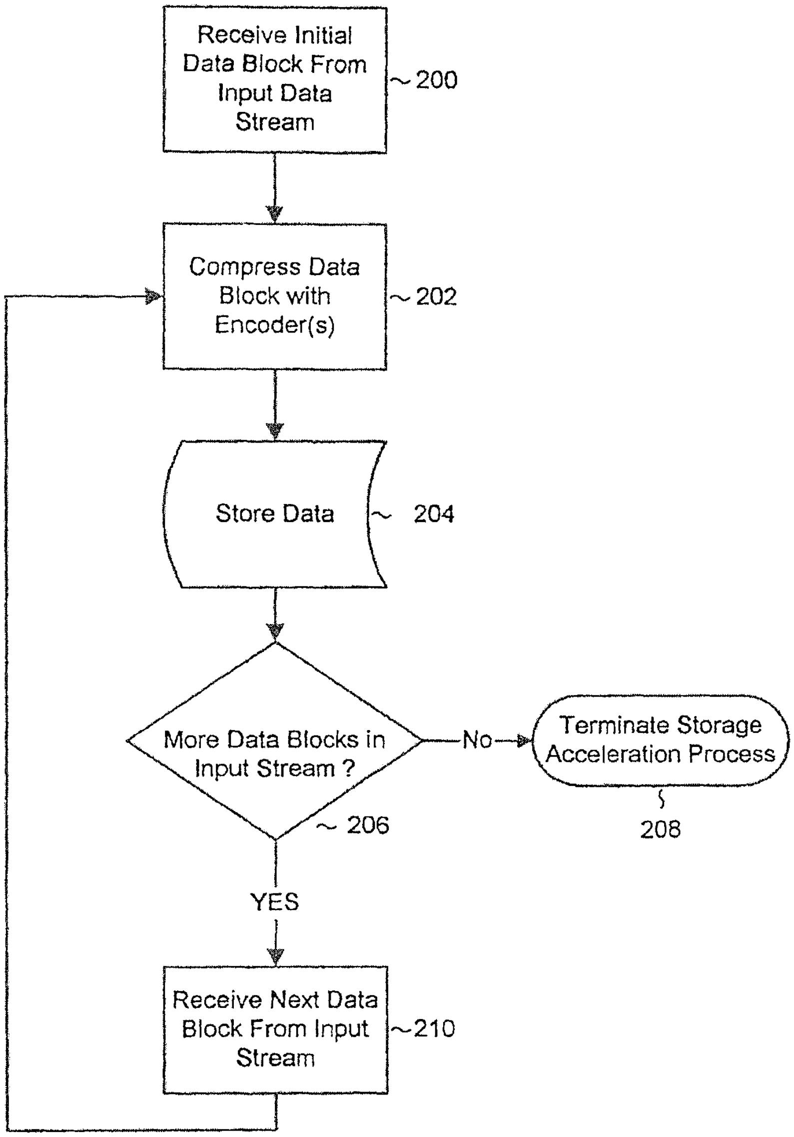
Receive Initial Data Block From Input Data Stream
200
Compress Data Block with Encoder(s)
202
Store Data
204
More Data Blocks in Input Stream ?
206
No
Terminate Storage Acceleration Process
208
YES
Receive Next Data Block From Input Stream
210

FIGURE 2

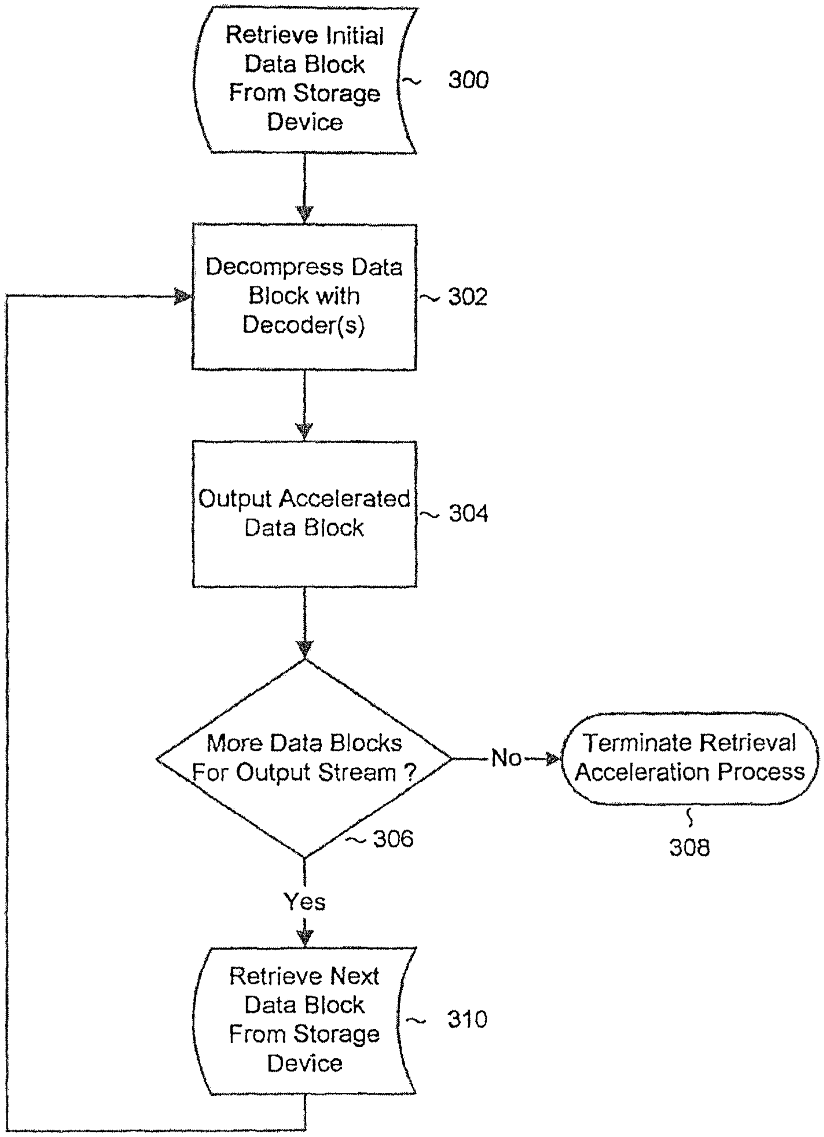
Retrieve Initial Data Block From Storage Device
300
Decompress Data Block with Decoder(s)
302
Output Accelerated Data Block
304
More Data Blocks For Output Stream ?
306
No
Terminate Retrieval Acceleration Process
308
Yes
Retrieve Next Data Block From Storage Device
310

FIGURE 3

Time Interval	T1	T2	T3	T4		Ti
Receive Data Block	Receive Data Block 1	Receive Data Block 2	Receive Data Block 3	Receive Data Block 4		Receive Data Block i
<u>METHOD 1</u>						
Compress Data Block	Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block 4		Compress Data Block i
Store Encoded Data Block	Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block 3	Store Encoded Data Block 4		Store Encoded Data Block i
<u>METHOD 2</u>						
Compress Data Block		Compress Data Block 1	Compress Data Block 2	Compress Data Block 3		Compress Data Block (i-1)
Store Encoded Data Block			Store Encoded Data Block 1	Store Encoded Data Block 2		Store Encoded Data Block (i-2)

FIGURE 4a

Time Interval	T(i+1)	T(i+2)	Tn	T(n+1)	T(n+2)
Receive Data Block	Receive Data Block (i+1)	Receive Data Block (i+2)	Receive Data Block n		
<u>METHOD 1</u>					
Compress Data Block	Compress Data Block (i+1)	Compress Data Block (i+2)	Compress Data Block n		
Store Encoded Data Block	Store Encoded Data Block (i+1)	Store Encoded Data Block (i+2)	Store Encoded Data Block n		
<u>METHOD 2</u>					
Compress Data Block	Compress Data Block i	Compress Data Block (i+1)	Compress Data Block (n-1)	Compress Data Block n	
Store Encoded Data Block	Store Encoded Data Block (i-1)	Store Encoded Data Block i	Store Encoded Data Block (n-2)	Store Encoded Data Block (n-1)	Store Encoded Data Block n

FIGURE 4b

Time Interval	T1	T2	T3	T4	Ti
Retrieve Data Block	Retrieve Data Block 1	Retrieve Data Block 2	Retrieve Data Block 3	Retrieve Data Block 4	Retrieve Data Block i
<u>METHOD 1</u>					
Decompress Data Block	Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block 4	Decompress Data Block i
Output Decoded Data Block	Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block 3	Output Decoded Data Block 4	Output Decoded Data Block i
<u>METHOD 2</u>					
Decompress Data Block		Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block (i-1)
Output Decoded Data Block			Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block (i-2)

FIGURE 5a

Time Interval	T(i+1)	T(i+2)	Tn	T(n+1)	T(n+2)
Retrieve Data Block	Retrieve Data Block (i+1)	Retrieve Data Block (i+2)	Retrieve Data Block n		
METHOD 1					
Decompress Data Block	Decompress Data Block (i+1)	Decompress Data Block (i+2)	Decompress Data Block n		
Output Decoded Data Block	Output Decoded Data Block (i+1)	Output Decoded Data Block (i+2)	Output Decoded Data Block n		
METHOD 2					
Decompress Data Block	Decompress Data Block i	Decompress Data Block (i+1)	Decompress Data Block (n-1)	Decompress Data Block n	
Output Decoded Data Block	Output Decoded Data Block (i-1)	Output Decoded Data Block i	Output Decoded Data Block (n-2)	Output Decoded Data Block (n-1)	Output Decoded Data Block n

FIGURE 5b

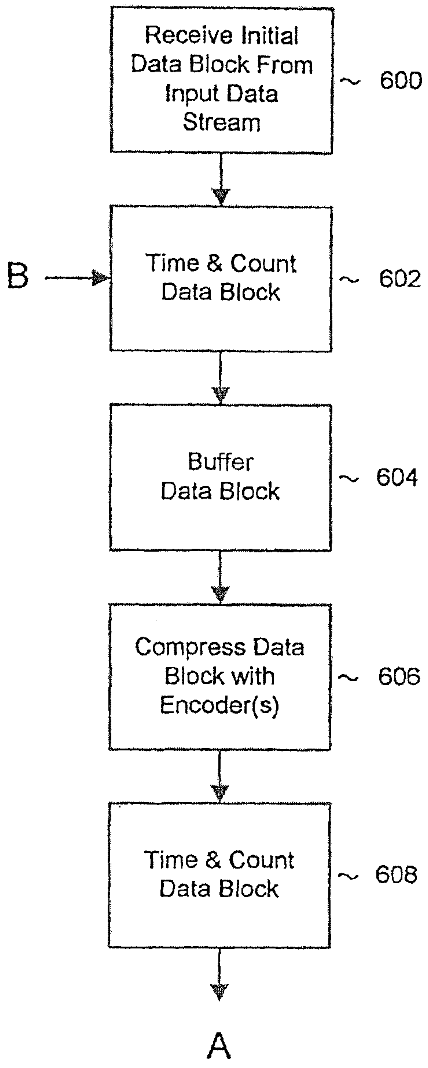
Receive Initial Data Block From Input Data Stream
600
B
Time & Count Data Block
602
Buffer Data Block
604
Compress Data Block with Encoder(s)
606
Time & Count Data Block
608
A

FIGURE 6a

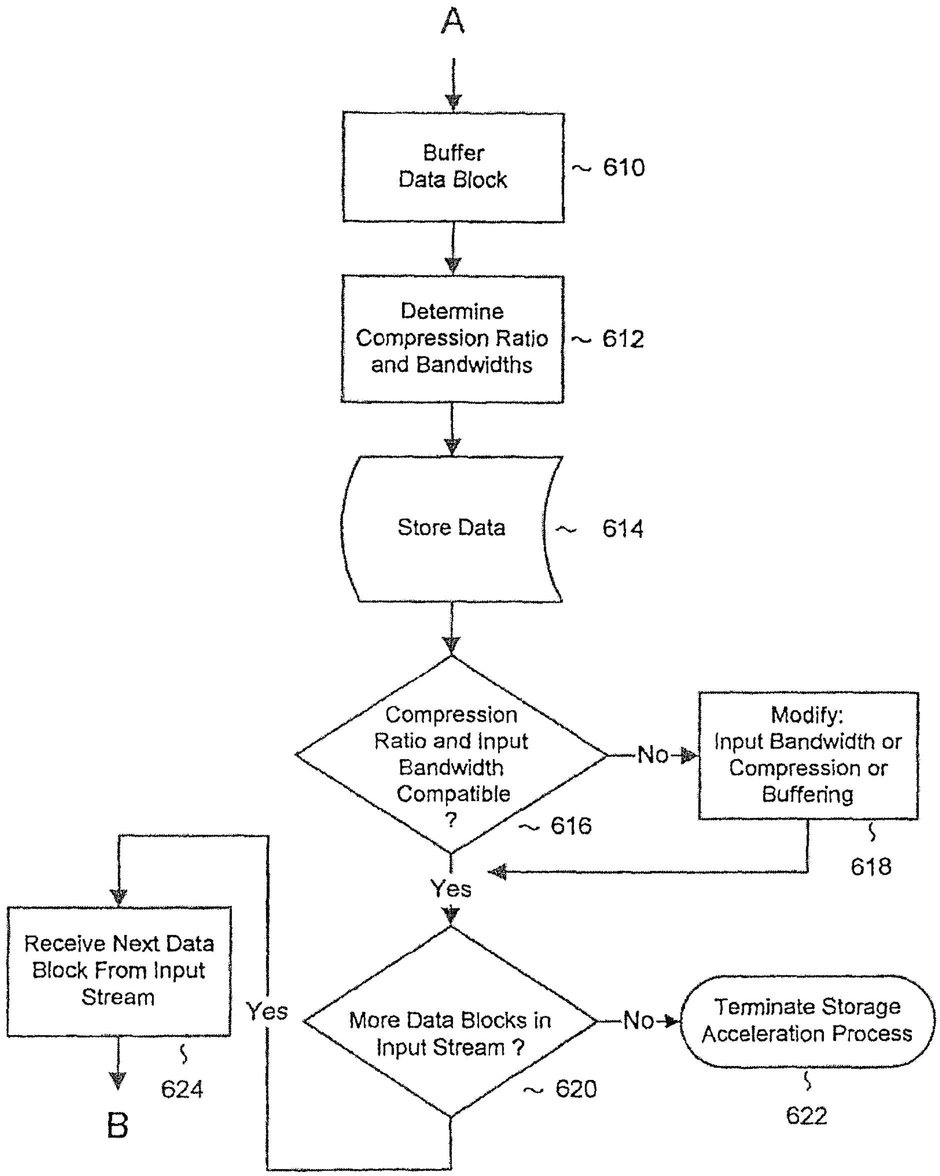
A
Buffer Data Block
610
Determine Compression Ratio and Bandwidths
612
Store Data
614
Compression Ratio and Input Bandwidth Compatible ?
616
No
Modify: Input Bandwidth or Compression or Buffering
618
Yes
Receive Next Data Block From Input Stream
624
B
Yes
More Data Blocks in Input Stream ?
620
No
Terminate Storage Acceleration Process
622

FIGURE 6b

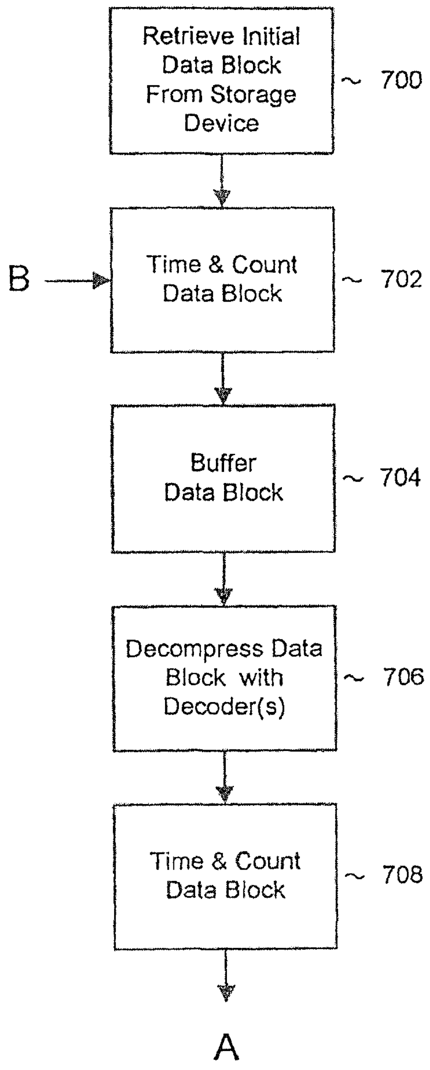
Retrieve Initial Data Block From Storage Device
700
B
Time & Count Data Block
702
Buffer Data Block
704
Decompress Data Block with Decoder(s)
706
Time & Count Data Block
708
A

FIGURE 7a

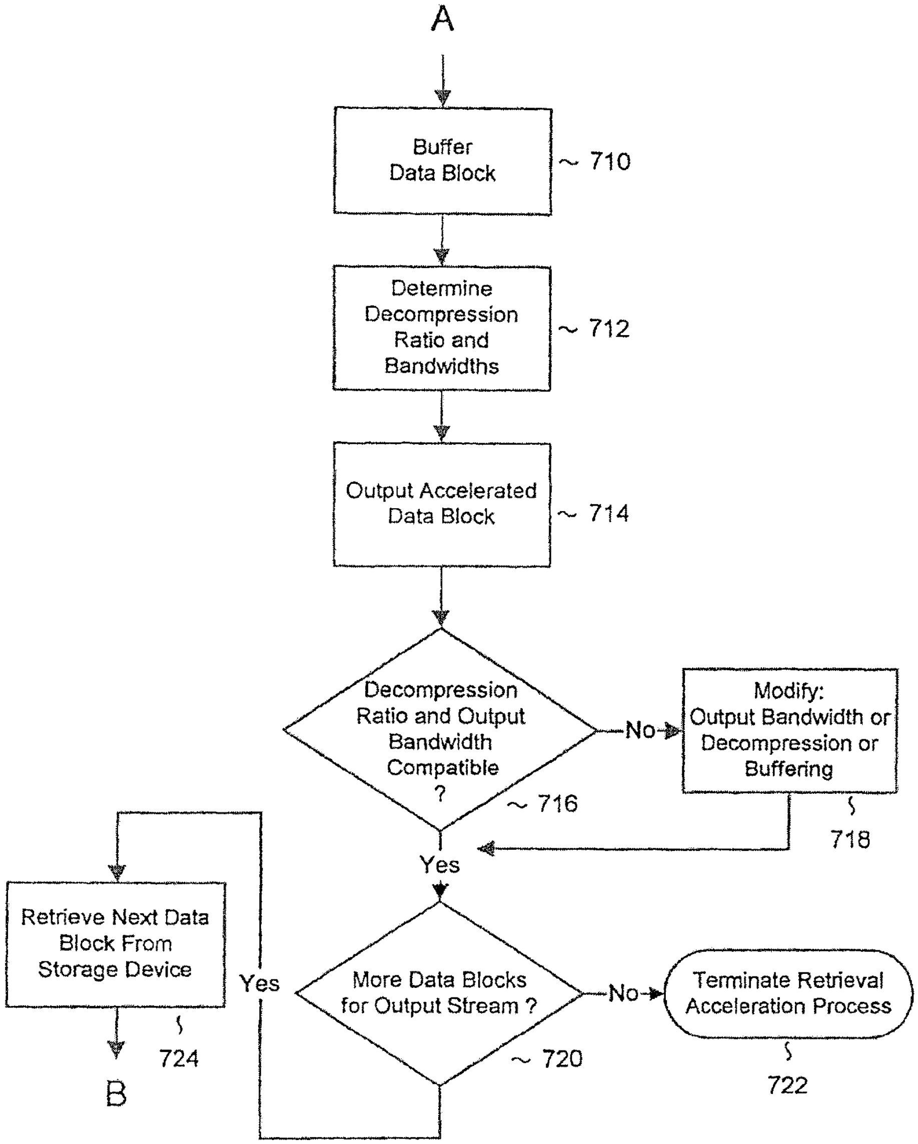
A
Buffer Data Block
710
Determine Decompression Ratio and Bandwidths
712
Output Accelerated Data Block
714
Decompression Ratio and Output Bandwidth Compatible ?
716
No
Modify: Output Bandwidth or Decompression or Buffering
718
Yes
More Data Blocks for Output Stream ?
720
No
Terminate Retrieval Acceleration Process
722
Yes
Retrieve Next Data Block From Storage Device
724
B

FIGURE 7b

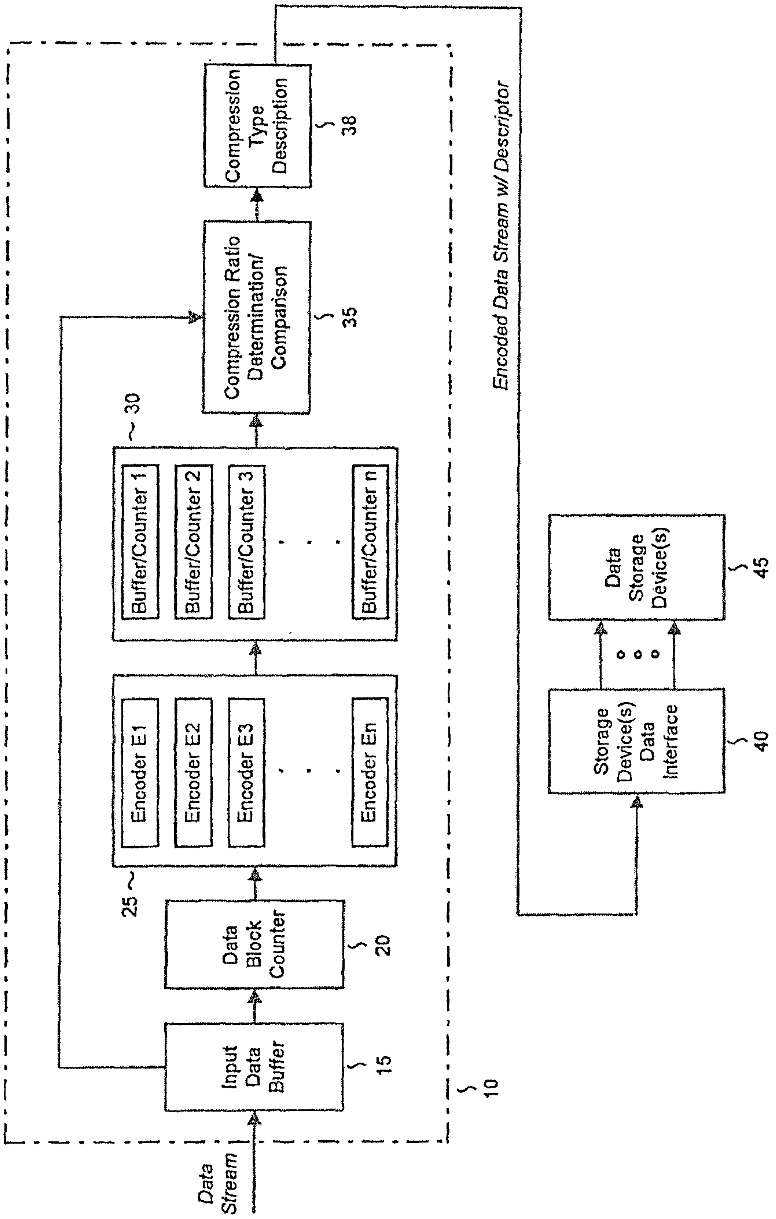
Data Stream
Input Data Buffer
15
Data Block Counter
20
25
Encoder E1
Encoder E2
Encoder E3
Encoder En
Buffer/Counter 1
Buffer/Counter 2
Buffer/Counter 3
Buffer/Counter n
30
Compression Ratio Determination/ Comparison
35
Compression Type Description
38
10
Encoded Data Stream w/ Descriptor
Storage Device(s) Data Interface
40
Data Storage Device(s)
45

FIGURE 8

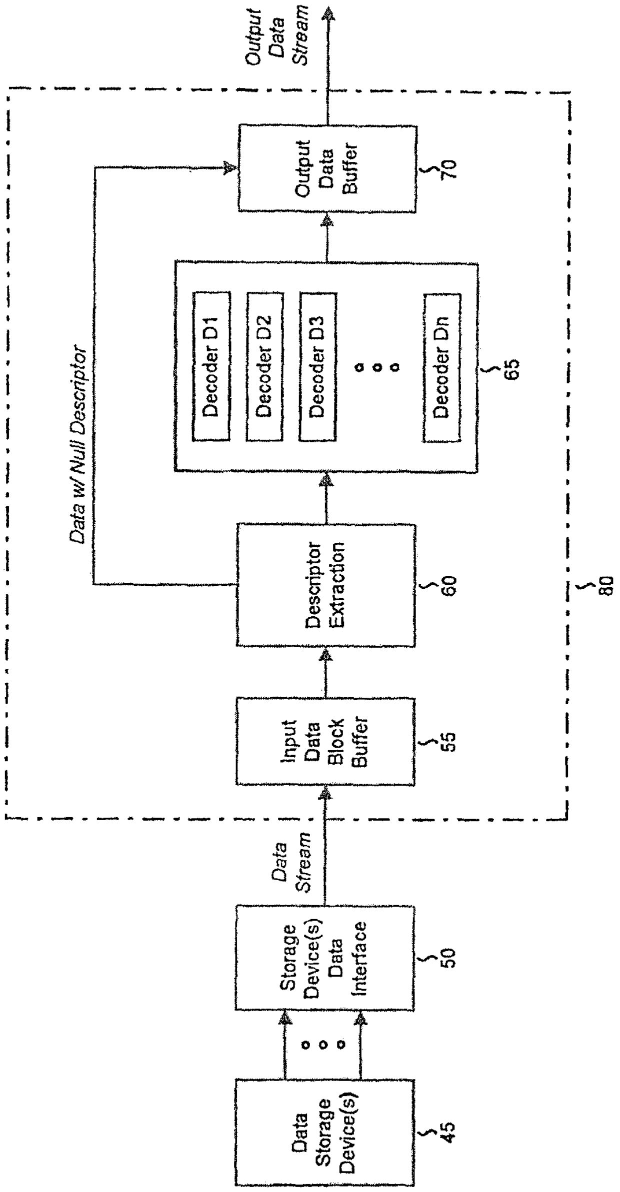
Data Storage Device(s)
45
Storage Device(s) Data Interface
50
Data Stream
Input Data Block Buffer
55
Descriptor Extraction
60
Data w/ Null Descriptor
Decoder D1
Decoder D2
Decoder D3
Decoder Dn
65
Output Data Buffer
70
Output Data Stream
80

FIGURE 9

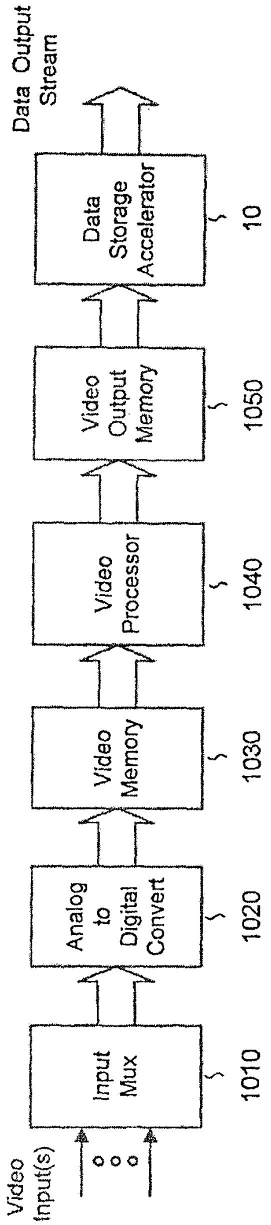
Video Input(s)
Input Mux
1010
Analog to Digital Convert
1020
Video Memory
1030
Video Processor
1040
Video Output Memory
1050
Data Storage Accelerator
10
Data Output Stream

FIGURE 10

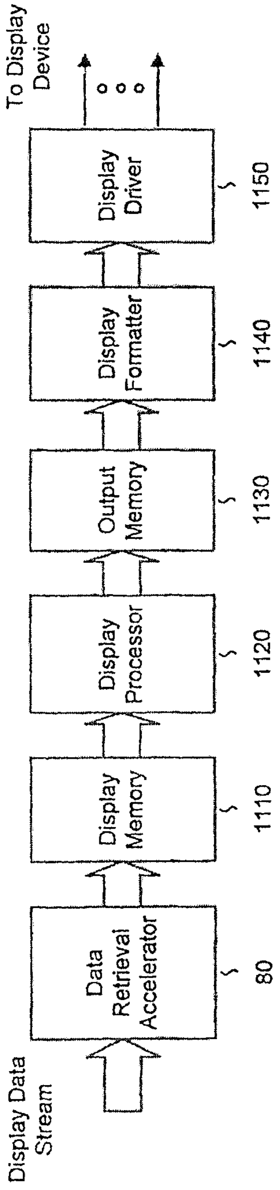
Display Data Stream
Data Retrieval Accelerator
80
Display Memory
1110
Display Processor
1120
Output Memory
1130
Display Formatter
1140
Display Driver
1150
To Display Device

FIGURE 11

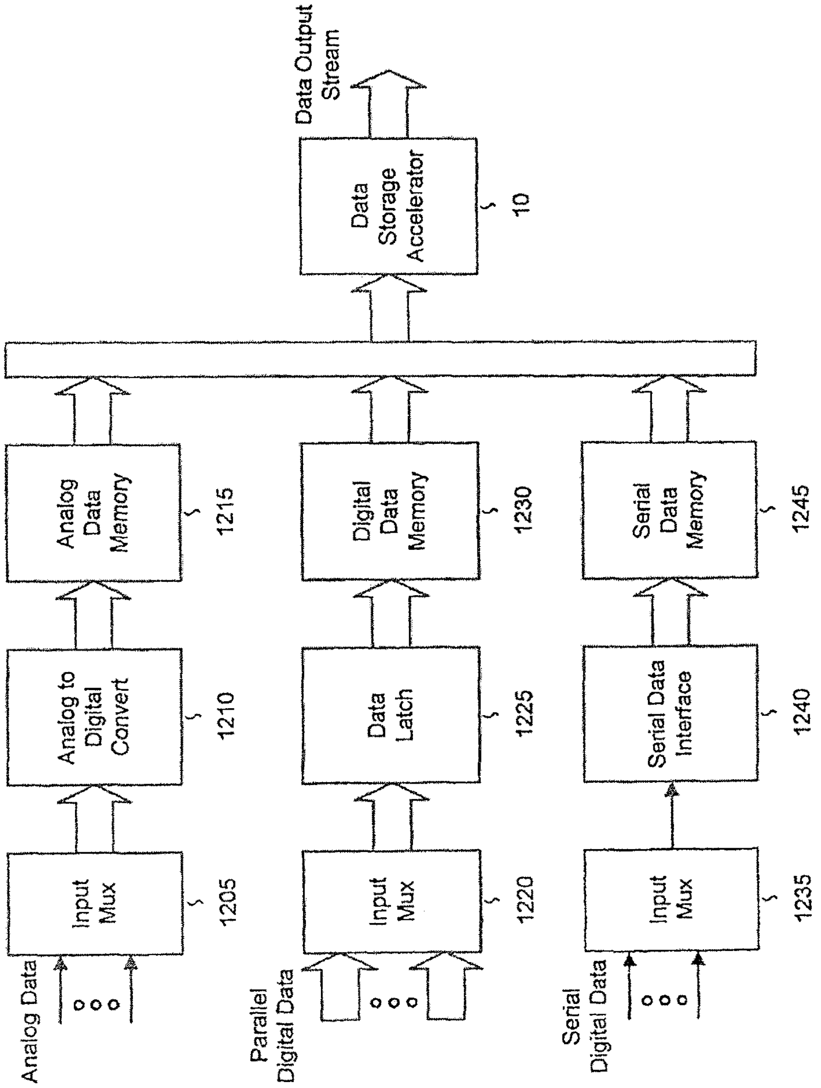
Analog Data
Input Mux
1205
Analog to Digital Convert
1210
Analog Data Memory
1215
Parallel Digital Data
Input Mux
1220
Data Latch
1225
Digital Data Memory
1230
Serial Digital Data
Input Mux
1235
Serial Data Interface
1240
Serial Data Memory
1245
Data Storage Accelerator
10
Data Output Stream

FIGURE 12

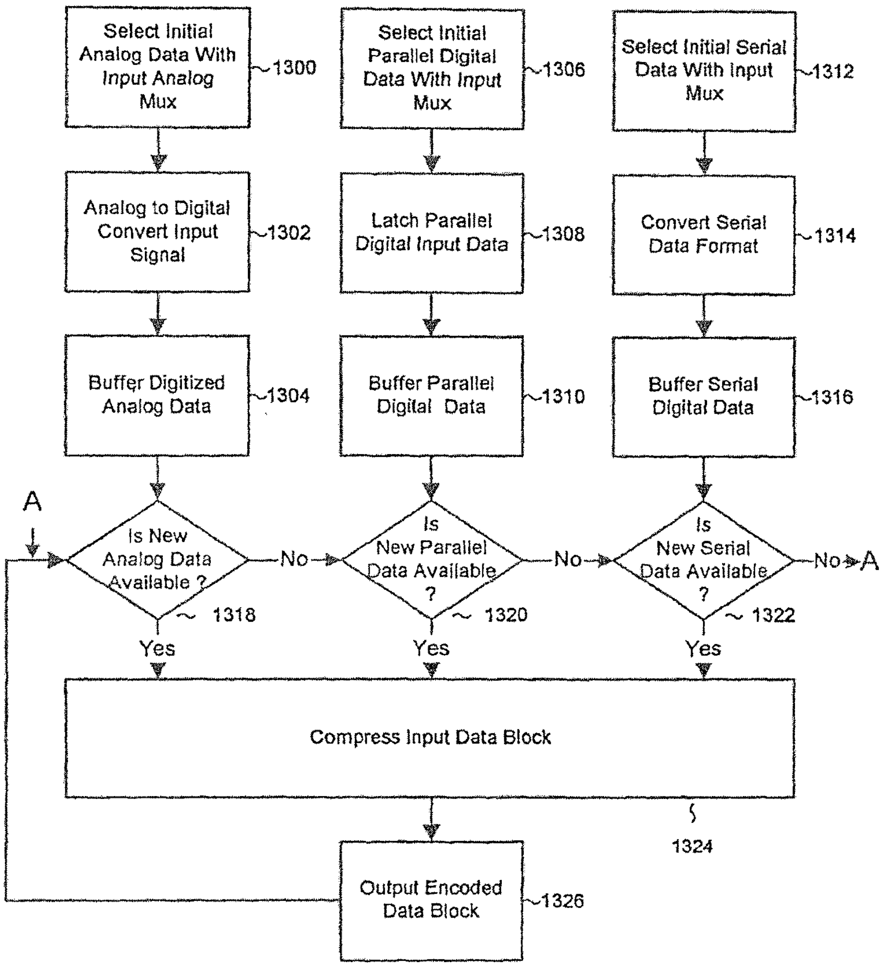
Select Initial Analog Data With Input Analog Mux
1300
Analog to Digital Convert Input Signal
1302
Buffer Digitized Analog Data
1304
Select Initial Parallel Digital Data With Input Mux
1306
Latch Parallel Digital Input Data
1308
Buffer Parallel Digital Data
1310
Select Initial Serial Data With Input Mux
1312
Convert Serial Data Format
1314
Buffer Serial Digital Data
1316
A
Is New Analog Data Available ?
1318
No
Is New Parallel Data Available ?
1320
No
Is New Serial Data Available ?
1322
No
A
Yes
Yes
Yes
Compress Input Data Block
1324
Output Encoded Data Block
1326

FIGURE 13

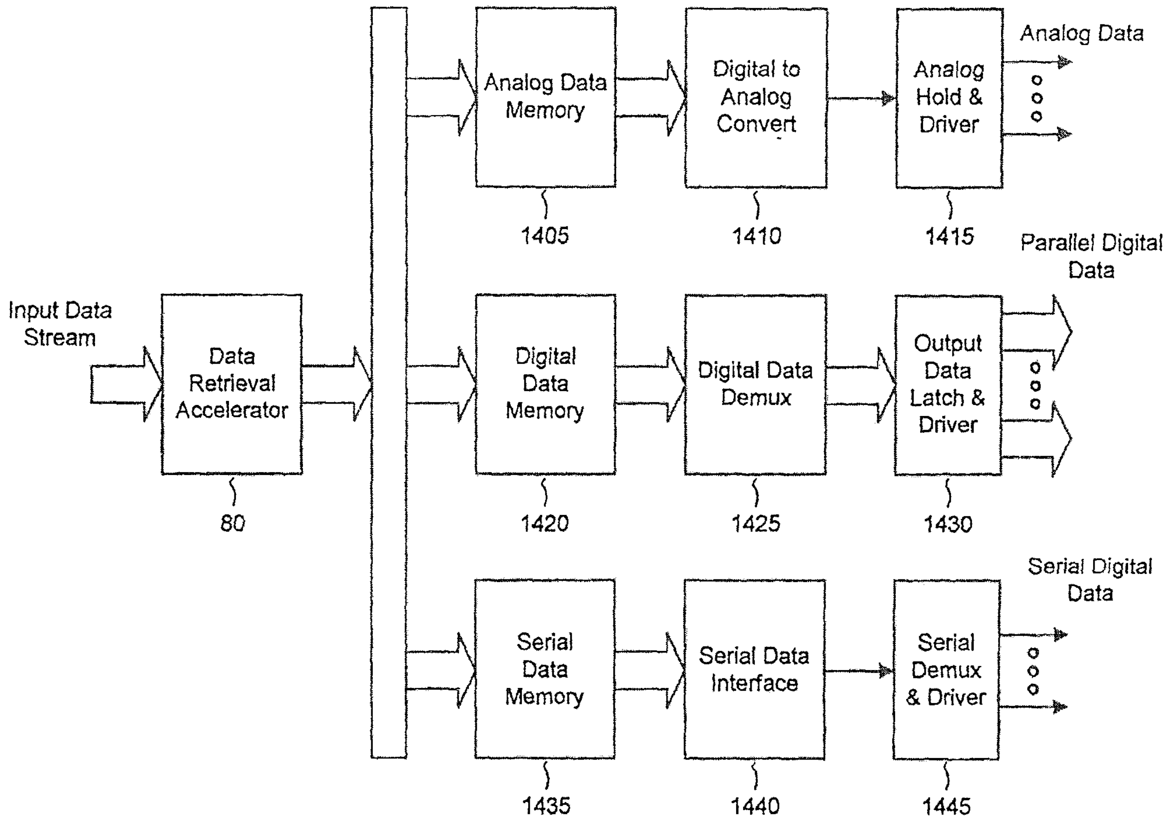
Input Data Stream
Data Retrieval Accelerator
80
Analog Data Memory
1405
Digital to Analog Convert
1410
Analog Hold & Driver
1415
Analog Data
Digital Data Memory
1420
Digital Data Demux
1425
Output Data Latch & Driver
1430
Parallel Digital Data
Serial Data Memory
1435
Serial Data Interface
1440
Serial Demux & Driver
1445
Serial Digital Data

FIGURE 14

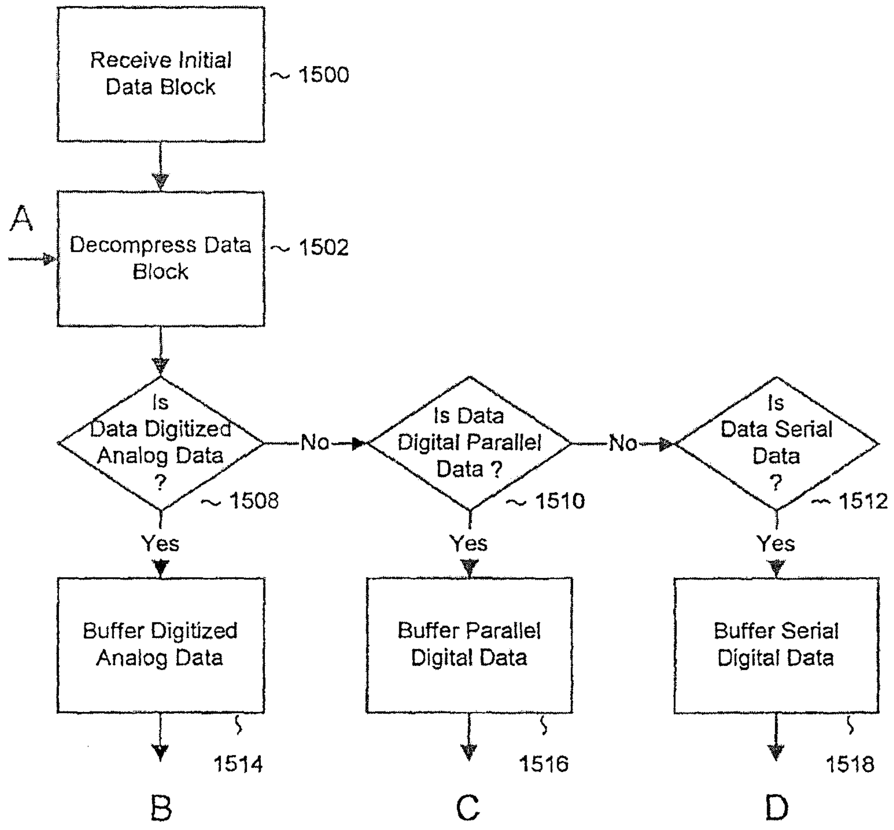
Receive Initial Data Block
1500
A
Decompress Data Block
1502
Is Data Digitized Analog Data ?
1508
No
Is Data Digital Parallel Data ?
1510
No
Is Data Serial Data ?
1512
Yes
Yes
Yes
Buffer Digitized Analog Data
Buffer Parallel Digital Data
Buffer Serial Digital Data
1514
1516
1518
B
C
D

FIGURE 15a

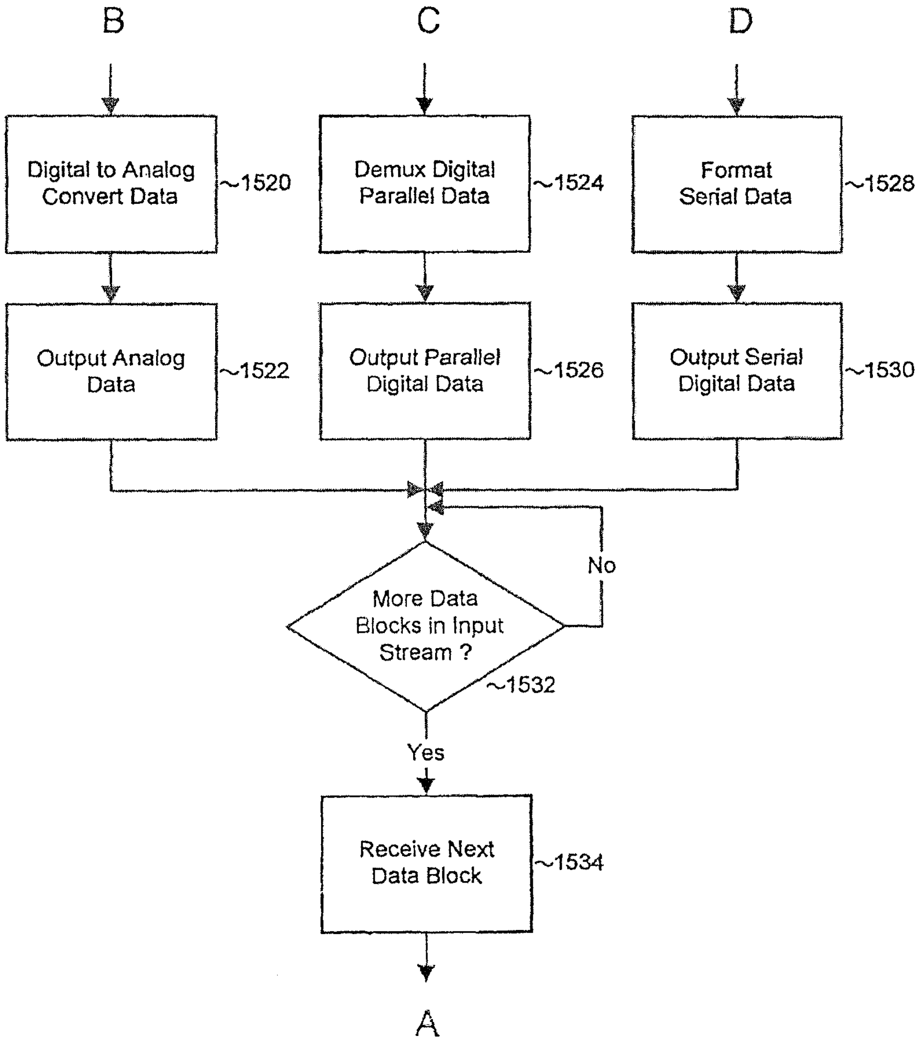
B
C
D
Digital to Analog Convert Data
1520
Demux Digital Parallel Data
1524
Format Serial Data
1528
Output Analog Data
1522
Output Parallel Digital Data
1526
Output Serial Digital Data
1530
No
More Data Blocks in Input Stream ?
1532
Yes
Receive Next Data Block
1534
A

FIGURE 15b

SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL

This application is a continuation of U.S. patent application Ser. No. 14/303,276, filed Jun. 12, 2014, which is a continuation of Ser. No. 11/553,419, filed on Oct. 26, 2006, now U.S. Pat. No. 8,756,332, which is a continuation of U.S. patent application Ser. No. 10/628,795, filed on Jul. 28, 2003, now U.S. Pat. No. 7,130,913, which is a continuation of U.S. patent application Ser. No. 09/266,394 filed on Mar. 11, 1999, now U.S. Pat. No. 6,601,104, all of which are incorporated by reference in their entirety.

BACKGROUND

The present invention relates generally to data storage and retrieval and, more particularly to systems and methods for improving data storage and retrieval bandwidth utilizing lossless data compression and decompression.

DESCRIPTION OF THE RELATED ART

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video frequently exists in the natural world as analog information. As is well-known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossy and lossless data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Negentropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than that dictated by the negentropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio of the target display device.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the negentropy of a given data set.

It is well known within the current art that data compression provides several unique benefits. First, data compression can reduce the time to transmit data by more efficiently utilizing low bandwidth data links. Second, data compression economizes on data storage and allows more information to be stored for a fixed memory size by representing information more efficiently.

One problem with the current art is that existing memory storage devices severely limit the performance of consumer, entertainment, office, workstation, servers, and mainframe computers for all disk and memory intensive operations. For example, magnetic disk mass storage devices currently employed in a variety of home, business, and scientific computing applications suffer from significant seek-time access delays along with profound read/write data rate limitations. Currently the fastest available (10,000) rpm disk drives support only a 17.1 Megabyte per second data rate (MB/sec). This is in stark contrast to the modem Personal Computer's Peripheral Component Interconnect (PCI) Bus's input/output capability of 264 MB/sec and internal local bus capability of 800 MB/sec.

Another problem within the current art is that emergent high performance disk interface standards such as the Small Computer Systems Interface (SCSI-3) and Fibre Channel offer only the promise of higher data transfer rates through intermediate data buffering in random access memory. These interconnect strategies do not address the fundamental problem that all modem magnetic disk storage devices for the personal computer marketplace are still limited by the same physical media restriction of 17.1 MB/sec. Faster disk access data rates are only achieved by the high cost solution of simultaneously accessing multiple disk drives with a technique known within the art as data striping.

Additional problems with bandwidth limitations similarly occur within the art by all other forms of sequential, pseudo-random, and random access mass storage devices. Typically mass storage devices include magnetic and optical tape, magnetic and optical disks, and various solid-state mass storage devices. It should be noted that the present invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing accelerated data storage and retrieval by utilizing lossless data compression and decompression. The present invention provides an effective increase of the data storage and retrieval bandwidth of a memory storage device.

In one aspect of the present invention, a method for providing accelerated data storage and retrieval comprises the steps of:

receiving a data stream at an input data transmission rate which is greater than a data storage rate of a target storage device;

compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate;

storing the compressed data stream in the target storage device;

retrieving the compressed data stream from the target storage device at a rate equal to a data access rate of the target storage device; and

decompressing the compressed data at a decompression ratio to provide an output data stream having an output transmission rate which is greater than the data access rate of the target storage device.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a compression ratio that is at least equal to the ratio of the input data transmission rate to the data storage rate so as to provide continuous storage of the input data stream at the input data transmission rate.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a decompression ratio which is equal to or greater than the ratio of the data access rate to a maximum accepted output data transmission rate so as to provide a continuous and optimal data output transmission rate.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a disk storage adapter to reduce the time required to store and retrieve data from computer to a disk memory device.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory.

In another aspect of the present invention a data storage and retrieval accelerator method and system is employed in a video data storage system to reduce the time required to store digital video data.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a display controller to reduce the time required to send display data to the display controller or processor.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in an input/output controller to reduce the time required to store, retrieve, or transmit data various forms of data.

The present invention is realized due to recent improvements in processing speed, inclusive of dedicated analog and digital hardware circuits, central processing units, digital signal processors, dedicated finite state machines (and any hybrid combinations thereof), that, coupled with advanced data compression and decompression algorithms, are enabling of ultra high bandwidth data compression and decompression methods that enable improved data storage and retrieval bandwidth.

These and other aspects, features and advantages, of the present invention will become apparent from the following detailed description of preferred embodiments, that is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a system for accelerated data storage and retrieval according to one embodiment of the present invention;

FIG. **2** is a flow diagram of a method for accelerated data storage in accordance with one aspect of the present invention;

FIG. **3** is a flow diagram of a method for accelerated data retrieval in accordance with one aspect of the present invention;

FIGS. **4***a* and **4***b* are timing diagrams of methods for accelerated data storage according to the present invention;

FIGS. **5***a* and **5***b* are timing diagrams of methods for accelerated data retrieval according to the present invention;

FIGS. **6***a* and **6***b* comprise a flow diagram of a method for accelerated data storage in accordance with a further aspect of the present invention;

FIGS. **7***a* and **7***b* comprise a flow diagram of a method for accelerated data retrieval in accordance with a further aspect of the present invention;

FIG. **8** is a detailed block diagram of a system for accelerated data storage according to a preferred embodiment of the present invention;

FIG. **9** is a detailed block diagram of a system for accelerated data retrieval according to a preferred embodiment of the present invention;

FIG. **10** is a block diagram of a system for accelerated video storage according to one embodiment of the present invention;

FIG. **11** is a block diagram of a system for accelerated retrieval of video data according to one embodiment of the present invention;

FIG. **12** is a block diagram of an input/output controller system for accelerated storage of analog, digital, and serial data according to one embodiment of the present invention;

FIG. **13** is a flow diagram of a method for accelerated storage of analog, digital, and serial data according to one aspect of the present invention;

FIG. **14** is a block diagram of an input/output system for accelerated retrieval of analog, digital, and serial data according to one embodiment of the present invention; and

FIGS. **15***a* and **15***b* comprise a flow diagram of method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed to systems and methods for providing improved data storage and retrieval bandwidth utilizing lossless data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU) or digital signal processors (DSP), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform may also include an operating system, microinstruction code, and dedicated processing hardware utilizing combinatorial logic or finite state machines. The various processes and functions described herein may be either part of the hardware, microinstruction code or application programs that are executed via the operating system, or any combination thereof.

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to simultaneously or sequentially losslessly compress data at a rate equivalent to or faster than the transmission rate of an input data stream. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to simultaneously or sequentially losslessly decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device. The data storage and retrieval accelerator method and system may employed: in a disk storage adapter to reduce the time required to store and retrieve data from computer to disk; in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory; in a display controller to reduce the time required to send display data to the display controller or processor; and/or in an input/output controller to reduce the time required to store, retrieve, or transmit data.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in that the systems are programmed. It is to be appreciated that special purpose microprocessors, digital signal processors, dedicated hardware, or and combination thereof may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **1**, a block diagram illustrates a system for accelerated data storage and retrieval in accordance with an embodiment of the present invention. The system includes a data storage accelerator **10**, operatively coupled to a data storage device **45**. The data storage accelerator operates to increase the effective data storage rate of the data storage device **45**. It is to be appreciated that the data storage device **45** may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The memory storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

The data storage accelerator **10** receives and processes data blocks from an input data stream. The data blocks may range in size from individual bits through complete files or collections of multiple files, and the data block size may be fixed or variable. In order to achieve continuous data storage acceleration, the data storage accelerator **10** must be configured to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Thus, to achieve optimum throughput, the rate that data blocks from the input data stream may be accepted by the data storage accelerator **10** is a function of the size of each input data block, the compression ratio achieved, and the bandwidth of the target storage device. For example, if the data storage device **45** (e.g., a typical target mass storage device) is capable of storing 20 megabytes per second and the data storage accelerator **10** is capable of providing an average compression ratio of 3:1, then 60 megabytes per second may be accepted as input and the data storage acceleration is precisely 3:1, equivalent to the average compression ratio.

It should be noted that it is not a requirement of the present invention to configure the storage accelerator **10** to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Indeed, if the storage accelerator **10** compresses data at a rate that is less than the input data rate, buffering may be applied to accept data from the input data stream for subsequent compression.

Additionally, it is not a requirement that the data storage accelerator **10** utilize data compression with a ratio that is at least the ratio of the input data stream to the data storage access rate of the data storage device **45**. Indeed, if the compression ratio is less than this ratio, the input data stream may be periodically halted to effectively reduce the rate of the input data stream. Alternatively, the input data stream or the output of the data accelerator **10** may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to reduce the input data rate to rate that is equal to or slower than the ratio of the input data rate to the data storage device access rate by signaling the data input source and requesting a slower data input rate, if possible.

Referring again to FIG. **1**, a data retrieval accelerator **80** is operatively connected to and receives data from the data storage device **45**. The data retrieval accelerator **80** receives and processes compressed data from data storage device **45** in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator **80** is configured to decompress each compressed data block which is received from the data storage device **45**. In order to achieve continuous accelerated data retrieval, the data retrieval accelerator must decompress a given input data block at a rate that is equal to or faster than receipt of the input data.

In a manner analogous to the data storage accelerator **10**, achieving optimum throughput with the data retrieval accelerator **80** is a function of the rate that compressed data blocks are retrieved from the data storage device **45**, the size of each data block, the decompression ratio achieved, and the limitation on the bandwidth of the output data stream, if any. For example, if the data storage device **45** is capable of continuously supplying 20 megabytes per second and the data retrieval accelerator **80** is capable of providing an average decompression ratio of 1:3, then a 60 megabytes per second output data stream is achieved, and the corresponding data retrieval acceleration is precisely 1:3, equivalent to the average decompression ratio.

It is to be understood that it is not required that the data retrieval accelerator **80** utilize data decompression with a ratio that is at most equal to the ratio of the retrieval rate of the data storage device **45** to the maximum rate data output stream. Indeed, if the decompression ratio is greater than this ratio, retrieving data from the data storage device may be periodically halted to effectively reduce the rate of the output data stream to be at or below its maximum. Alternatively, the compressed data retrieved from the data storage device **45** or the output of the data decompressor may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to increase the output data rate by signaling or otherwise requesting the data output device(s) receiving the output data stream to accept a higher bandwidth, if possible.

Referring now to FIG. **2**, a flow diagram of a method for accelerated data storage according to one aspect of the present invention illustrates the operation of the data storage acceleration shown in FIG. **1**. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream (step **200**) is input into and compressed by the data storage accelerator **10** (step **202**). Upon completion of the encoding of the input data block, the encoded data block is then stored in the data storage device **45** (step **204**). A check or other form of test is performed to see if there are additional data blocks available in the input stream (step **206**). If no more data blocks are available, the storage acceleration process is terminated (step **208**). If more data blocks are available in the input data stream, the next data block is received (step **210**) and the process repeats beginning with data compression (step **202**).

Referring now to FIG. **3**, a flow diagram of a method for accelerated data retrieval according to one aspect of the present invention illustrates the operation of the data retrieval accelerator **80** shown in FIG. **1**. Data decompression is also performed on a per data block basis. The initial compressed data block is retrieved from the storage device **45** (step **300**) and is decompressed by the data retrieval accelerator **80** (step **302**). Upon completion of the decoding of the initial data block, the decoded data block is then output for subsequent processing, storage, or transmittal (step **304**). A check or other form of test is performed to see if additional data blocks available from the data storage device (step **306**). If no more data blocks are available, the data retrieval acceleration process is terminated (step **308**). If more data blocks are available from the data storage device, the next data block is retrieved (step **310**) and the process repeats beginning with data decompression (step **302**).

Referring now to FIGS. **4***a* and **4***b*, a timing diagram illustrates methods for accelerated data storage utilizing data compression in accordance with the present invention. Successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** is received from an input stream of one or more data blocks. Similarly, data block **2** through data block n are received during time intervals T**2** through Tn, respectively. For the purposes of discussion, FIGS. **4***a* and **4***b* demonstrate one embodiment of the data storage utilizing a stream of n data blocks. As previously stated, the input data stream is comprised of one or more data blocks data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable.

In accordance with Method **1**, compression of data block **1** and subsequent storage of the encoded data block **1** occurs within time interval T**1**. Similarly, the compression and storage of each successive data block occurs within the time interval the data block is received. Specifically, data blocks **2** . . . n are compressed in time intervals T**2** . . . Tn, respectively, and the corresponding encoded data blocks **2** . . . n are stored during the time intervals T**2** . . . Tn, respectively. It is to be understood that Method **1** relies on data compression and encoding techniques that process data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data compression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of encoding data when received. Method **1** possesses the advantage of introducing a minimum delay in the time from receipt of input to storage of encoded data blocks.

Referring again to FIGS. **4***a* and **4***b*, Method **2** illustrates compressing and storing data utilizing pipelined data processing. For Method **2**, successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** is received from an input stream of one or more data blocks during time interval T**1**. Similarly, data block **2** through data block n are received during time intervals T**2** through Tn, respectively. Compression of data block **1** occurs during time interval T**2** and the storage of encoded data block **1** occurs during time interval T**3**. As shown by Method **2**, compression of each successive data block occurs within the next time interval after the data block is received and data storage of the corresponding encoded data block occur in the next time interval after completion of data compression.

The pipelining of Method **2**, as shown, utilizes successive single time interval delays for data compression and data storage. Within the current invention, it is permissible to have increased pipelining to facilitate additional data processing or storage delays. For example, data compression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data compressors to process successive data blocks, e.g., data compression processing of a single data block through three successive time intervals requires three data compressors, each processing a successive input data block. Due to the principle of causality, encoded data blocks are output only after compression encoding.

Method **2** provides for block oriented processing of the input data blocks. Within the current art, block oriented data compression techniques provide the opportunity for increased data compression ratios. The disadvantage of Method **2** is increased delay from receipt of input data block to storage of encoded data. Depending on factors such as the size of input data blocks, the rate that they are received, the time required for data compression processing, the data compression ratio achieved, the bandwidth of the data storage device, and the intended application, the delay may or may not be significant. For example, in a modern database system, recording data for archival purposes, the opportunity for increased data compression may far outweigh the need for minimum delay. Conversely, in systems such as a military real-time video targeting system, minimizing delay is often of the essence. It should be noted that Method **1** and Method **2** are not mutually exclusive, and may be utilized in any combination.

Referring now to FIGS. **5***a* and **5***b*, a timing diagram illustrates methods for accelerated data retrieval utilizing data decompression in accordance the present invention shown. Successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** is retrieved or otherwise accepted as input from one or more compressed data blocks retrieved from a data storage device. As shown, data block **2** through data block n are retrieved during time intervals T**2** through Tn, respectively. For the purposes of discussion, FIGS. **5***a* and **5***b* demonstrate one embodiment of the data retrieval accelerator utilizing a stream of n data blocks. Once again, the retrieved data stream is comprised of one or more data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the retrieved data block size may be fixed or variable.

In accordance with Method **1**, decompression of data block **1** and subsequent outputting of the decoded data block **1** occurs within time interval T**1**. Similarly, decompression and outputting of each successive data block occurs within the time intervals they are retrieved. In particular, data block **2** through data block n are decompressed and decoded data block **2** through decoded data block n are output during time intervals T**2** . . . Tn, respectively. It is to be understood that Method **1** relies on data decompression and decoding techniques that process compressed data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data decompression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of decoding data when received. Method **1** possesses the advantage of introducing a minimum delay in the time from retrieval of compressed data to output of decoded data blocks.

Referring again to FIGS. **5***a* and **5***b*, Method **2** involves decompressing and outputting data utilizing pipelined data processing. For Method **2**, successive time intervals of equal duration are represented as T**1** through T(n+2). Data block **1** through data block n are retrieved or otherwise accepted as input from a data storage device during time intervals T**1** through Tn, respectively. Decompression of data block **1** occurs during time interval T**2** and the decoded data block **1** is output during time interval T**3**. Similarly, decompression of each successive data block occurs within the next time interval after the data block is retrieved and the outputting of the decoded data block occurs during the next time interval after completion of data decompression.

The pipelining of Method **2**, utilizes successive single time interval delays for data decompression and data output. Within the current invention, it is permissible to have increased pipelining to facilitate additional data retrieval or data decompression processing delays. For example, data decompression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data decompressors to process successive compressed data blocks, e.g., data decompression processing of a single data block through three successive time intervals requires three data decompressors, each processing a successive input data block. Due to the principle of causality, decoded data blocks are only output after decompression decoding.

As before, Method **2** provides for block oriented processing of the retrieved data blocks. Within the current art, block oriented data decompression techniques provide the opportunity to utilize data compression encoders that increase data compression ratios. The disadvantage of method **2** is increased delay from retrieval of compressed data block to output of decompressed data. As previously discussed for data storage acceleration, depending on the size of retrieved data blocks, the rate that they are retrieved, the time required for data decompression processing, the data decompression ratio achieved, the bandwidth of the data output, and the intended application, the delay may or may not be significant.

Referring now to FIGS. **6***a* and **6***b*, a flow diagram illustrates a method for accelerated data storage according to a further aspect of the present invention. With this method, the data compression rate of the storage accelerator **10** is not required to be equal to or greater than the ratio of the input data rate to the data storage access rate. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream is received (step **600**) and then timed and counted (step **602**). Timing and counting enables determination of the bandwidth of the input data stream. The input data block is then buffered (step **604**) and compressed by the data storage accelerator **10** (step **606**). During and after the encoding of the input data block, the encoded data block is then timed and counted (step **608**), thus enabling determination of the compression ratio and compression bandwidth. The compressed, timed and counted data block is then buffered (step **610**). The compression ratio and bandwidths of the input data stream and the encoder are then determined (step **612**). The compressed data block is then stored in the data storage device **45** (step **614**). Checks or other forms of testing are applied to ensure that the data bandwidths of the input data stream, data compressor, and data storage device are compatible (step **616**). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step **618**). For instance, the input bandwidth may be adjusted by either not accepting input data requests, lowering the duty cycle of input data requests, or by signaling one or more of the data sources that transmit the input data stream to request or mandate a lower data rate. In addition, the data compression ratio of the data storage accelerator **10** may be adjusted by applying a different type of encoding process such as employing a single encoder, multiple parallel or sequential encoders, or any combination thereof. Furthermore, additional temporary buffering of either the input data stream or the compressed data stream (or both) may be utilized.

By way of example, assuming the input data rate is 90 MB/sec and the data storage accelerator **10** provides a compression ratio of 3:1, then the output of the data storage accelerator **10** would be 30 MB/sec. If the maximum data storage rate of the data storage device **45** is 20 MB/sec (which is less than the data rate output from the data storage accelerator **10**), data congestion and backup would occur at the output of the data storage accelerator **10**. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the compression ratio to provide a data output rate from the data storage accelerator **10** to be equal to the data storage rate of the data storage device **45**.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more of the system parameters), then a check or other form of test is performed to determine if there are additional data blocks available in the input stream (step **620**). If no more data blocks are available, the storage acceleration process is terminated (step **622**). If more data blocks are available in the input data stream, the next data block is received (step **624**) and the process repeats beginning with timing and counting of the input data block (step **602**).

Referring now to FIGS. **7***a* and **7***b*, a flow diagram illustrates a method for accelerated data retrieval according to one aspect of the present invention. With this method, the data decompression ratio is not required to be less than or equal to the ratio of the data retrieval access rate to the maximum output data rate. As previously stated above, data decompression is performed on a per data block basis. Accordingly, the initial input data block is retrieved from the storage device (step **700**) and is timed and counted (step **702**). Timing and counting enables determination of the bandwidth of data retrieval. The retrieved data block is then buffered (step **704**) and decompressed by the data retrieval accelerator **80** (step **706**). During and after the decoding of the input data block, the decoded data block is then timed and counted (step **708**), thus enabling determination of the decompression ratio and decompression bandwidth. The decompressed, timed and counted data block is then buffered (step **710**). The decompression ratio and bandwidths of the retrieved data and the decoder are then determined (step **712**). The decompressed data block is then output (step **714**). Checks or other forms of testing are applied to ensure that the data bandwidths of the retrieved data, data decompressor, and data output are compatible (step **716**). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step **718**). For instance, the data retrieval bandwidth may be adjusted either not accepting (continuously) data blocks retrieved from the data storage device or lowering the duty cycle of data blocks retrieved from the data storage device. In addition, one or more of the output data devices that receive the output data stream may be signaled or otherwise requested to accept a higher data rate. Moreover, a different type of decoding process may be applied to adjust the data decompression rate by applying, for example, a single decoder, multiple parallel or sequential decoders, or any combination thereof. Also, additional temporary buffering of either the retrieved or output data or both may be utilized.

By way of example, assuming the data storage device **45** has a data retrieval rate of 20 MB/sec and the data retrieval accelerator **80** provides a 1:4 decompression ratio, then the output of the data retrieval accelerator **80** would be 80 MB/sec. If the maximum output data transmission rate that can be accepted from the data retrieval accelerator **80** is 60 MB/sec (which is lower than the data output data rate of 80 MB/sec of the data retrieval accelerator **80**), data congestion and backup would occur at the output of the data retrieval accelerator **80**. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the decompression ratio to provide a data output rate from the data storage accelerator **80** to be equal to the maximum accepted output data transmission rate.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more system parameters), then a check or other form of test is performed to see if there are additional data blocks available from the data storage device (step **720**). If no more data blocks are available for output, the retrieval acceleration process is terminated (step **722**). If more data blocks are available to be retrieved from the data storage device, the next data block is retrieved (step **724**) and the process repeats beginning with timing and counting of the retrieved data block (return to step **702**).

It is to be understood that any conventional compression/decompression system and method (which comply with the above mentioned constraints) may be employed in the data storage accelerator **10** and data retrieval accelerator **80** for providing accelerated data storage and retrieval in accordance with the present invention. Preferably, the present invention employs the data compression/decompression techniques disclosed in U.S. Ser. No. 09/210,491 entitled "Content Independent Data Compression Method and System," filed on Dec. 11, 1998, which is commonly assigned and which is fully incorporated herein by reference. It is to be appreciated that the compression and decompression systems and methods disclosed in U.S. Ser. No. 09/210,491 are suitable for compressing and decompressing data at rates which provide accelerated data storage and retrieval.

Referring now to FIG. **8**, a detailed block diagram illustrates a preferred system for accelerated data storage which employs a compression system as disclosed in the above-incorporated U.S. Ser. No. 09/210,491. In this embodiment, the data storage accelerator **10** accepts data blocks from an input data stream and stores the input data block in an input buffer or cache **15**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. A counter **20** counts or otherwise enumerates the size of input data block in any convenient units including bits, bytes, words, double words. It should be noted that the input buffer **15** and counter **20** are not required elements of the present invention. The input data buffer **15** may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold.

Data compression is performed by an encoder module **25** which may comprise a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" (where n may=1) of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **25** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **20**). Data compression is performed by the encoder module **25** wherein each of the encoders E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **25** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **30** is operatively connected to the encoder module **25** for buffering and counting the size of each of the encoded data blocks output from encoder module **25**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **35**, operatively connected to the output buffer/counter **30**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **35** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **38**, operatively coupled to the compression ratio module **35**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block. A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal. If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit, then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto. A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal.

The data storage acceleration device **10** is connected to a data storage device interface **40**. The function of the data storage interface **40** is to facilitate the formatting and transfer of data to one or more data storage devices **45**. The data storage interface may be any of the data interfaces known to those skilled in the art such as SCSI (Small Computer Systems Interface), Fibre Channel, “Firewire”, IEEE P1394, SSA (Serial Storage Architecture), IDE (Integrated Disk Electronics), and ATA/ATAPI interfaces. It should be noted that the storage device data interface **40** is not required for implementing the present invention. As before, the data storage device **45** may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The data storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory (RAM), magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices (e.g., ATA/ATAPI IDE disk). Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

Again, it is to be understood that the embodiment of the data storage accelerator **10** of FIG. **8** is exemplary of a preferred compression system which may be implemented in the present invention, and that other compression systems and methods known to those skilled in the art may be employed for providing accelerated data storage in accordance with the teachings herein. Indeed, in another embodiment of the compression system disclosed in the above-incorporated U.S. Ser. No. 09/210,491, a timer is included to measure the time elapsed during the encoding process against an a priori-specified time limit. When the time limit expires, only the data output from those encoders (in the encoder module **25**) that have completed the present encoding cycle are compared to determine the encoded data with the highest compression ratio. The time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved. In addition, the results from each encoder in the encoder module **25** may be buffered to allow additional encoders to be sequentially applied to the output of the previous encoder, yielding a more optimal lossless data compression ratio. Such techniques are discussed in greater detail in the above-incorporated U.S. Ser. No. 09/210,491.

Referring now to FIG. **9**, a detailed block diagram illustrates a preferred system for accelerated data retrieval employing a decompression system as disclosed in the above-incorporated U.S. Ser. No. 09/210,491. In this embodiment, the data retrieval accelerator **80** retrieves or otherwise accepts data blocks from one or more data storage devices **45** and inputs the data via a data storage interface **50**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. As stated above, the memory storage device **45** may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof. The data storage device interface **50** converts the input data from the storage device format to a format useful for data decompression.

The storage device data interface **50** is operatively connected to the data retrieval accelerator **80** which is utilized for decoding the stored (compressed) data, thus providing accelerated retrieval of stored data. In this embodiment, the data retrieval accelerator **80** comprises an input buffer **55** which receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **55** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **60** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **65** includes one or more decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source.

As with the data compression systems discussed in U.S. application Ser. No. 09/210,491, the decoder module **65** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time. The data retrieval accelerator **80** also includes an output data buffer or cache **70** for buffering the decoded data block output from the decoder module **65**. The output buffer **70** then provides data to the output data stream. It is to be appreciated by those skilled in the art that the data retrieval accelerator **80** may also include an input data counter and output data counter operatively coupled to the input and output, respectively, of the decoder module **65**. In this manner, the compressed and corresponding decompressed data block may be counted to ensure that sufficient decompression is obtained for the input data block.

Again, it is to be understood that the embodiment of the data retrieval accelerator **80** of FIG. **9** is exemplary of a preferred decompression system and method which may be implemented in the present invention, and that other data decompression systems and methods known to those skilled in the art may be employed for providing accelerated data retrieval in accordance with the teachings herein.

In accordance with another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in for increasing the storage rate of video data. In particular, referring now to FIG. **10**, a block diagram illustrates a system for providing accelerated video data storage in accordance with one embodiment of the present invention. The video data storage acceleration system accepts as input one or more video data streams that are analog, digital, or any combination thereof in nature. The input multiplexer **1010** selects the initial video data stream for data compression and acceleration. The input multiplexer **1010** is operatively connected to an analog to digital converter **1020** which converts analog video inputs to digital format of desired resolution. The analog to digital converter **1020** may also include functions to strip video data synchronization to perform other data formatting functions. It should be noted that the analog to digital conversion process is not required for digital video inputs. The analog to digital converter **1020** is operatively connected a video memory **1030** that is, in turn, operatively connected to a video processor **1040**. The video processor **1040** performs manipulation of the digital video data in accordance with any user desired processing functions. The video processor **1040** is operatively coupled to a video output memory **1050**, that is operatively connected to a data storage accelerator **10** which compresses the video data to provide accelerated video data to the output data stream for subsequent data processing, storage, or transmittal of the video data. This video data acceleration process is repeated for all data blocks in the input data stream. If more video data blocks are available in the input data stream, the video multiplexer selects the next block of video for accelerated processing. Again, it is to be understood that the data storage accelerator **10** may employ any compression system which is capable of compressing data at a rate suitable for providing accelerated video data storage in accordance with the teachings herein.

In accordance with another aspect of the present invention, the accelerated data storage and retrieval system may be employed in a display controller to reduce the time required to send display data to a display controller or processor. In particular, referring now to FIG. **11**, a block diagram illustrates a display accelerator system in accordance with one embodiment of the present invention. The video display accelerator accepts as input one or more digital display data blocks from an input display data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input video data block size may be fixed or variable. The input data blocks are processed by a data retrieval accelerator **80** which employs a data decompression system in accordance with the teachings herein. Upon completion of data decompression, the decompressed data block is then output to a display memory **1110** that provides data to a display processor **1120**. The display processor **1120** performs any user desired processing function. It is well known within the current art that display data is often provided in one or more symbolic formats such as Open Graphics Language (Open GL) or another display or image language. The display processor **1120** is operatively connected an output memory buffer **1130**. The output memory **1130** supplies data to a display formatter **1140** that converts the data to a format compatible with the output display device or devices. Data from the display formatter **1140** is provided to the display driver **1150** that outputs data in appropriate format and drive signal levels to one or more display devices. It should be noted that the display memory **1110**, display processor **1120**, output memory **1130**, display formatter **1140**, and display driver **1150** are not required elements of the present invention.

In accordance with yet another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in an I/O controller to reduce the time for storing, retrieving or transmitting parallel data streams. In particular, referring now to FIG. **12**, a block diagram illustrates a system for accelerated data storage of analog, digital, and serial data in accordance with one embodiment of the present invention. The data storage accelerator **10** is capable of accepting one or more simultaneous analog, parallel digital, and serial data inputs. An analog input multiplexer **1205** selects the initial analog data for data compression and acceleration. The analog input multiplexer **1205** is operatively connected to an analog to digital converter **1210** that converts the analog input signal to digital data of the desired resolution. The digitized data output of the analog to digital converter **1210** is stored in an analog data memory buffer **1215** for subsequent data storage acceleration. Similarly, a parallel digital data input multiplexer **1220** selects the initial parallel digital data for data compression and acceleration. The parallel digital data input multiplexer **1220** is operatively connected to an input data latch **1225** that holds the input parallel digital data. The parallel digital data is then stored in digital data memory buffer **1245** for subsequent data storage acceleration. In addition, a serial digital data input multiplexer **1235** selects the initial serial digital data for data compression and acceleration. The serial digital data input multiplexer **1235** is operatively connected to a serial data interface **1240** that converts the serial data stream to a format useful for data acceleration. The formatted serial digital data is then stored in serial data memory buffer **1245** for subsequent data acceleration. The analog data memory **1215**, parallel digital data memory **1230**, and serial data memory **1245** are operatively connected to the data storage accelerator device **10**. Data is selected from each data memory subsystem based upon a user defined algorithm or other selection criteria. It should be noted that the analog input multiplexer **1205**, analog to digital converter **1210**, analog data memory **1215**, parallel data input multiplexer **1220**, data latch **1225**, digital data memory **1230**, serial data input multiplexer **1235**, serial data interface **1240**, serial data memory **1245**, and counter **20** are not required elements of the present invention. As stated above, the data storage accelerator **10** employs any of the data compression methods disclosed in the above-incorporated U.S. Ser. No. 09/210,491, or any conventional data compression method suitable for compressing data at a rate necessary for obtaining accelerated data storage. The data storage accelerator supplies accelerated data to the output data stream for subsequent data processing, storage, or transmittal.

Referring now to FIG. **13**, a flow diagram illustrates a method for accelerated data storage of analog, digital, and serial data according to one aspect of the present invention. The analog input multiplexer selects the initial analog data for data compression and acceleration (step **1300**). The analog input multiplexer provides analog data to the analog to digital converter that converts the analog input signal to digital data of the desired resolution (step **1302**). The digitized data output of the analog to digital converter is then buffered in the analog data memory buffer (step **1304**) for subsequent data acceleration. Similarly, the parallel digital data multiplexer selects the initial parallel digital data for data compression and acceleration (step **1306**). The parallel digital data multiplexer provides data to the input data latch that then holds the input parallel digital data (step **1308**). The parallel digital data is then stored in digital data memory buffer for subsequent data acceleration (step **1310**). The serial digital data input multiplexer selects the initial serial digital data for data compression and acceleration (step **1312**). The serial digital data input multiplexer provides serial data to the serial data interface that converts the serial data stream to a format useful for data acceleration (step **1314**). The formatted serial digital data is then stored in the serial data memory buffer for subsequent data acceleration (step **1316**). A test or other check is performed to see if new analog data is available (step **1318**). If no new analog data is available a second check is performed to see if new parallel data is available (step **1320**). If no new parallel data is available, a third test is performed to see if new serial data is available (step **1322**). If no new serial data is available (step **1322**) the test sequence repeats with the test for new analog data (step **1318**). If new analog data block is available (step **1318**), or if new parallel data block is available (step **1320**), or if new serial data block is available (step **1322**), the input data block is compressed by the data storage accelerator (step **1324**) utilizing any compression method suitable for providing accelerated data storage in accordance with the teachings herein. After data compression is complete, the compressed data block is then output subsequent accelerated data processing, storage, or transmittal (step **1326**). After outputting data the process repeats beginning with a test for new analog data (return to step **1318**).

Referring now to FIG. **14**, a block diagram illustrates a system for accelerated retrieval of analog, digital, and serial data in accordance with one embodiment of the present invention. A data retrieval accelerator **80** receives data from an input data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator **80** decompresses the input data utilizing any of the decompression methods suitable for providing accelerated data retrieval in accordance with the teachings herein. The data retrieval accelerator **80** is operatively connected to analog data memory **1405**, digital data memory **1420**, and serial data memory **1435**. Dependent upon the type of input data block, the decoded data block is stored in the appropriate analog **1405**, digital **1420**, or serial **1435** data memory.

The analog data memory **1405** is operatively connected to a digital to analog converter **1410** that converts the decompressed digital data block into an analog signal. The digital to analog converter **1410** is further operatively connected to an analog hold and output driver **1415**. The analog hold and output driver **1415** demultiplexes the analog signal output from the digital to analog converter **1410**, samples and holds the analog data, and buffers the output analog data.

In a similar manner, the digital data memory **1420** is operatively connected to a digital data demultiplexer **1425** that routes the decompressed parallel digital data to the output data latch and driver **1430**. The output latch and driver **1430** holds the digital data and buffers the parallel digital output.

Likewise, the serial data memory **1435** is operatively connected to a serial data interface **1440** that converts the decompressed data block to an output serial data stream. The serial data interface **1440** is further operatively connected to the serial demultiplexer and driver **1445** that routes the serial digital data to the appropriate output and buffers the serial data output.

Referring now to FIGS. **15***a* and **15***b*, a flow diagram illustrates a method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention. An initial data block is received (step **1500**) and then decompressed by the data storage retrieval accelerator (step **1502**). Upon completion of data decompression, a test or other check is performed to see if the data block is digitized analog data (step **1508**). If the data block is not digitized analog data, a second check is performed to see if the data block is parallel digital data (step **1510**). If the data block is not parallel digital data, a third test is performed to see if the data block serial data (step **1512**). The result of at least one of the three tests will be affirmative.

If the data block is comprised of digitized analog data, the decoded data block is buffered in an “analog” digital data memory (step **1514**). The decoded data block is then converted to an analog signal by a digital to analog converter (step **1520**). The analog signal is then output (step **1522**).

If the data block is comprised of parallel digital data, the decoded data block is buffered in a “parallel” digital data memory (step **1516**). The decoded data block is then demultiplexed (step **1524**) and routed to the appropriate the output data latch and driver. The output latch and driver then holds the digital data and buffers the parallel digital output (step **1526**).

If the data block is comprised of serial data, the decoded data block is buffered in “serial” digital data memory (step **1518**). The decoded data is then formatted to a serial data format (step **1528**). The serial data is then demultiplexed, routed to the appropriate output, and output to a buffer (step **1530**).

Upon output of analog data (step **1522**), parallel digital data (step **1526**), or serial digital data (step **1530**), a test or other form of check is performed for more data blocks in the input stream (step **1532**). If no more data blocks are available, the test repeats (return to step **1532**). If a data block is available, the next data block is received (step **1534**) and the process repeats beginning with step **1502**.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A system for accelerating data storage, comprising:

a memory device; and

one or more processors coupled to the memory device, wherein the one or more processors are configured to:

analyze a first data block to determine a parameter of the first data block;

apply a first encoder associated with the determined parameter of the first data block to create a first encoded data block, wherein the first encoder utilizes a lossless dictionary compression technique;

analyze a second data block to determine a parameter of the second data block;

apply a second encoder associated with the determined parameter of the second data block to create a second encoded data block, wherein the second encoder utilizes a lossless compression technique different than the lossless dictionary compression technique; and

store the first and second encoded data blocks on the memory device, wherein encoding and storage of the first encoded data block occur faster than the first data block is able to be stored on the memory device in unencoded form.

2. The system of claim **1**, wherein encoding and storage of the first encoded data block and the second encoded data block occur faster than the first and second data blocks are able to be stored together on the memory device in unencoded form.

3. The system of claim **1**, wherein the analysis of the first data block excludes analysis based solely on reading a descriptor.

4. The system of claim **3**, wherein the analysis of the second data block excludes analysis based solely on reading a descriptor.

5. The system of claim **1**, wherein the one or more processors are further configured to select the second encoder from a plurality of encoders.

6. The system of claim **1**, wherein the one or more processors are further configured to write a descriptor to the memory device and the descriptor indicates the lossless compression technique used to encode the second data block.

7. The system of claim **1**, wherein the one or more processors are further configured to store a descriptor on the memory device indicative of the lossless compression technique used to encode the second data block such that the descriptor is capable of being utilized to decode at least a portion of the second encoded data block.

8. The system of claim **1**, wherein the first encoded data block includes a reference to the unencoded first data block.

9. A method for accelerating data storage comprising:

analyzing a first data block to determine a parameter of the first data block;

applying a first encoder associated with the determined parameter of the first data block to create a first encoded data block, wherein the first encoder utilizes a lossless dictionary compression technique;

analyzing a second data block to determine a parameter of the second data block;

applying a second encoder associated with the determined parameter of the second data block to create a second encoded data block, wherein the second encoder utilizes a lossless compression technique different than the lossless dictionary compression technique; and

storing the first and second encoded data blocks on a memory device, wherein encoding and storage of the first encoded data block occur faster than the first data block is able to be stored on the memory device in unencoded form.

10. The method of claim **9**, wherein encoding and storage of the first and second encoded data blocks occur faster than the first and second data blocks are able to be stored together on the memory device in unencoded form.

11. The method of claim **9**, wherein the analyzing of the first data block excludes analysis based solely on reading a descriptor.

12. The method of claim **11**, wherein the analyzing of the second data block excludes analysis based solely on reading a descriptor.

13. The method of claim **9**, further comprising selecting the second encoder from a plurality of encoders.

14. The method of claim **9**, further comprising writing a descriptor to the memory device, wherein the descriptor indicates the lossless compression technique used to encode the second data block.

15. The method of claim **9**, further comprising storing a descriptor on the memory device indicative of the lossless compression technique used to encode the second data block such that the descriptor is capable of being utilized to decode at least a portion of the second encoded data block.

16. The method of claim **9**, wherein the first encoded data block includes a reference to the unencoded first data block.

17. A computer-readable storage device having instructions stored thereon, execution of which by at least one processor, causes the at least one processor to perform operations comprising:

analyzing a first data block to determine a parameter of the first data block;

applying a first encoder associated with the determined parameter of the first data block to create a first encoded data block, wherein the first encoder utilizes a lossless dictionary compression technique;

analyzing a second data block to determine a parameter of the second data block;

applying a second encoder associated with the determined parameter of the second data block to create a second encoded data block, wherein the second encoder utilizes a lossless compression technique different than the lossless dictionary compression technique; and

storing the first and second encoded data blocks on a memory device,

wherein encoding and storage of the first encoded data block occur faster than the first data block is able to be stored on the memory device in unencoded form.

18. The storage device of claim **17**, wherein encoding and storage of the first and second encoded data blocks occur faster than the first and second data blocks are able to be stored together on the memory device in unencoded form.

19. The storage device of claim **17**, wherein the analyzing of the first data block excludes analysis based solely on reading a descriptor.

20. The storage device of claim **19**, wherein the analyzing of the second data block excludes analysis based solely on reading a descriptor.

21. The storage device of claim **17**, wherein the operations further comprise selecting the second encoder from a plurality of encoders.

22. The storage device of claim **17**, wherein the first encoded data block includes a reference to the unencoded first data block.

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US009054728B2

(12) **United States Patent**
Fallon

(10) **Patent No.: US 9,054,728 B2**
(45) **Date of Patent: *Jun. 9, 2015**

(54) **DATA COMPRESSION SYSTEMS AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/495,574**

(22) Filed: **Sep. 24, 2014**

(65) **Prior Publication Data**

US 2015/0009051 A1 Jan. 8, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/251,453, filed on Apr. 11, 2014, now Pat. No. 8,933,825, which is a

(Continued)

(51) **Int. Cl.**

H03M 7/34	(2006.01)
H03M 7/30	(2006.01)
G06T 9/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H03M 7/3059*** (2013.01); ***G06T 9/00*** (2013.01); ***H03M 7/30*** (2013.01)

(58) **Field of Classification Search**

CPC ... H03M 7/30; H03M 7/3059; H03M 7/3086; H03M 7/3088; H03M 7/48; H03M 7/3084; H03M 7/40; H03M 13/091

USPC 341/65, 67, 87, 107

See application file for complete search history.

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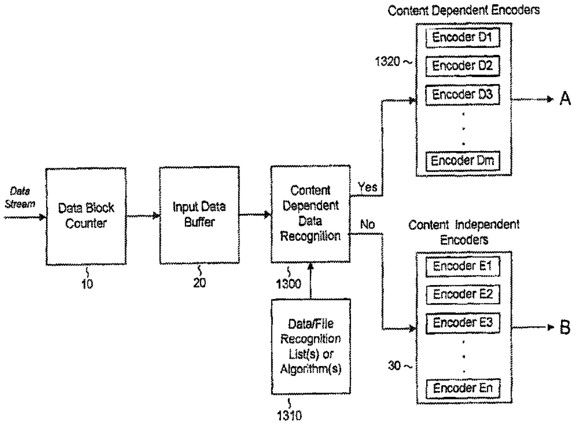
(57) **ABSTRACT**

Data compression using a combination of content independent data compression and content dependent data compression. In one aspect, a system for compressing data comprises: a processor; one or more content dependent data compression encoders; and a single data compression encoder. The processor is configured to analyze data within a data block to identify one or more parameters or attributes of the data wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based solely on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block; to perform content dependent data compression with the one or more content dependent data compression if the one or more parameters or attributes of the data are identified; and to perform data compression with the single data compression encoder, if the one or more parameters or attributes of the data are not identified.

25 Claims, 34 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/035,561, filed on Sep. 24, 2013, now Pat. No. 8,717,203, which is a continuation of application No. 13/154,211, filed on Jun. 6, 2011, now Pat. No. 8,643,513, which is a continuation of application No. 12/703,042, filed on Feb. 9, 2010, now Pat. No. 8,502,707, which is a continuation of application No. 11/651,366, filed on Jan. 8, 2007, now abandoned, and a continuation of application No. 11/651,365, filed on Jan. 8, 2007, now Pat. No. 7,714,747, which is a continuation of application No. 10/668,768, filed on Sep. 22, 2003, now Pat. No. 7,161,506, said application No. 11/651,366 is a continuation of application No. 10/668,768, which is a continuation of application No. 10/016,355, filed on Oct. 29, 2001, now Pat. No. 6,624,761, which is a continuation-in-part of application No. 09/705,446, filed on Nov. 3, 2000, now Pat. No. 6,309,424, which is a continuation of application No. 09/210,491, filed on Dec. 11, 1998, now Pat. No. 6,195,024.

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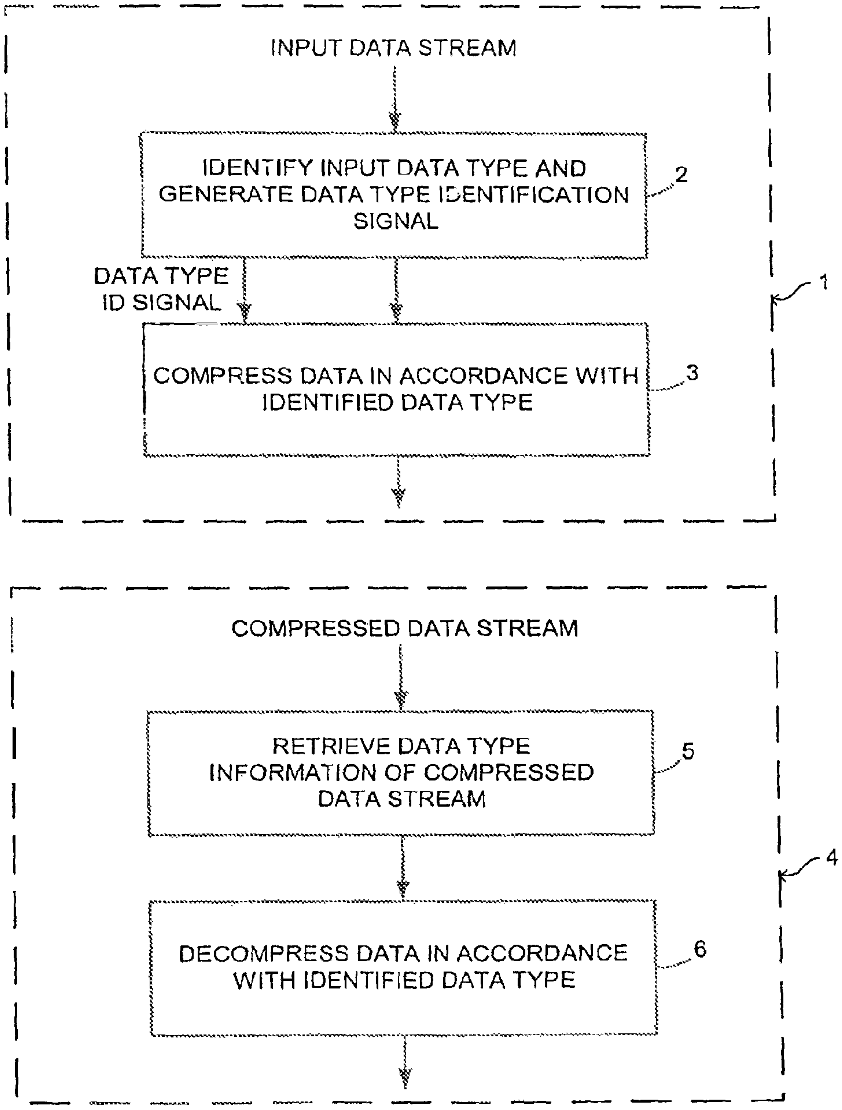
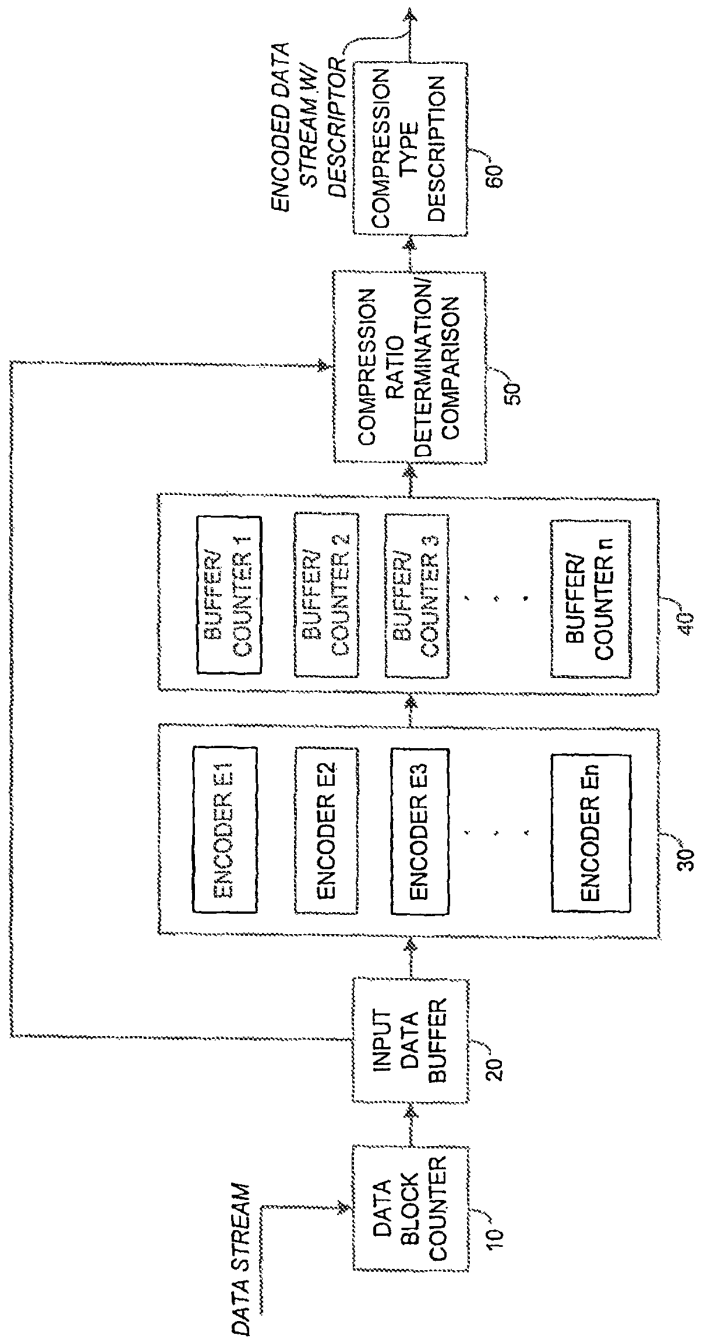


FIG. 1
PRIOR ART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10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
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BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
. . .
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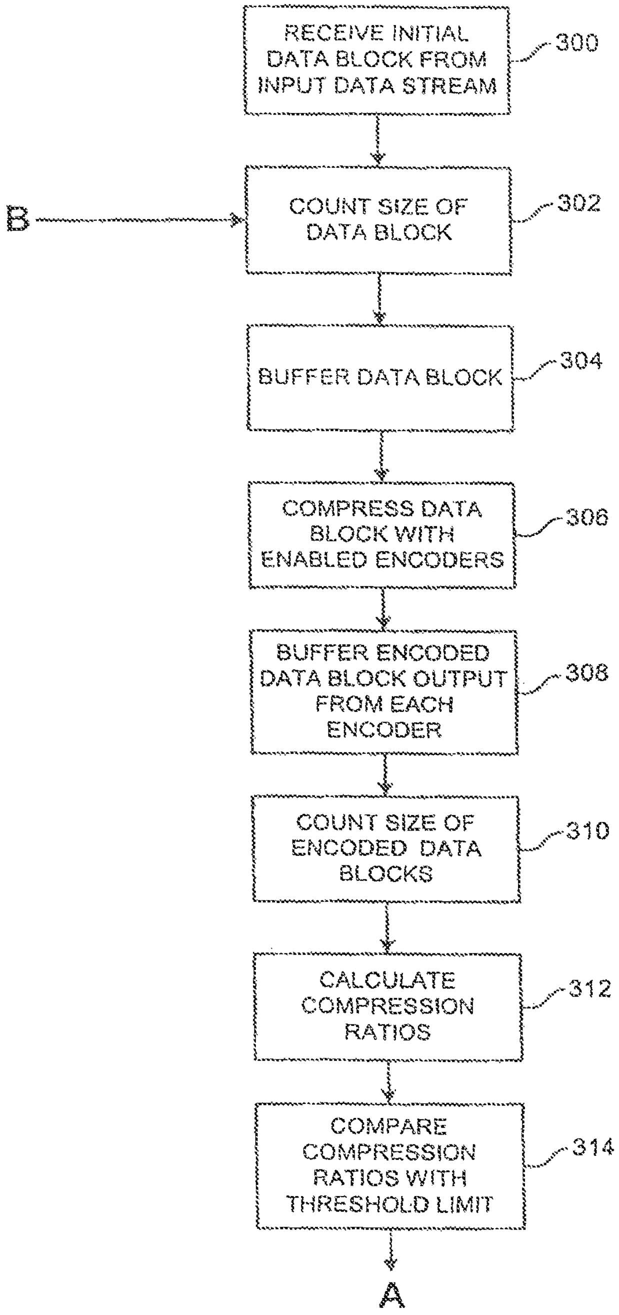
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 2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300
B
COUNT SIZE OF DATA BLOCK
302
BUFFER DATA BLOCK
304
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
306
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
308
COUNT SIZE OF ENCODED DATA BLOCKS
310
CALCULATE COMPRESSION RATIOS
312
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
314
A

FIG. 3a

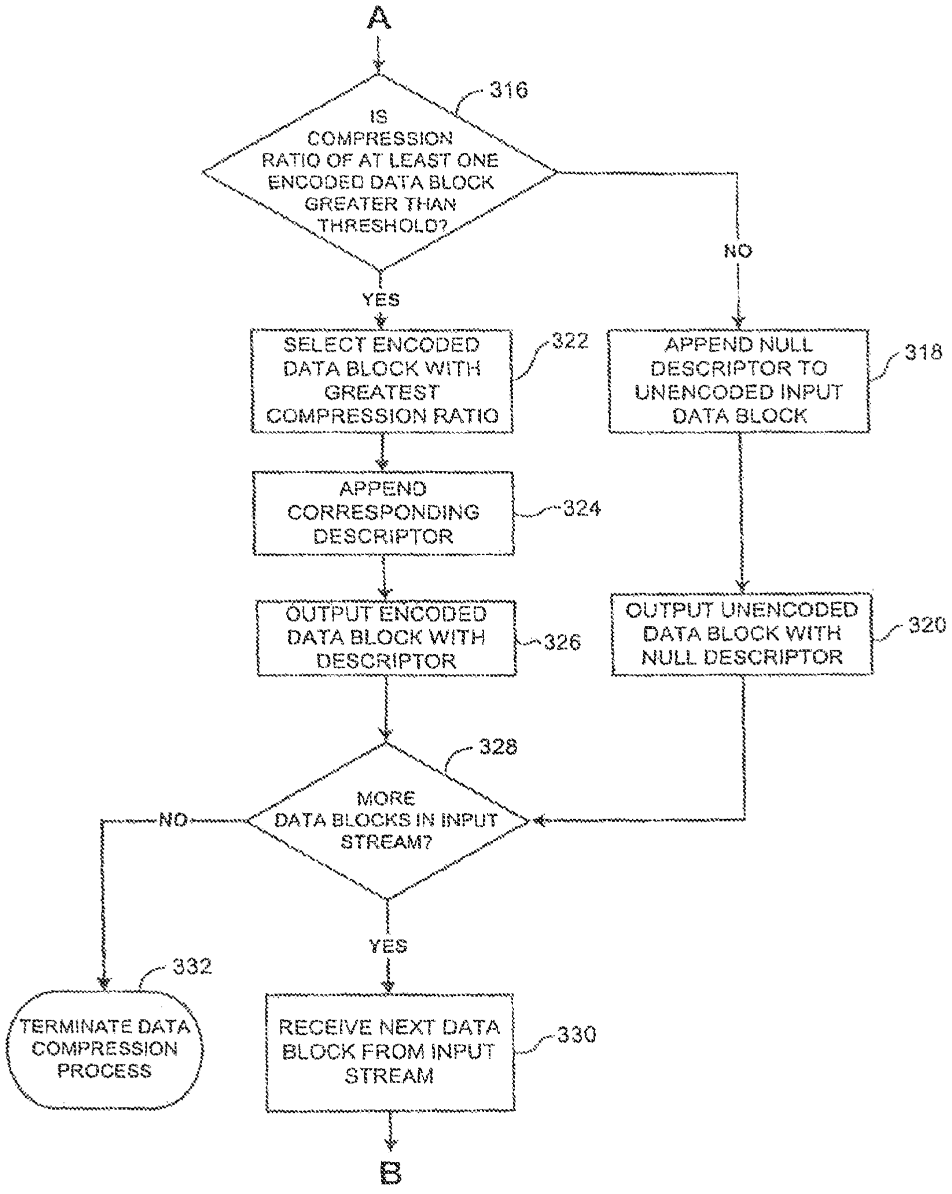
A
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
316
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
322
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
318
APPEND CORRESPONDING DESCRIPTOR
324
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
326
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
320
MORE DATA BLOCKS IN INPUT STREAM?
328
NO
YES
TERMINATE DATA COMPRESSION PROCESS
332
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
330
B

FIG. 3b

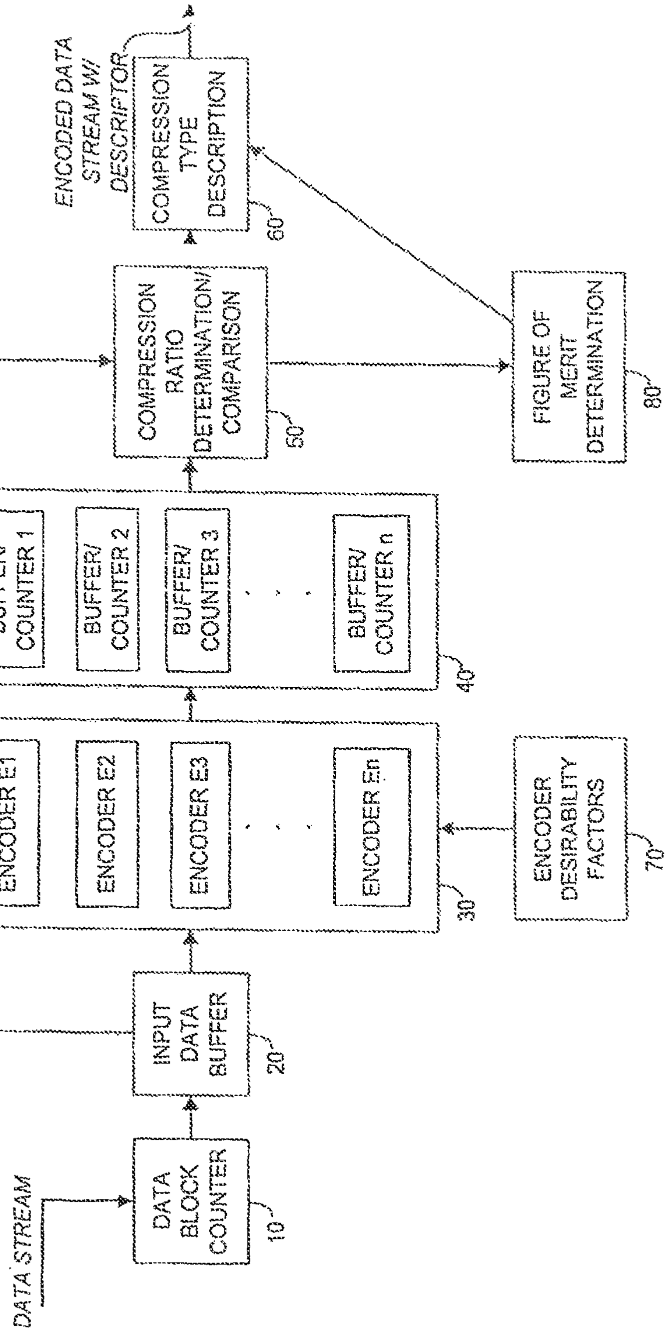
DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 4

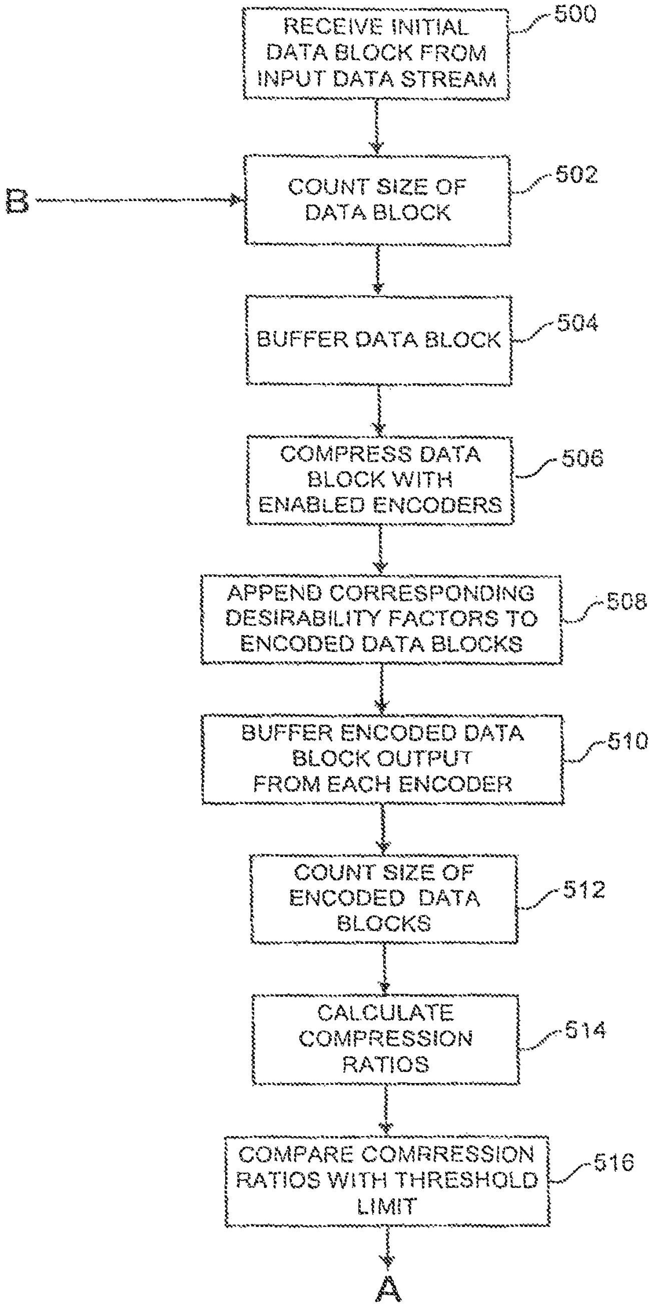
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
500
B
COUNT SIZE OF DATA BLOCK
502
BUFFER DATA BLOCK
504
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
506
APPEND CORRESPONDING DESIRABILITY FACTORS TO ENCODED DATA BLOCKS
508
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
510
COUNT SIZE OF ENCODED DATA BLOCKS
512
CALCULATE COMPRESSION RATIOS
514
COMPARE COMRRESSION RATIOS WITH THRESHOLD LIMIT
516
A

FIG. 5a

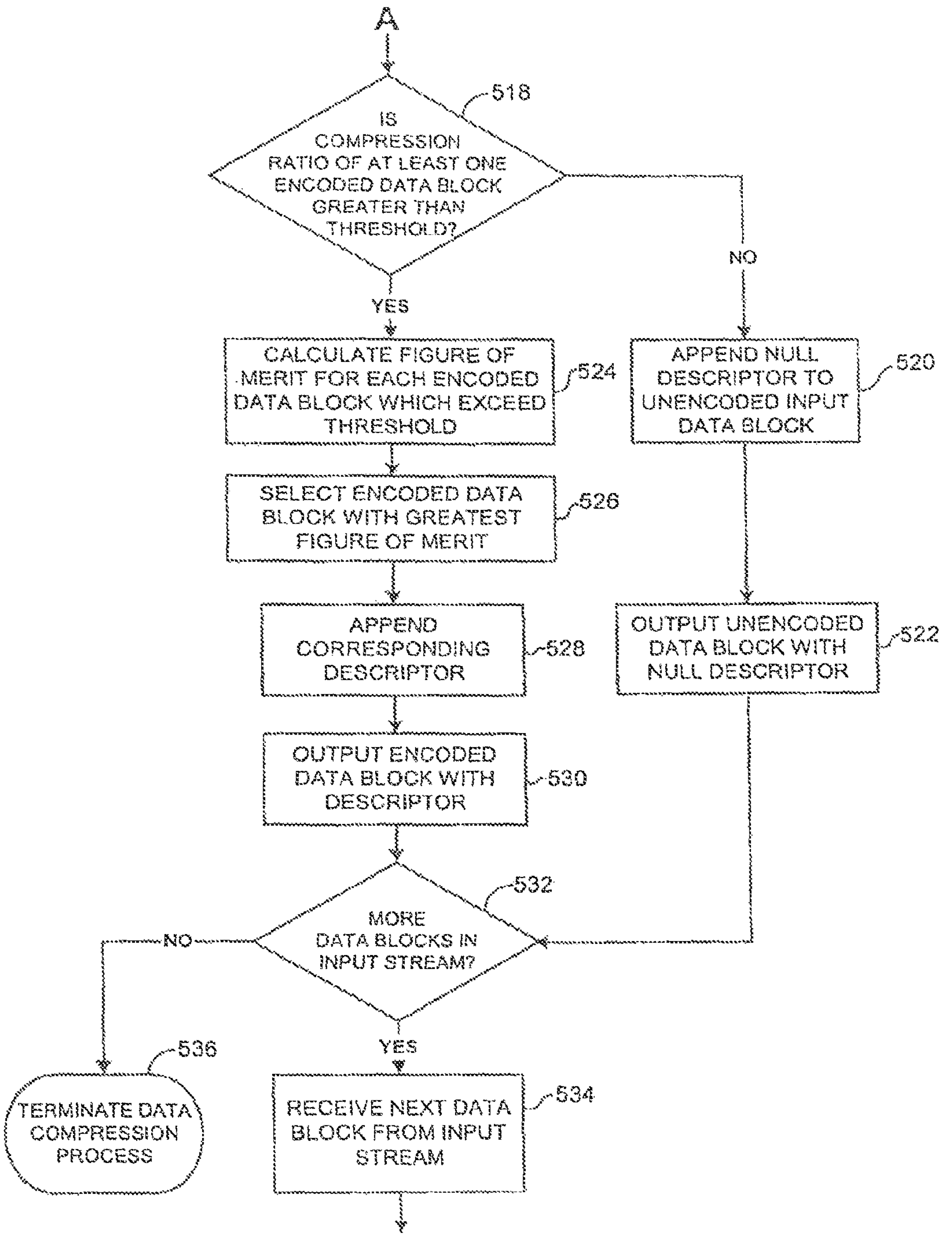
A
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
518
NO
YES
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
524
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
520
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
526
APPEND CORRESPONDING DESCRIPTOR
528
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
522
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
530
MORE DATA BLOCKS IN INPUT STREAM?
532
NO
YES
TERMINATE DATA COMPRESSION PROCESS
536
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
534
B

FIG. 5b

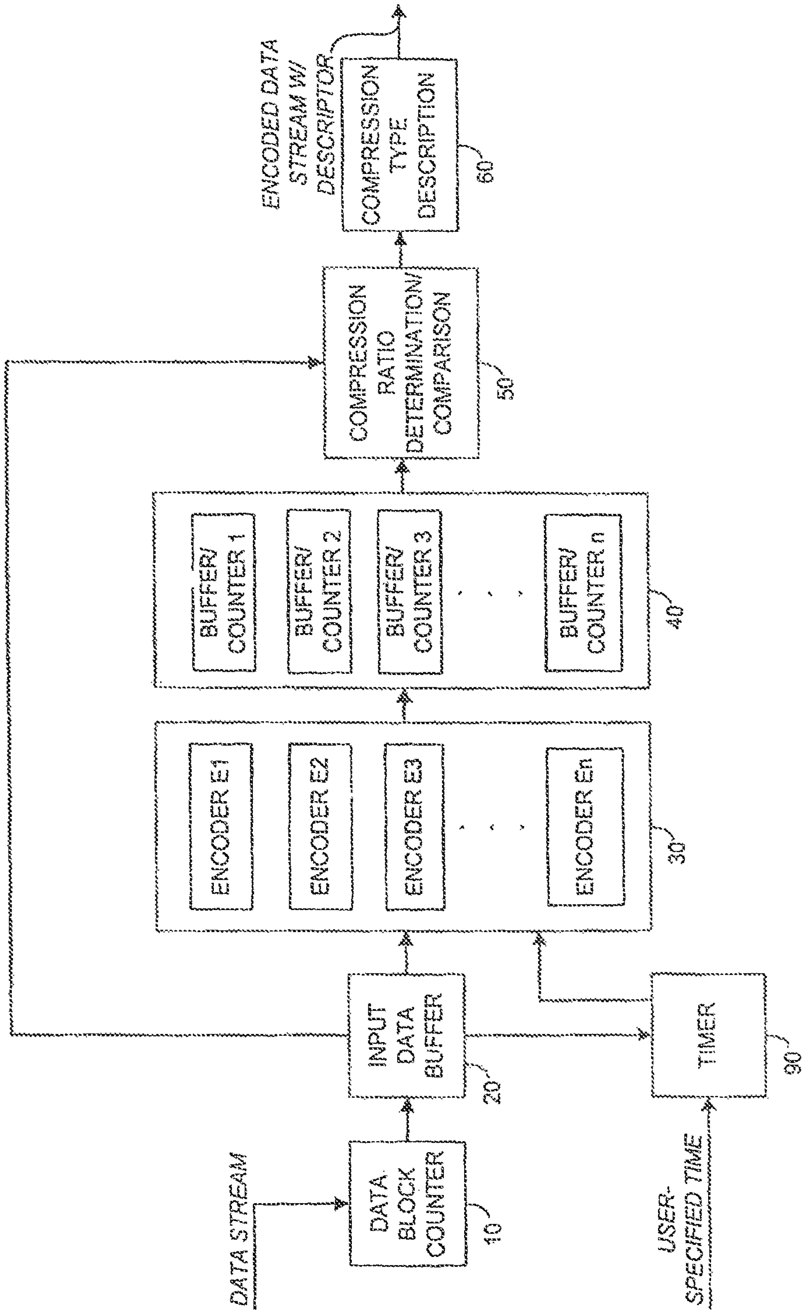
DATA STREAM
DATA BLOCK COUNTER
10
USER-SPECIFIED TIME
INPUT DATA BUFFER
20
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
. . .
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
. . .
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 6

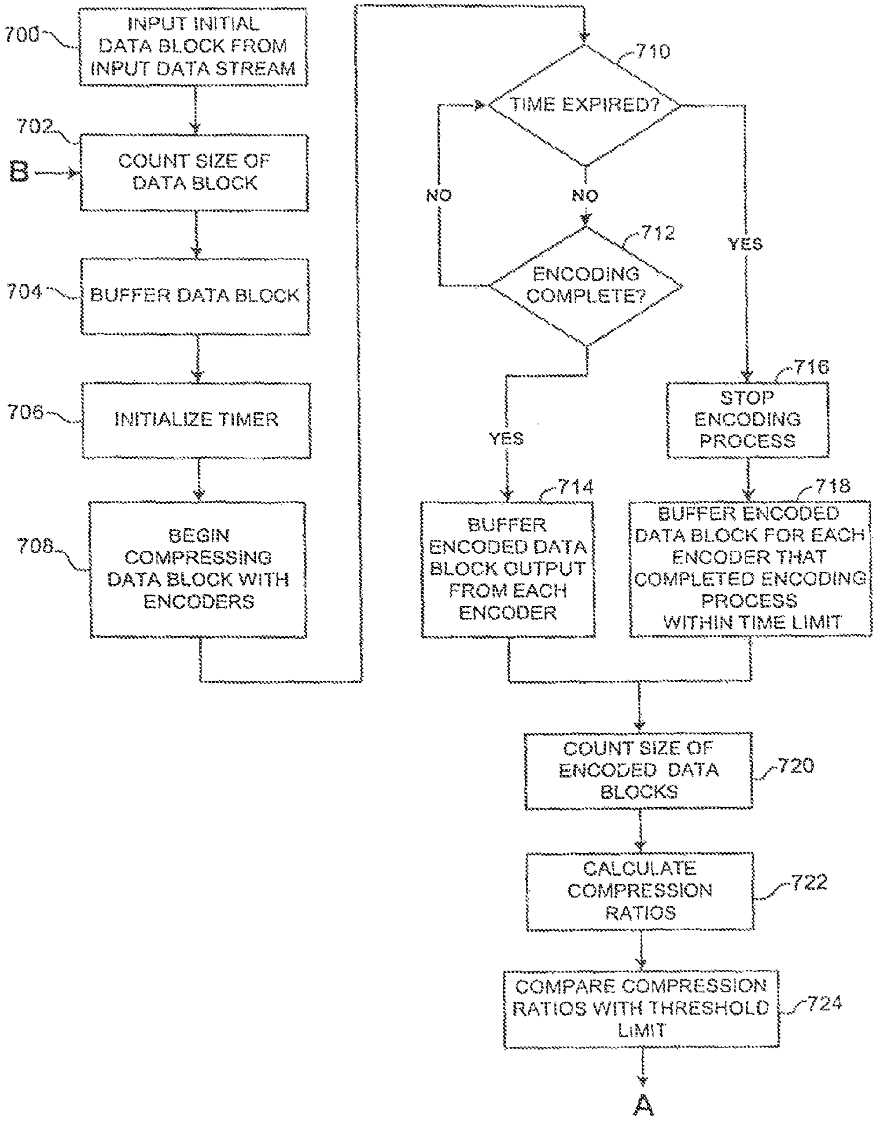
700
INPUT INITIAL DATA BLOCK FROM INPUT DATA STREAM
702
B
COUNT SIZE OF DATA BLOCK
704
BUFFER DATA BLOCK
706
INITIALIZE TIMER
708
BEGIN COMPRESSING DATA BLOCK WITH ENCODERS
710
TIME EXPIRED?
NO
NO
712
ENCODING COMPLETE?
YES
YES
716
STOP ENCODING PROCESS
714
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
718
BUFFER ENCODED DATA BLOCK FOR EACH ENCODER THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
COUNT SIZE OF ENCODED DATA BLOCKS
720
CALCULATE COMPRESSION RATIOS
722
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
724
A

FIG. 7a

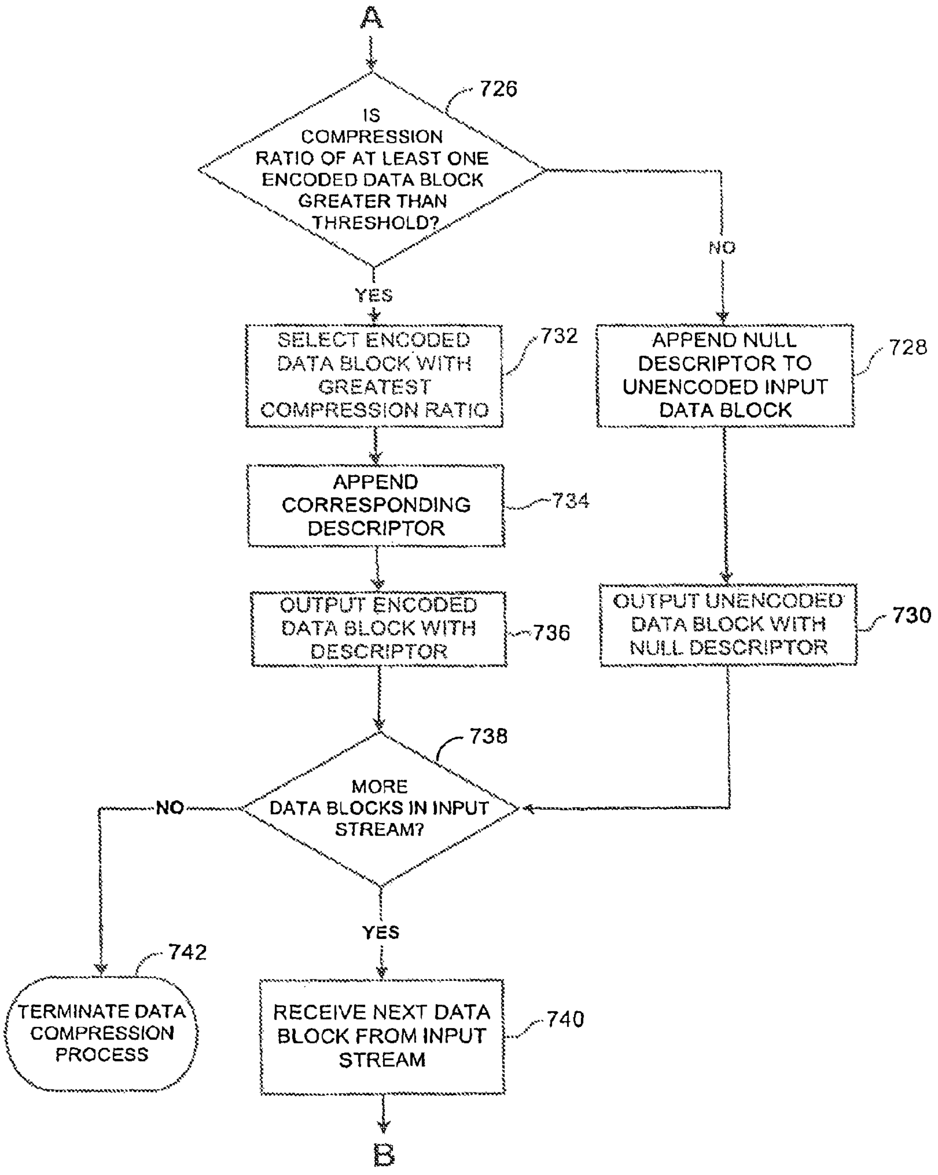
A
726
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
732
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
728
APPEND CORRESPONDING DESCRIPTOR
734
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
736
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
730
738
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
742
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
740
B

FIG. 7b

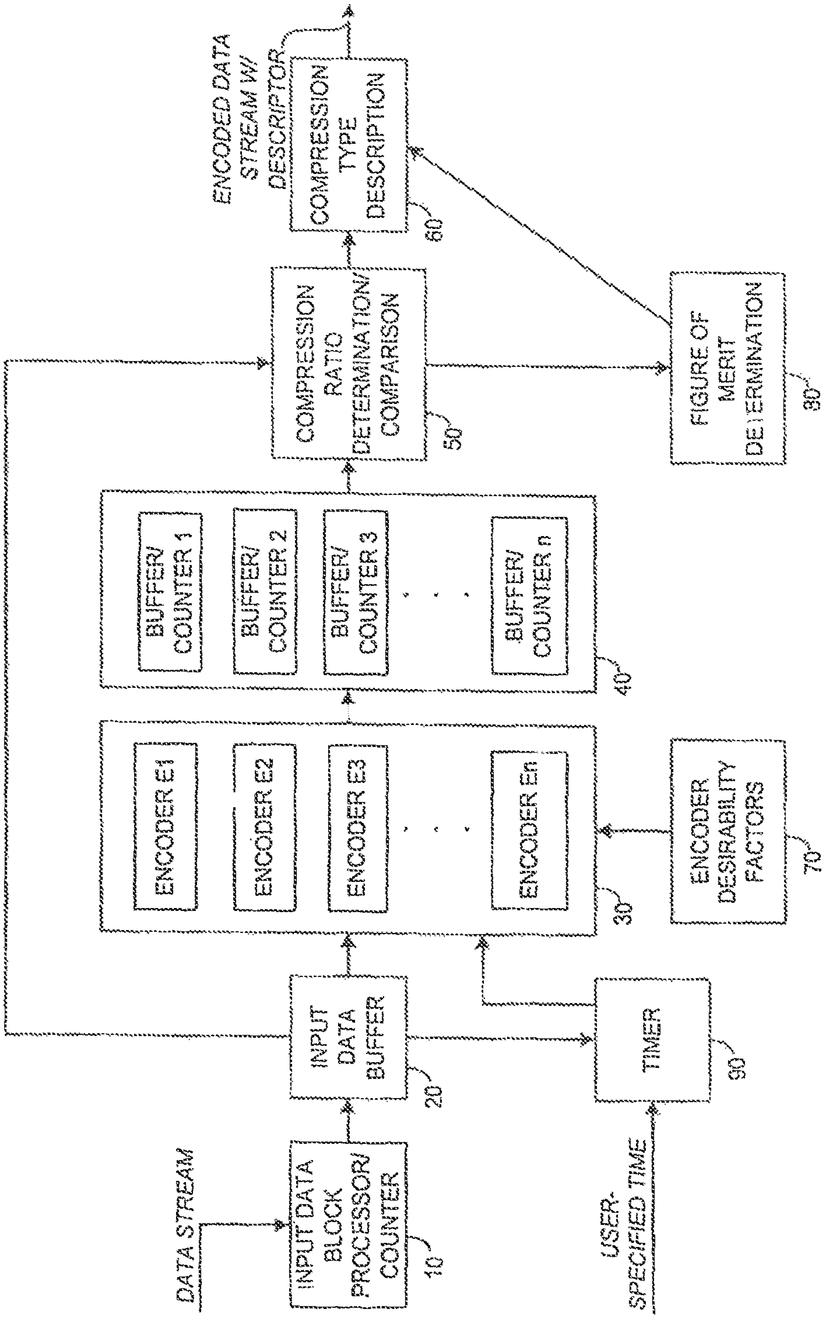
DATA STREAM
INPUT DATA BLOCK PROCESSOR/ COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
. . .
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
. . .
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
90
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 8

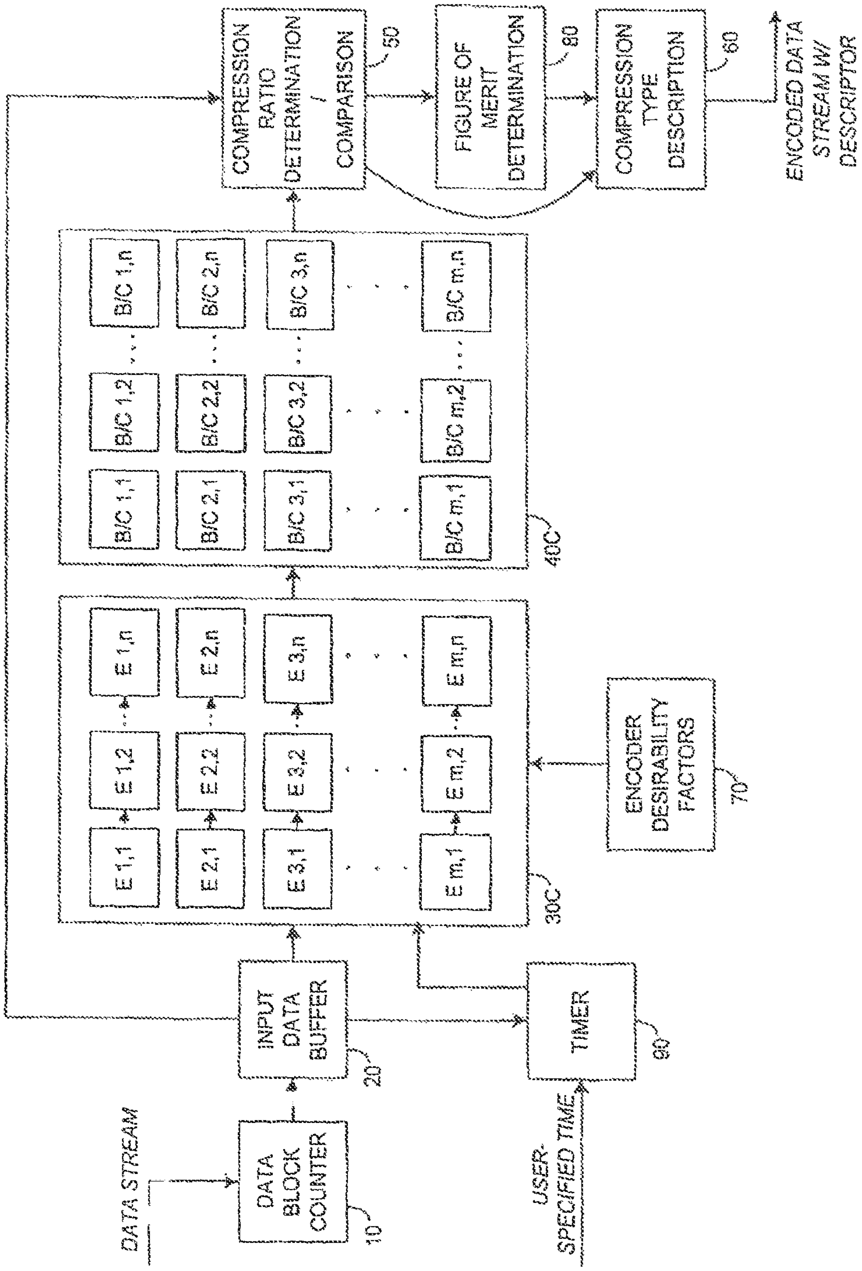
DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
E 1,1
E 1,2
E 1,n
E 2,1
E 2,2
E 2,n
E 3,1
E 3,2
E 3,n
E m,1
E m,2
E m,n
30C
ENCODER DESIRABILITY FACTORS
70
B/C 1,1
B/C 1,2
B/C 1,n
B/C 2,1
B/C 2,2
B/C 2,n
B/C 3,1
B/C 3,2
B/C 3,n
B/C m,1
B/C m,2
B/C m,n
40C
COMPRESSION RATIO DETERMINATION / COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 9

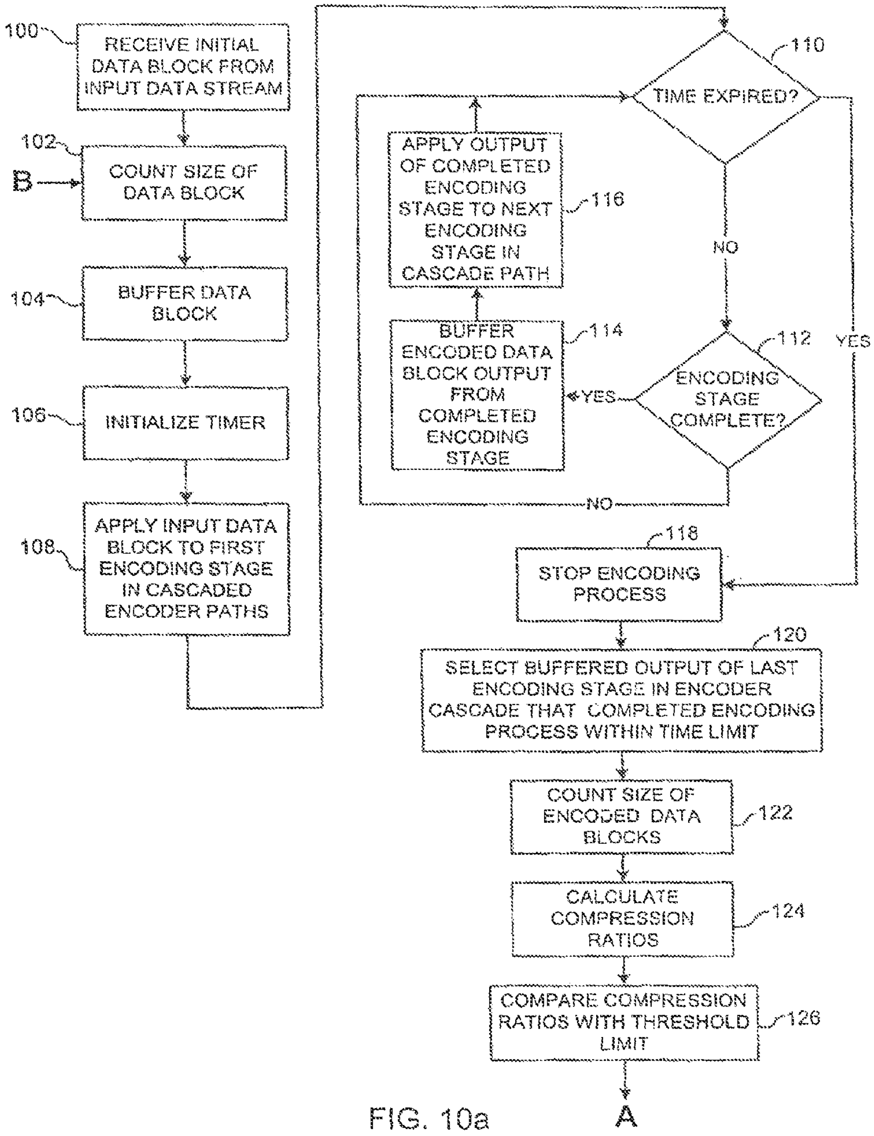
100
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
102
B
COUNT SIZE OF DATA BLOCK
104
BUFFER DATA BLOCK
106
INITIALIZE TIMER
108
APPLY INPUT DATA BLOCK TO FIRST ENCODING STAGE IN CASCADED ENCODER PATHS
110
TIME EXPIRED?
NO
YES
116
APPLY OUTPUT OF COMPLETED ENCODING STAGE TO NEXT ENCODING STAGE IN CASCADE PATH
114
BUFFER ENCODED DATA BLOCK OUTPUT FROM COMPLETED ENCODING STAGE
112
ENCODING STAGE COMPLETE?
YES
NO
118
STOP ENCODING PROCESS
120
SELECT BUFFERED OUTPUT OF LAST ENCODING STAGE IN ENCODER CASCADE THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
122
COUNT SIZE OF ENCODED DATA BLOCKS
124
CALCULATE COMPRESSION RATIOS
126
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
A

FIG. 10a

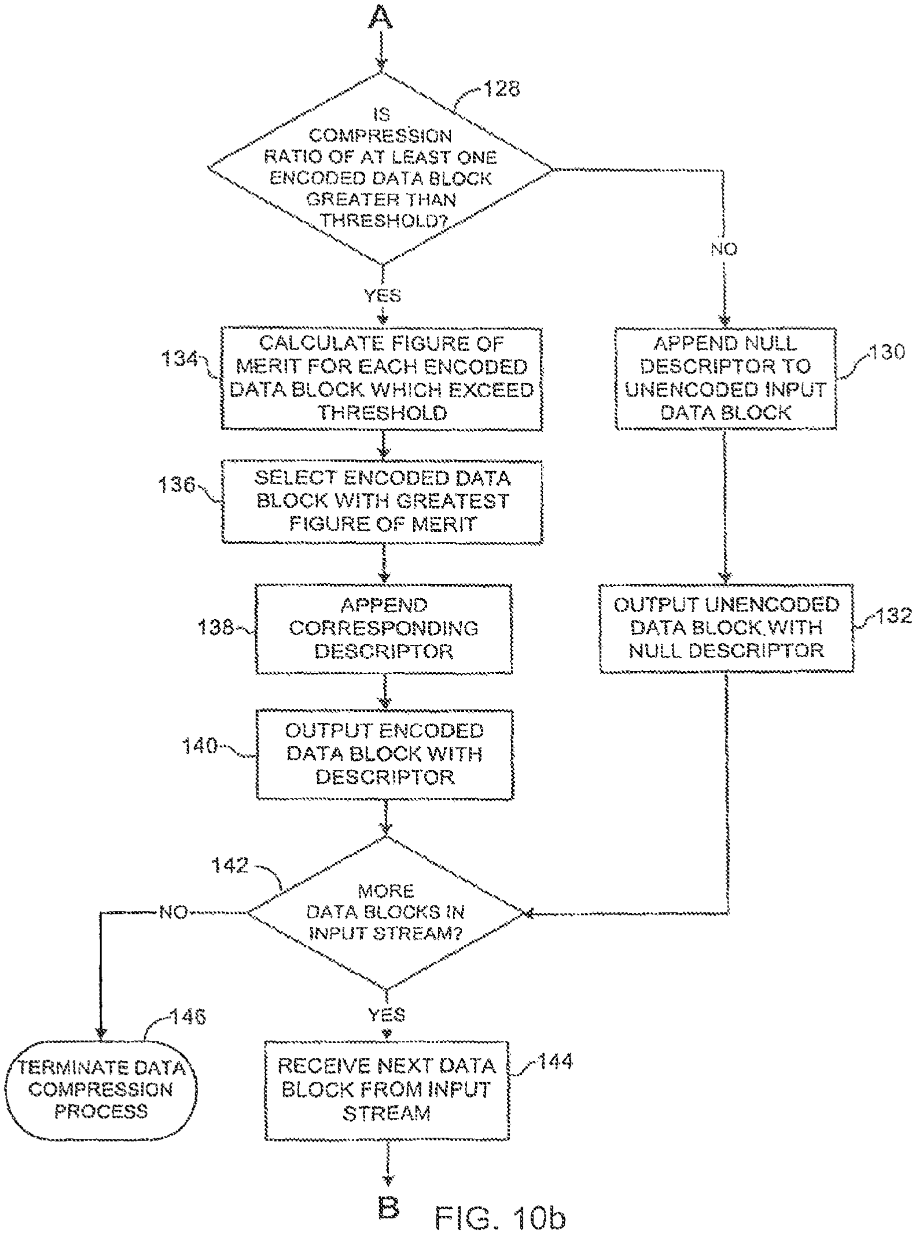
A
128
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
134
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
130
136
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
138
APPEND CORRESPONDING DESCRIPTOR
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
132
140
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
142
NO
MORE DATA BLOCKS IN INPUT STREAM?
YES
146
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
144
B

FIG. 10b

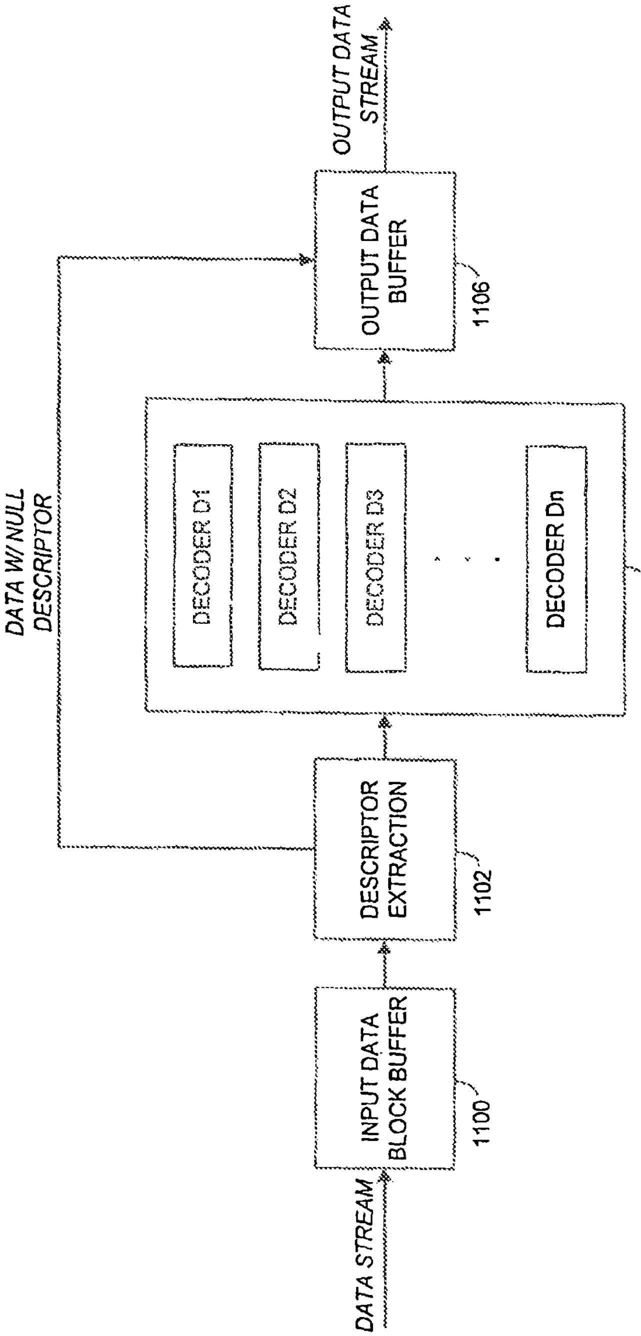
DATA STREAM
INPUT DATA BLOCK BUFFER
1100
DESCRIPTOR EXTRACTION
1102
DATA W/ NULL DESCRIPTOR
DECODER D1
DECODER D2
DECODER D3
. . .
DECODER Dn
1104
OUTPUT DATA BUFFER
1106
OUTPUT DATA STREAM

FIG. 11

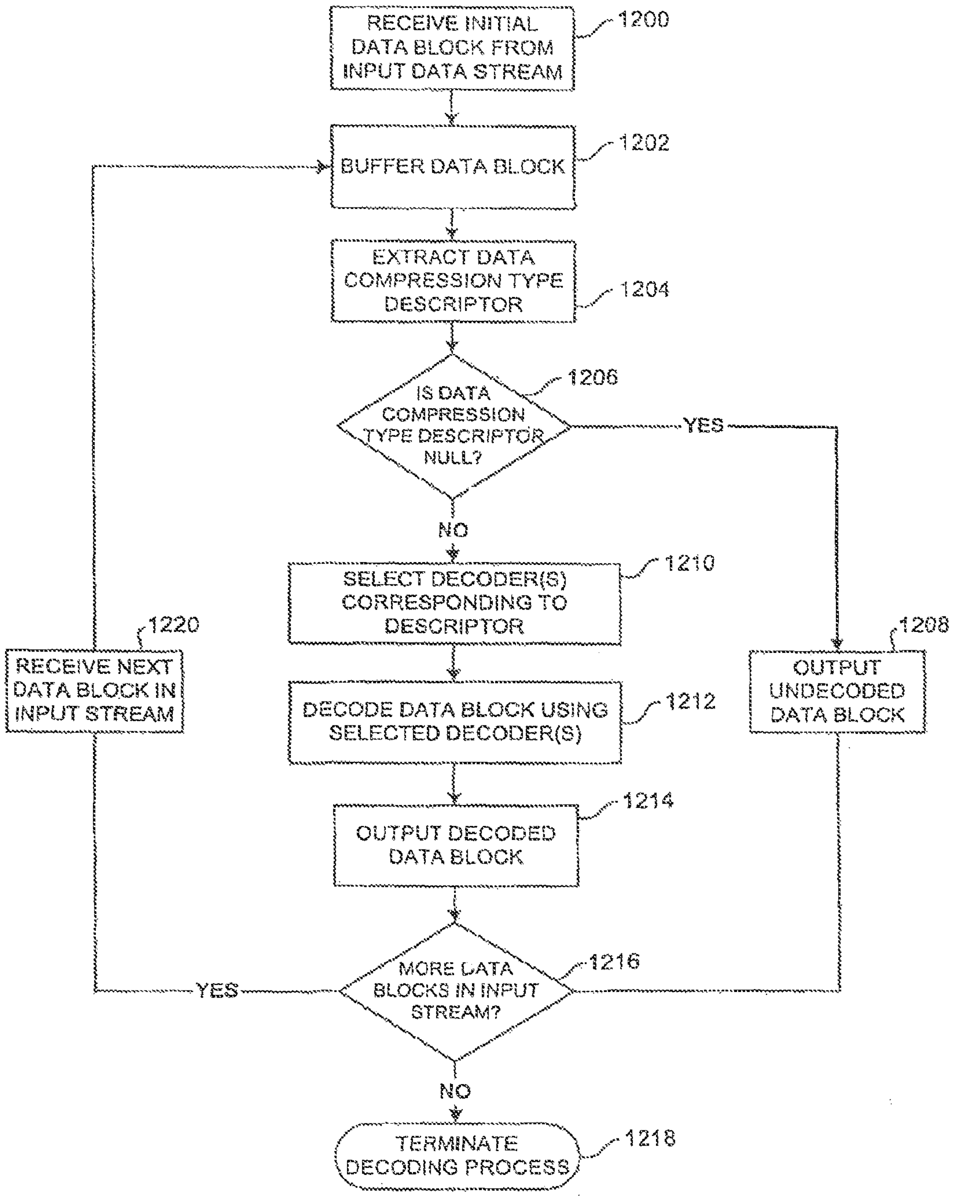
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
1200
BUFFER DATA BLOCK
1202
EXTRACT DATA COMPRESSION TYPE DESCRIPTOR
1204
IS DATA COMPRESSION TYPE DESCRIPTOR NULL?
1206
YES
NO
SELECT DECODER(S) CORRESPONDING TO DESCRIPTOR
1210
RECEIVE NEXT DATA BLOCK IN INPUT STREAM
1220
OUTPUT UNDECODED DATA BLOCK
1208
DECODE DATA BLOCK USING SELECTED DECODER(S)
1212
OUTPUT DECODED DATA BLOCK
1214
MORE DATA BLOCKS IN INPUT STREAM?
1216
YES
NO
TERMINATE DECODING PROCESS
1218

FIG. 12

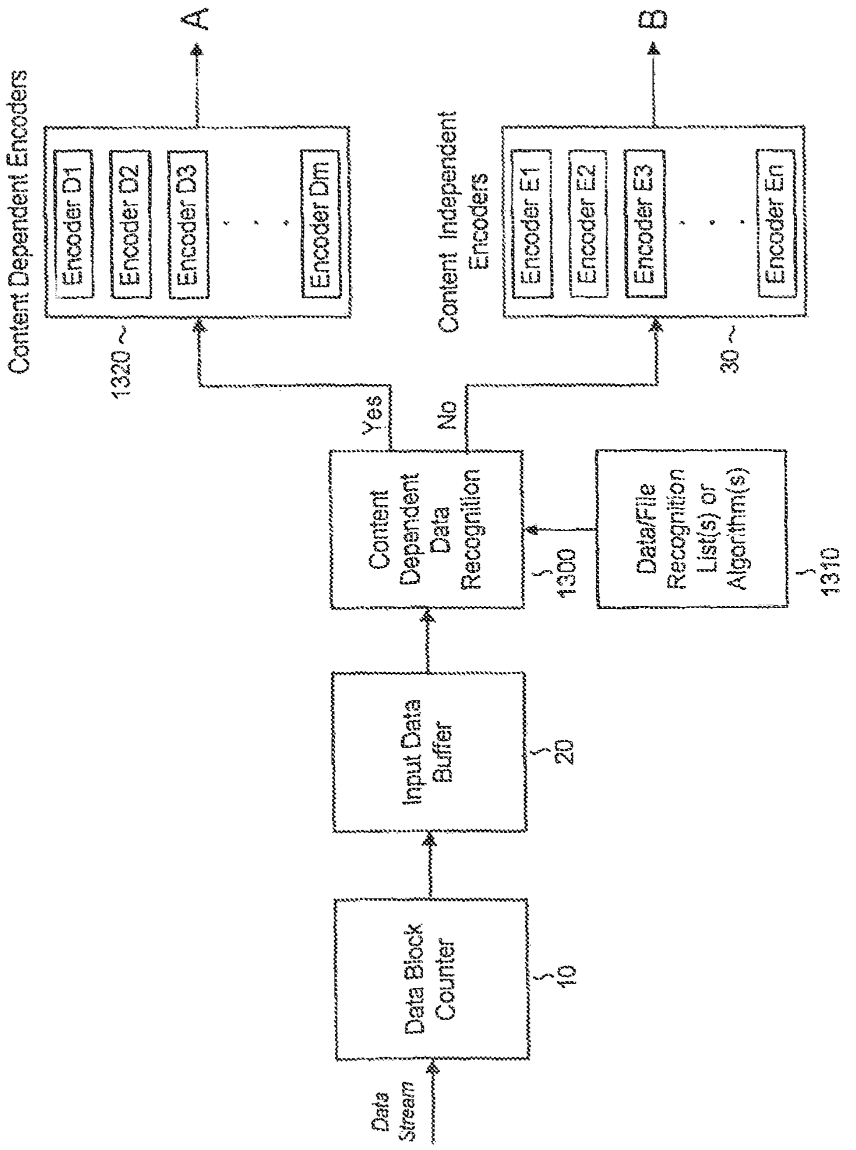
Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
. . .
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
. . .
Encoder En
B

FIGURE 13A

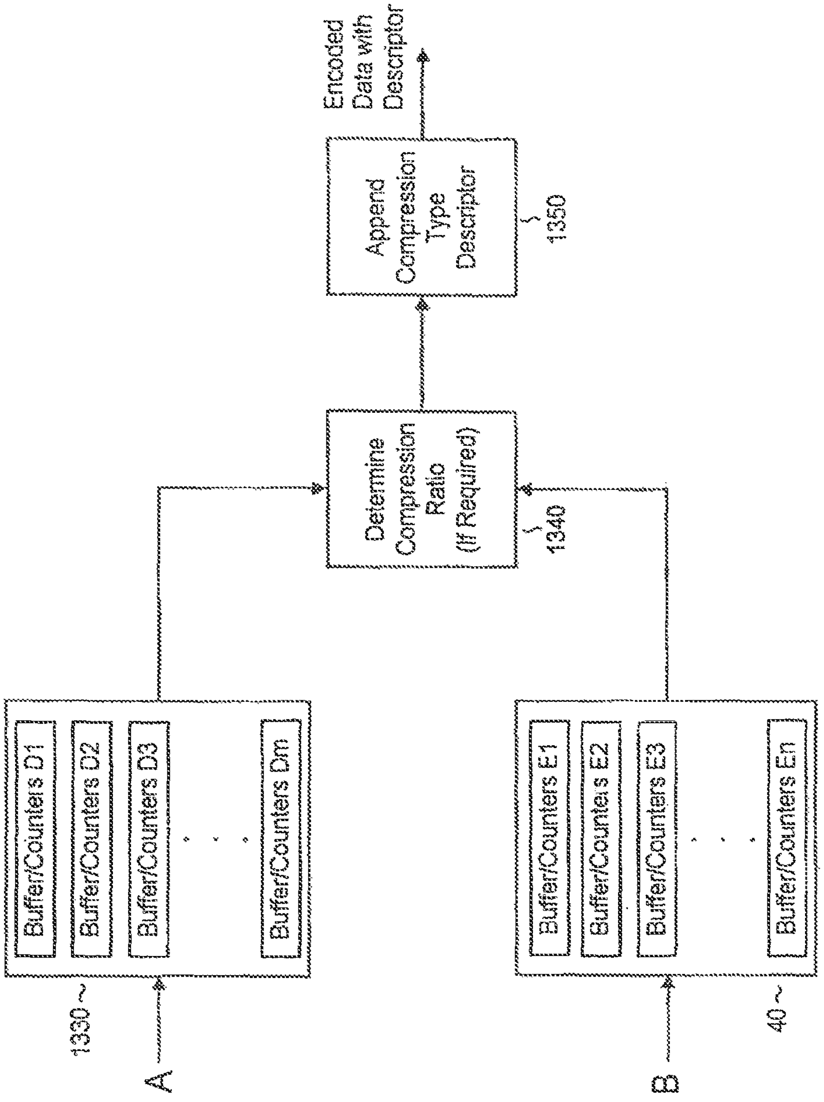
A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
. . .
Buffer/Counters Dm
B
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
. . .
Buffer/Counters En
Determine Compression Ratio (If Required)
1340
Append Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 13B

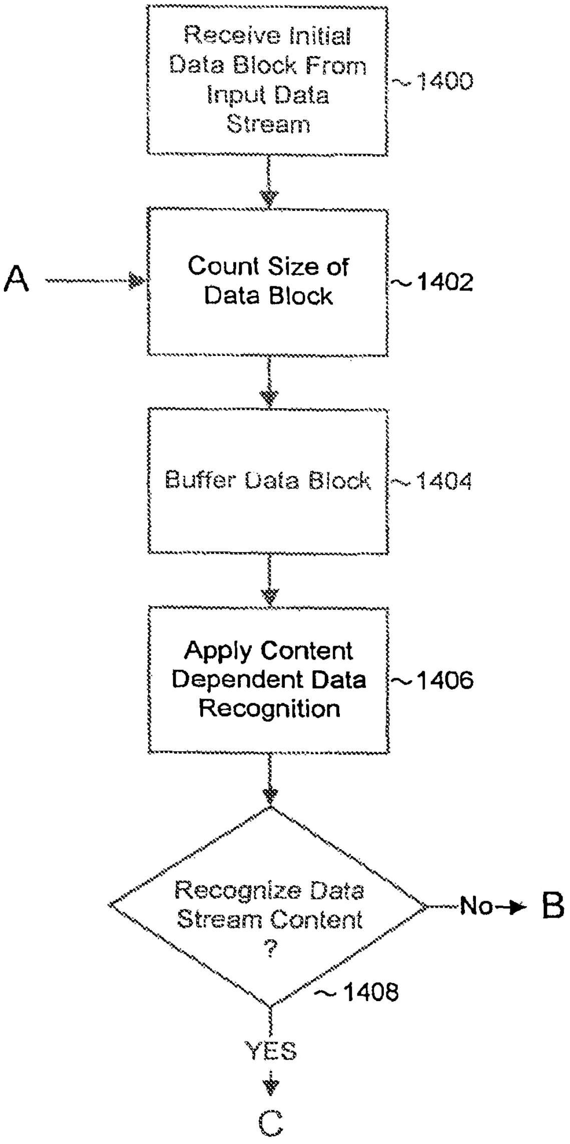
Receive Initial Data Block From Input Data Stream
1400
A
Count Size of Data Block
1402
Buffer Data Block
1404
Apply Content Dependent Data Recognition
1406
Recognize Data Stream Content ?
No
B
1408
YES
C

FIGURE 14A

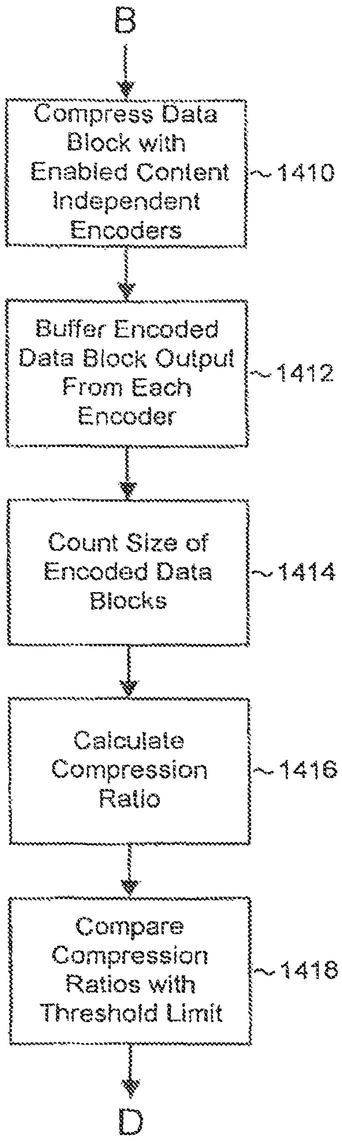
B
Compress Data Block with Enabled Content Independent Encoders
1410
Buffer Encoded Data Block Output From Each Encoder
1412
Count Size of Encoded Data Blocks
1414
Calculate Compression Ratio
1416
Compare Compression Ratios with Threshold Limit
1418
D

FIGURE 14B

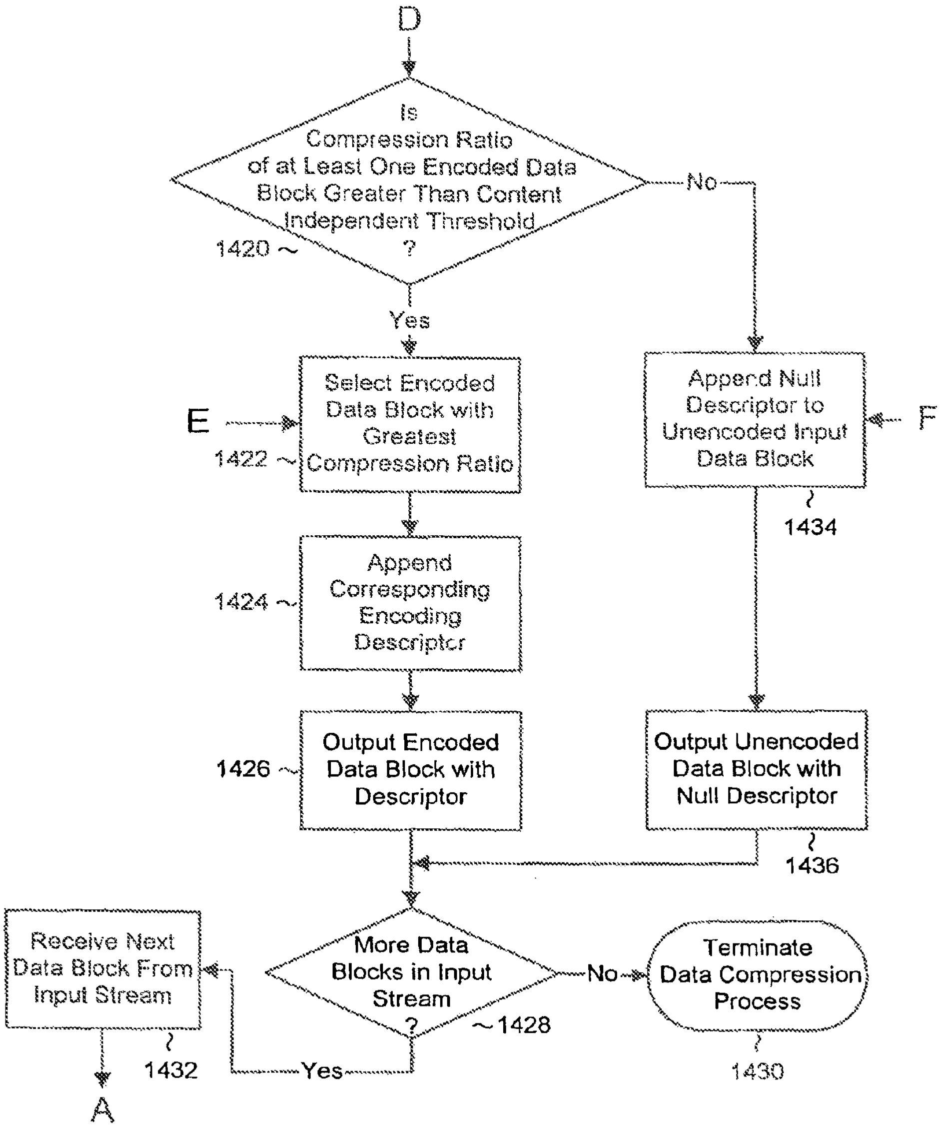
D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1420
No
Yes
E
Select Encoded Data Block with Greatest Compression Ratio
1422
Append Null Descriptor to Unencoded Input Data Block
F
1434
Append Corresponding Encoding Descriptor
1424
Output Encoded Data Block with Descriptor
1426
Output Unencoded Data Block with Null Descriptor
1436
Receive Next Data Block From Input Stream
1432
A
More Data Blocks in Input Stream ?
1428
Yes
No
Terminate Data Compression Process
1430

FIGURE 14C

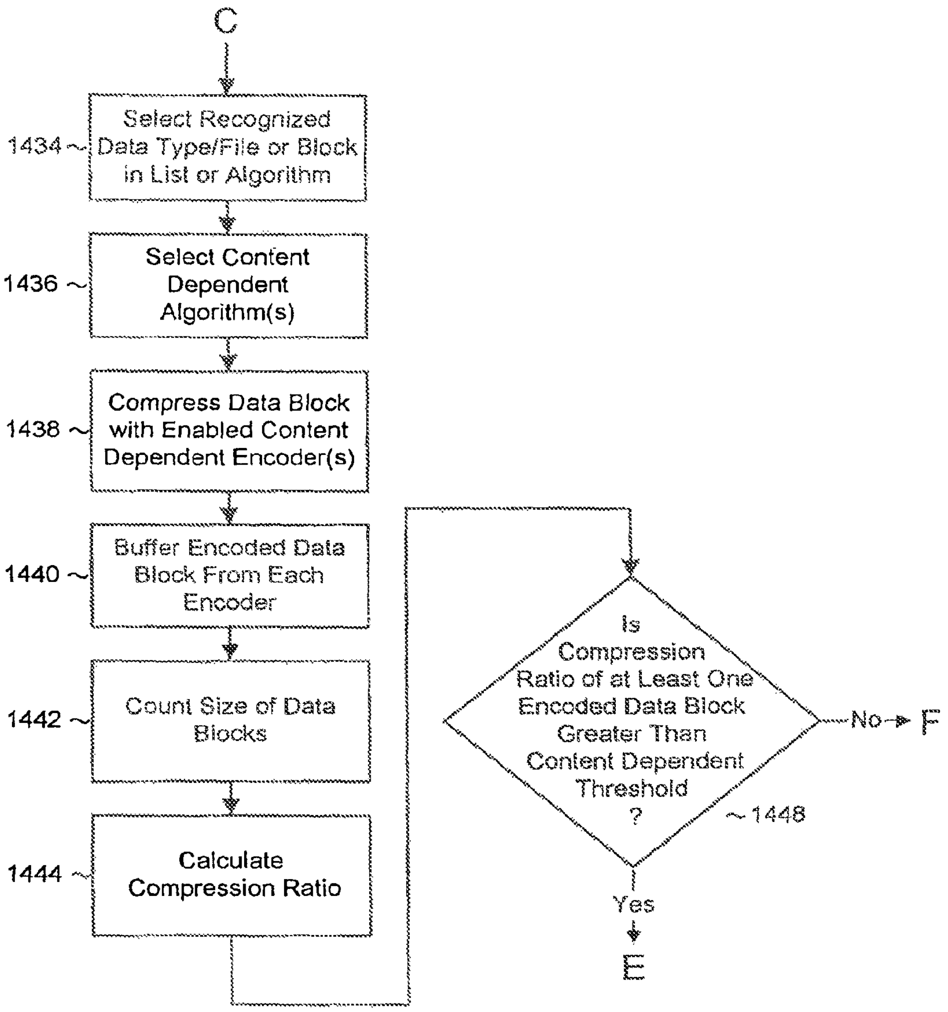
C
1434
Select Recognized Data Type/File or Block in List or Algorithm
1436
Select Content Dependent Algorithm(s)
1438
Compress Data Block with Enabled Content Dependent Encoder(s)
1440
Buffer Encoded Data Block From Each Encoder
1442
Count Size of Data Blocks
1444
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1448
No
F
Yes
E

FIGURE 14D

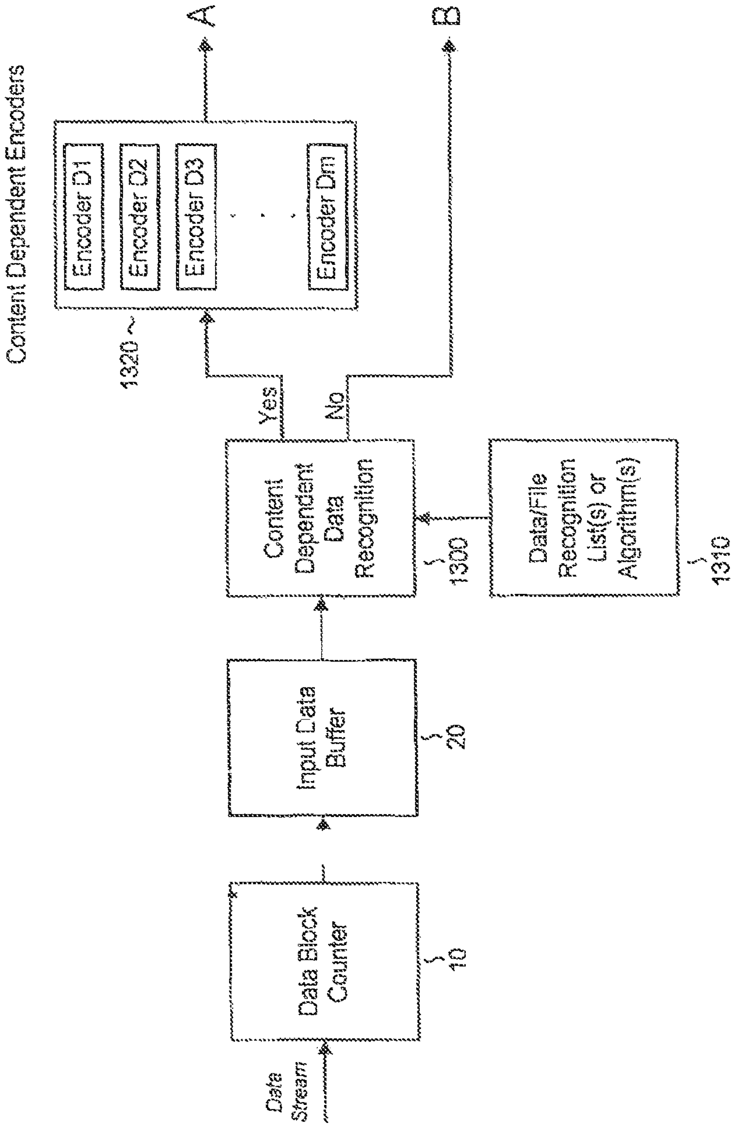
Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
. . .
Encoder Dm
A
B

FIGURE 15A

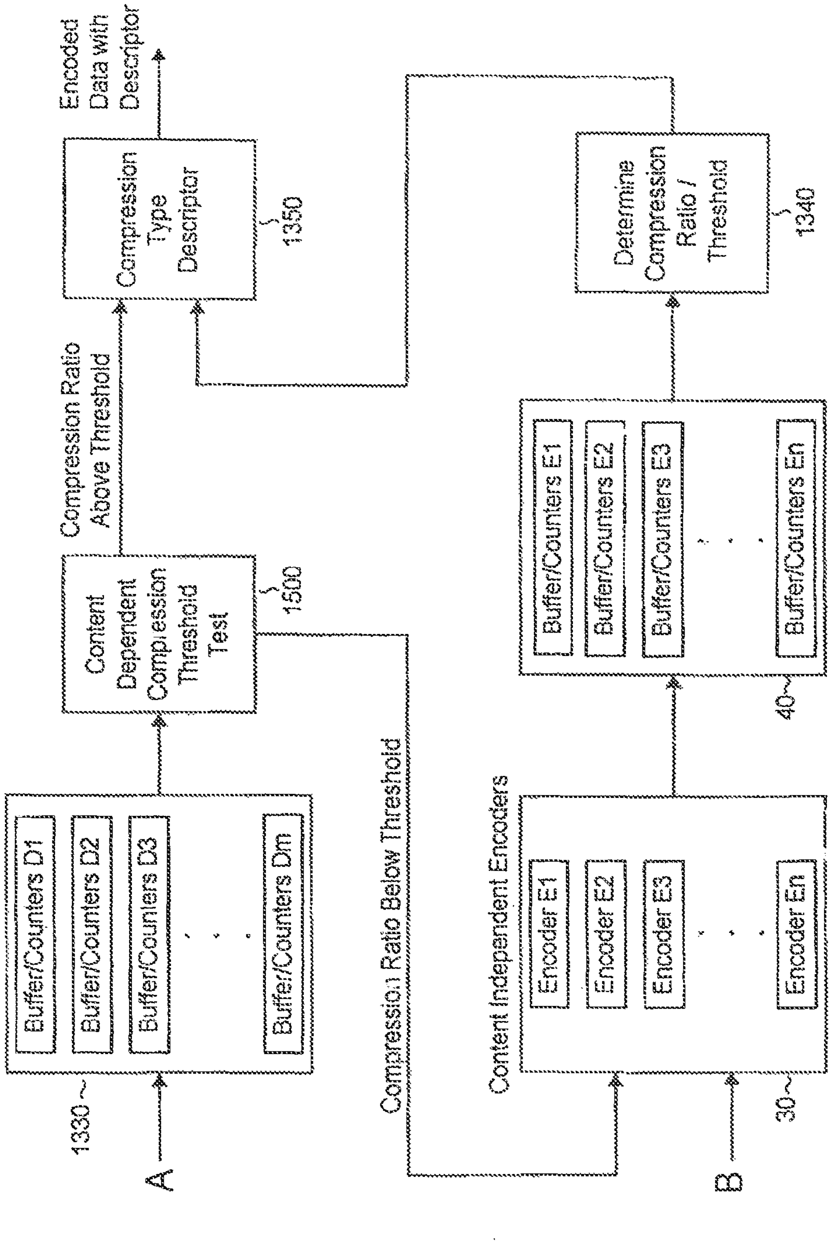
A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
Content Dependent Compression Threshold Test
1500
Compression Ratio Above Threshold
Compression Type Descriptor
1350
Encoded Data with Descriptor
Compression Ratio Below Threshold
B
30
Content Independent Encoders
Encoder E1
Encoder E2
Encoder E3
Encoder En
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio / Threshold
1340

FIGURE 15B

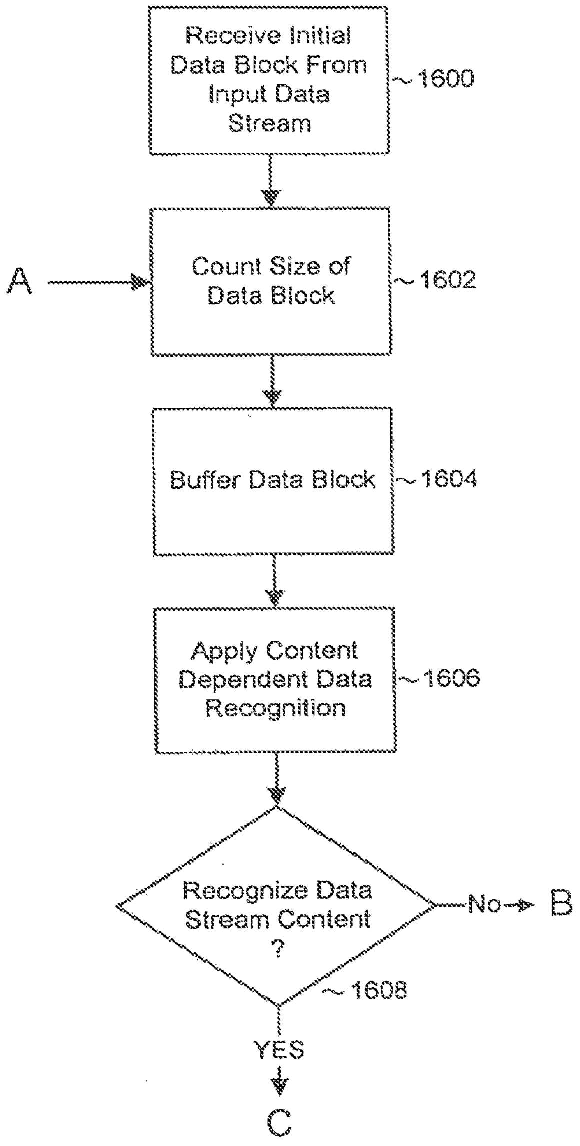
Receive Initial Data Block From Input Data Stream
1600
A
Count Size of Data Block
1602
Buffer Data Block
1604
Apply Content Dependent Data Recognition
1606
Recognize Data Stream Content ?
1608
No
B
YES
C

FIGURE 16A

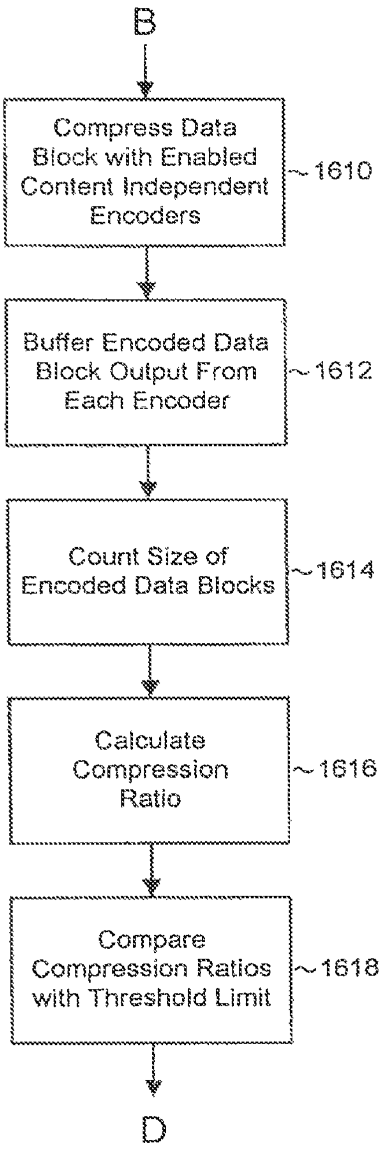
B
Compress Data Block with Enabled Content Independent Encoders
1610
Buffer Encoded Data Block Output From Each Encoder
1612
Count Size of Encoded Data Blocks
1614
Calculate Compression Ratio
1616
Compare Compression Ratios with Threshold Limit
1618
D

FIGURE 16B

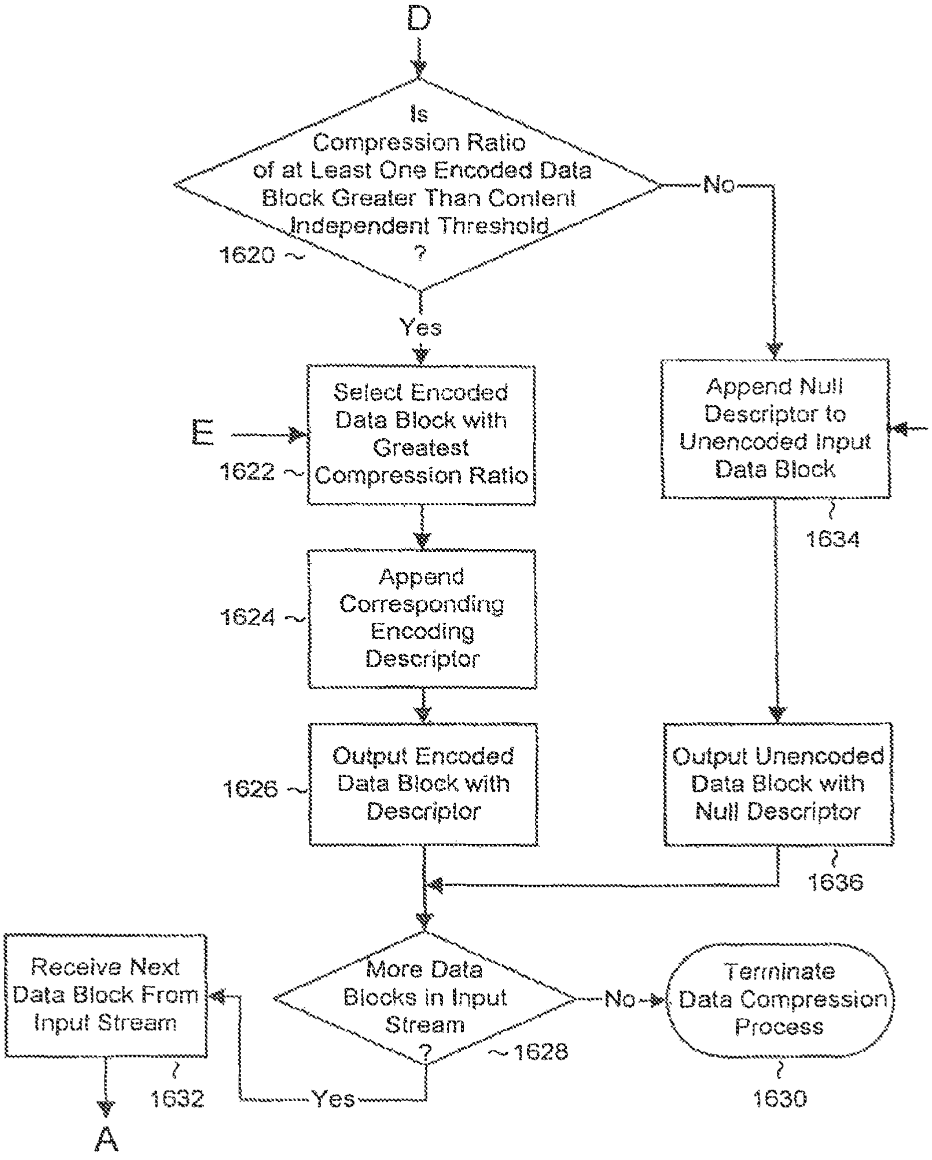
D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1620
No
Yes
E
Select Encoded Data Block with Greatest Compression Ratio
1622
Append Null Descriptor to Unencoded Input Data Block
F
1634
Append Corresponding Encoding Descriptor
1624
Output Encoded Data Block with Descriptor
1626
Output Unencoded Data Block with Null Descriptor
1636
Receive Next Data Block From Input Stream
More Data Blocks in Input Stream ?
1628
No
Terminate Data Compression Process
1632
Yes
1630
A

FIGURE 16C

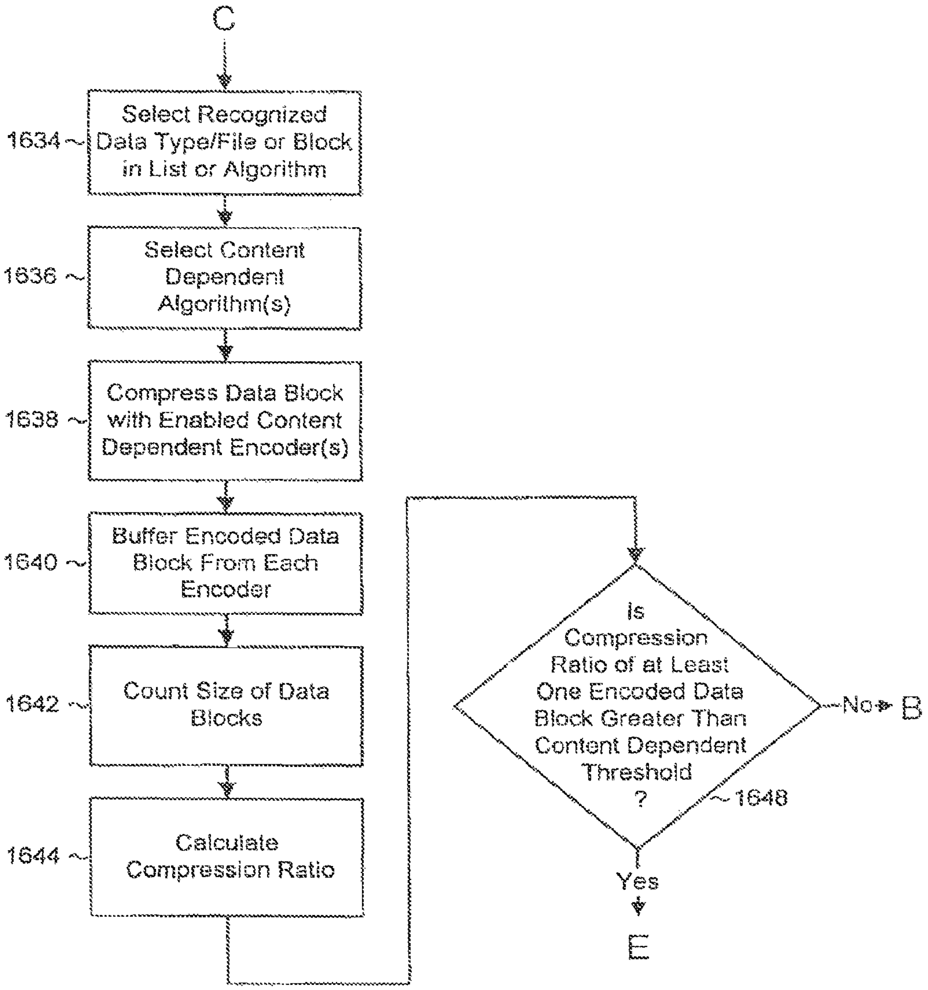
C
1634
Select Recognized Data Type/File or Block in List or Algorithm
1636
Select Content Dependent Algorithm(s)
1638
Compress Data Block with Enabled Content Dependent Encoder(s)
1640
Buffer Encoded Data Block From Each Encoder
1642
Count Size of Data Blocks
1644
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1648
No
B
Yes
E

FIGURE 16D

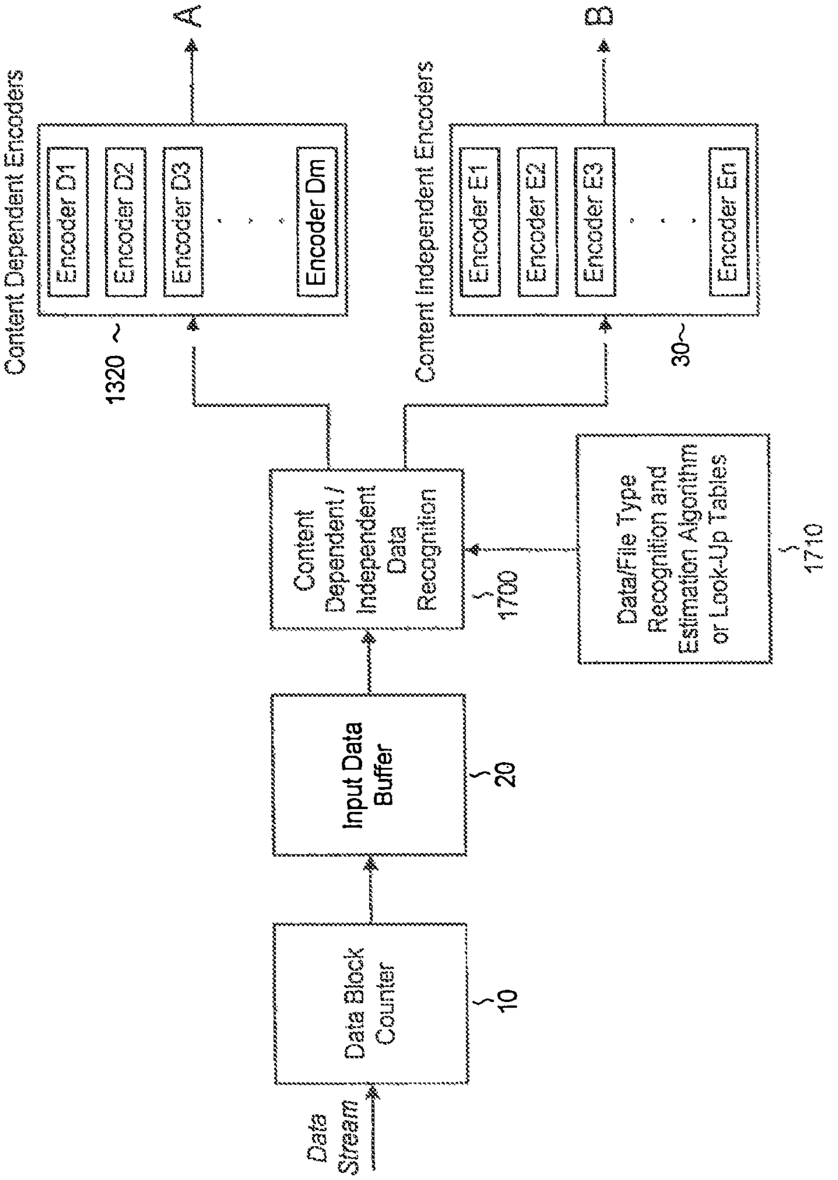
Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent / Independent Data Recognition
1700
Data/File Type Recognition and Estimation Algorithm or Look-Up Tables
1710
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
Encoder En
B

FIGURE 17A

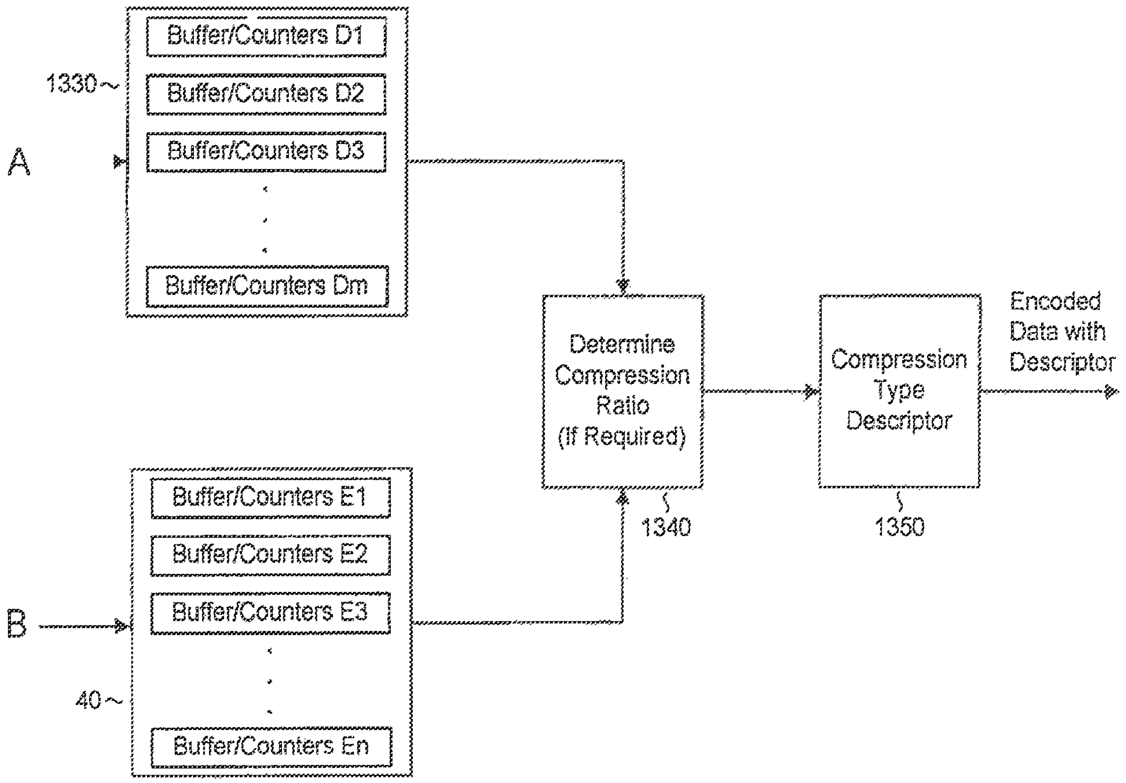
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
1330
A
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
B
40
Determine Compression Ratio (If Required)
1340
Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 17B

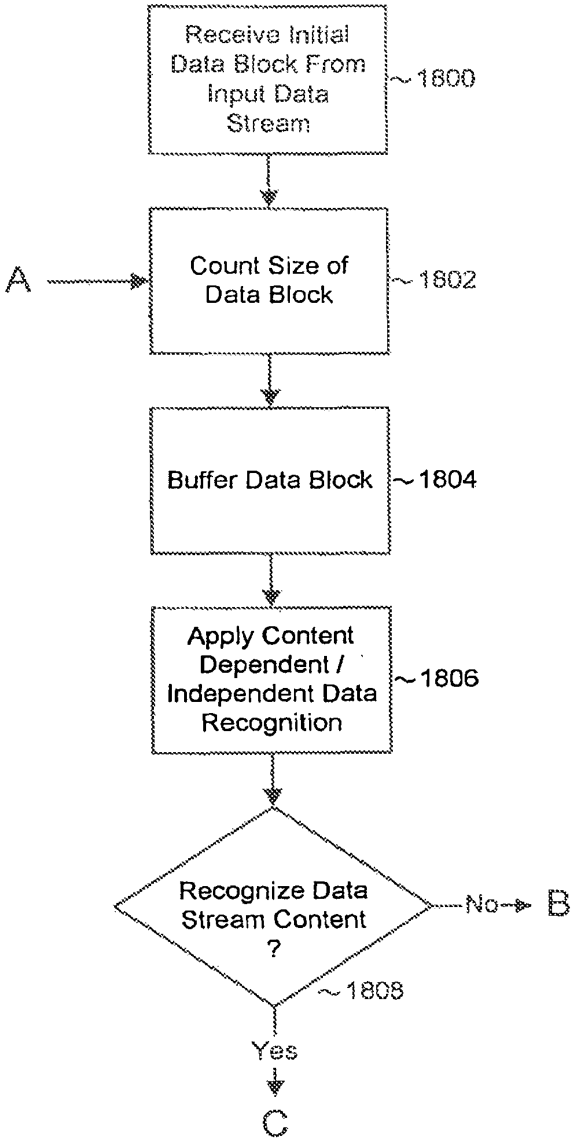
Receive Initial Data Block From Input Data Stream
1800
A
Count Size of Data Block
1802
Buffer Data Block
1804
Apply Content Dependent / Independent Data Recognition
1806
Recognize Data Stream Content ?
1808
No
B
Yes
C

FIGURE 18A

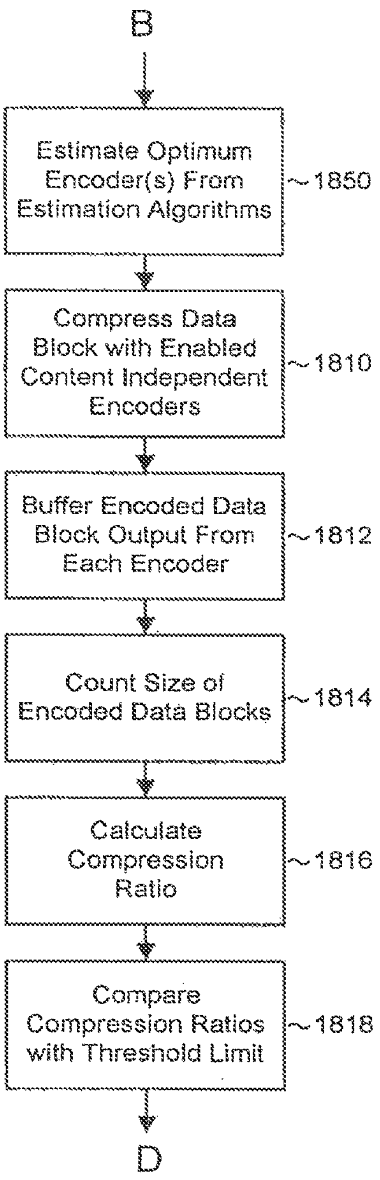
B
Estimate Optimum Encoder(s) From Estimation Algorithms
1850
Compress Data Block with Enabled Content Independent Encoders
1810
Buffer Encoded Data Block Output From Each Encoder
1812
Count Size of Encoded Data Blocks
1814
Calculate Compression Ratio
1816
Compare Compression Ratios with Threshold Limit
1818
D

FIGURE 18B

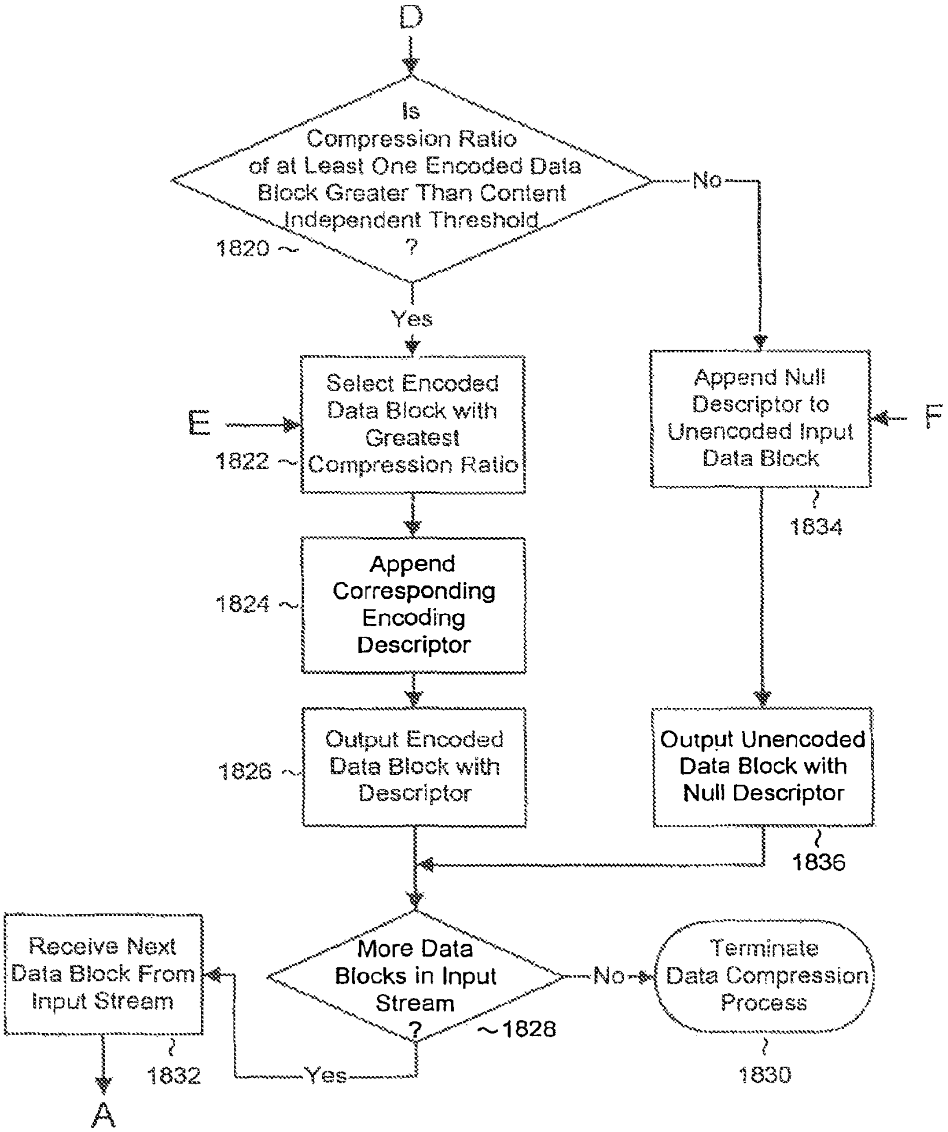
D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1820
No
Yes
E
Select Encoded Data Block with Greatest Compression Ratio
1822
Append Null Descriptor to Unencoded Input Data Block
F
1834
Append Corresponding Encoding Descriptor
1824
Output Encoded Data Block with Descriptor
1826
Output Unencoded Data Block with Null Descriptor
1836
Receive Next Data Block From Input Stream
More Data Blocks in Input Stream ?
1828
No
Terminate Data Compression Process
1832
Yes
1830
A

FIGURE 18C

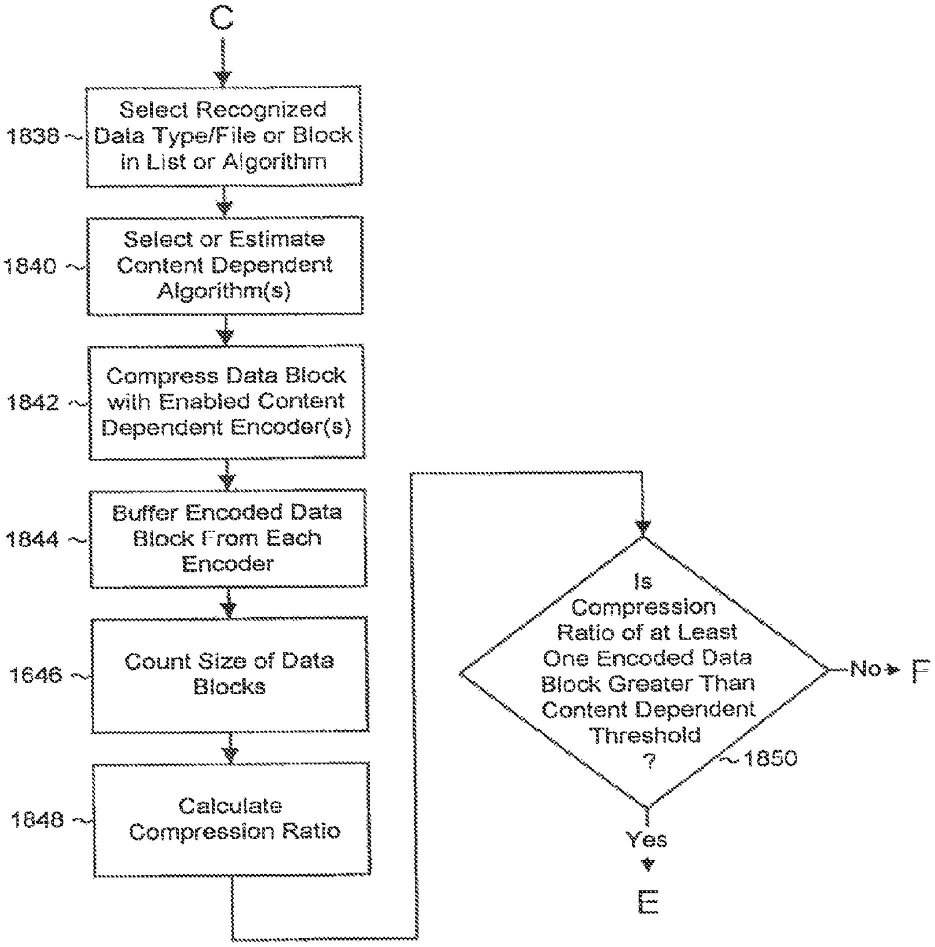
C
1838
Select Recognized Data Type/File or Block in List or Algorithm
1840
Select or Estimate Content Dependent Algorithm(s)
1842
Compress Data Block with Enabled Content Dependent Encoder(s)
1844
Buffer Encoded Data Block From Each Encoder
1646
Count Size of Data Blocks
1848
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1850
No
F
Yes
E

FIGURE 18D

DATA COMPRESSION SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 14/251,453, filed Apr. 11, 2014, which is a Continuation of U.S. patent application Ser. No. 14/035,561, filed Sep. 24, 2013, now U.S. Pat. No. 8,717,203, which is a Continuation of U.S. patent application Ser. No. 13/154,211, now U.S. Pat. No. 8,643,513, filed Jun. 6, 2011, which is a Continuation of U.S. patent application Ser. No. 12/703,042, filed Feb. 9, 2010, now U.S. Pat. No. 8,502,707, which is a Continuation of both U.S. patent application Ser. No. 11/651,366, filed Jan. 8, 2007, now abandoned, and U.S. patent application Ser. No. 11/651,365, filed Jan. 8, 2007, now U.S. Pat. No. 7,714,747. Each of application Ser. No. 11/651,366 and application Ser. No. 11/651,365 is a Continuation of U.S. patent application Ser. No. 10/668,768, filed Sep. 22, 2003, now U.S. Pat. No. 7,161,506, which is a Continuation of U.S. patent application Ser. No. 10/016,355, filed Oct. 29, 2001, now U.S. Pat. No. 6,624,761, which is a Continuation-In-Part of U.S. patent application Ser. No. 09/705,446, filed Nov. 3, 2000, now U.S. Pat. No. 6,309,424, which is a Continuation of U.S. patent application Ser. No. 09/210,491, filed Dec. 11, 1998, which is now U.S. Pat. No. 6,195,024. Each of the listed applications are incorporated herein by reference in their entireties.

BACKGROUND

1. Technical Field

The present invention relates generally to a data compression and decompression and, more particularly, to systems and methods for data compression using content independent and content dependent data compression and decompression.

2. Description of Related Art

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video, frequently exists in the natural world as analog information. As is well known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially

greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossless and lossy data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Entropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than the entropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the entropy of a given data set.

There are various problems associated with the use of lossless compression techniques. One fundamental problem encountered with most lossless data compression techniques are their content sensitive behavior. This is often referred to as data dependency. Data dependency implies that the compression ratio achieved is highly contingent upon the content of the data being compressed. For example, database files often have large unused fields and high data redundancies, offering the opportunity to losslessly compress data at ratios of 5 to 1 or more. In contrast, concise software programs have little to no data redundancy and, typically, will not losslessly compress better than 2 to 1.

Another problem with lossless compression is that there are significant variations in the compression ratio obtained when using a single lossless data compression technique for data streams having different data content and data size. This process is known as natural variation.

A further problem is that negative compression may occur when certain data compression techniques act upon many types of highly compressed data. Highly compressed data appears random and many data compression techniques will substantially expand, not compress this type of data.

For a given application, there are many factors that govern the applicability of various data compression techniques. These factors include compression ratio, encoding and decoding processing requirements, encoding and decoding time delays, compatibility with existing standards, and implementation complexity and cost, along with the is adaptability and robustness to variations in input data. A direct relationship exists in the current art between compression ratio and the amount and complexity of processing required. One of the limiting factors in most existing prior art lossless data compression techniques is the rate at which the encoding and decoding processes are performed. Hardware and software implementation tradeoffs are often dictated by encoder and decoder complexity along with cost.

Another problem associated with lossless compression methods is determining the optimal compression technique for a given set of input data and intended application. To combat this problem, there are many conventional content dependent techniques that may be utilized. For instance, file type descriptors are typically appended to file names to describe the application programs that normally act upon the data contained within the file. In this manner data types, data structures, and formats within a given file may be ascertained. Fundamental limitations with this content dependent technique include:

(1) the extremely large number of application programs, some of which do not possess published or documented file formats, data structures, or data type descriptors;

(2) the ability for any data compression supplier or consortium to acquire, store, and access the vast amounts of data required to identify known file descriptors and associated data types, data structures, and formats; and

(3) the rate at which new application programs are developed and the need to update file format data descriptions accordingly.

An alternative technique that approaches the problem of selecting an appropriate lossless data compression technique is disclosed, for example, in U.S. Pat. No. 5,467,087 to Chu entitled "High Speed Lossless Data Compression System" ("Chu"). FIG. 1 illustrates an embodiment of this data compression and decompression technique. Data compression 1 comprises two phases, a data pre-compression phase 2 and a data compression phase 3. Data decompression 4 of a compressed input data stream is also comprised of two phases, a data type retrieval phase 5 and a data decompression phase 6. During the data compression process 1, the data pre-compressor 2 accepts an uncompressed data stream, identifies the data type of the input stream, and generates a data type identification signal. The data compressor 3 selects a data compression method from a preselected set of methods to compress the input data stream, with the intention of producing the best available compression ratio for that particular data type.

There are several limitations associated with the Chu method. One such limitation is the need to unambiguously identify various data types. While these might include such common data types as ASCII, binary, or unicode, there, in fact, exists a broad universe of data types that fall outside the three most common data types. Examples of these alternate data types include: signed and unsigned integers of various lengths, differing types and precision of floating point numbers, pointers, other forms of character text, and a multitude of user defined data types. Additionally, data types may be interspersed or partially compressed, making data type recognition difficult and/or impractical. Another limitation is that given a known data type, or mix of data types within a specific set or subset of input data, it may be difficult and/or impractical to predict which data encoding technique yields the highest compression ratio.

Accordingly, there is a need for a data compression system and method that would address limitations in conventional data compression techniques as described above.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing fast and efficient data compression using a combination of content independent data compression and content dependent data compression. In one aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

performing content independent data compression on the data block, if the data type of the data block is not identified.

In another aspect, the step of performing content independent data compression comprises: encoding the data block with a plurality of encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the encoders; comparing each of the determined compression ratios with a first compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression ratios do not meet the first compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the first compression threshold.

In another aspect, the step of performing content dependent compression comprises the steps of: selecting one or more encoders associated with the identified data type and encoding the data block with the selected encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the selected encoders; comparing each of the determined compression ratios with a second compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression do not meet the second compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the second compression threshold.

In yet another aspect, the step of performing content independent data compression on the data block, if the data type of the data block is not identified, comprises the steps of: estimating a desirability of using of one or more encoder types based one characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of performing content dependent data compression on the data block, if the data type of the data block is identified, comprises the steps of: estimating a desirability of using of one or more encoder types based on characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of analyzing the data block comprises analyzing the data block to recognize one of a data type, data structure, data block format, file substructure, and/or file types. A further step comprises maintaining an association between encoder types and data types, data structures, data block formats, file substructure, and/or file types.

In yet another aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

determining a compression ratio of the compressed data block obtained using the content dependent compression and comparing the compression ratio with a first compression threshold; and

performing content independent data compression on the data block, if the data type of the data block is not identified or if the compression ratio of the compressed data block obtained using the content dependent compression does not meet the first compression threshold.

Advantageously, the present invention employs a plurality of encoders applying a plurality of compression techniques on an input data stream so as to achieve maximum compression in accordance with the real-time or pseudo real-time data rate constraint. Thus, the output bit rate is not fixed and the amount, if any, of permissible data quality degradation is user or data specified.

These and other aspects, features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments, which is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block/flow diagram of a content dependent high-speed lossless data compression and decompression system/method according to the prior art;

FIG. **2** is a block diagram of a content independent data compression system according to one embodiment of the present invention;

FIGS. **3***a* and **3***b* comprise a flow diagram of a data compression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **2**;

FIG. **4** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an enhanced metric for selecting an optimal encoding technique;

FIGS. **5***a* and **5***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **4**;

FIG. **6** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an a priori specified timer that provides real-time or pseudo real-time of output data;

FIGS. **7***a* and **7***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **6**;

FIG. **8** is a block diagram of a content independent data compression system according to another embodiment having an a priori specified timer that provides real-time or pseudo real-time of output data and an enhanced metric for selecting an optimal encoding technique;

FIG. **9** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an encoding architecture comprising a plurality of sets of serially cascaded encoders;

FIGS. **10***a* and **10***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **9**;

FIG. **11** is block diagram of a content independent data decompression system according to one embodiment of the present invention;

FIG. **12** is a flow diagram of a data decompression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **11**;

FIGS. **13***a* and **13***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to an embodiment of the present invention;

FIGS. **14***a*-**14***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to one aspect of the present invention;

FIGS. **15***a* and **15***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention;

FIGS. **16***a*-**16***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention;

FIGS. **17***a* and **17***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention; and

FIGS. **18***a*-**18***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to systems and methods for providing data compression and decompression using content independent and content dependent data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. In particular, the system modules described herein are preferably implemented in software as an application program that is executable by, e.g., a general purpose computer or any machine or device having any suitable and preferred microprocessor architecture. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform also includes an operating system and microinstruction code. The various processes and functions described herein may be either part of the microinstruction code or application programs which are executed via the operating system. In addition, various other peripheral devices may be connected to the computer platform such as an additional data storage device and a printing device.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in which the systems are programmed. It is to be appreciated that special purpose microprocessors may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **2** a block diagram illustrates a content independent data compression system according to one embodiment of the present invention. The data compression system includes a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

An encoder module **30** is operatively connected to the buffer **20** and comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **30** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **10**). Data compression is performed by the encoder module **30** wherein each of the encoders E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the is encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **40** is operatively connected to the encoding module **30** for buffering and counting the size of each of the encoded data blocks output from encoder module **30**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **50**, operatively connected to the output buffer/counter **40**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **50** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **60**, operatively coupled to the compression ratio module **50**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

The operation of the data compression system of FIG. **2** will now be discussed in is further detail with reference to the flow diagram of FIGS. **3***a* and **3***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **300**). As stated above, data compression is performed on a per data block basis. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **302**). The data block is then stored in the buffer **20** (step **304**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **306**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **308**), and the encoded data block size is counted (step **310**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of each encoded data block output from the enabled encoders (step **312**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **314**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art.

After the compression ratios are compared with the threshold, a determination is s made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **316**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **316**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **318**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **320**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **316**), then the encoded data block having the greatest compression ratio is selected (step **322**). An appropriate data compression type descriptor is then appended (step **324**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **326**).

After the encoded data block or the unencoded data input data block is output (steps **326** and **320**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **328**). If the input data stream includes additional data blocks (affirmative result in step **328**), the next successive data block is received (step **330**), its block size is counted (return to step **302**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **328**), data compression of the input data stream is finished (step **322**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

Referring now to FIG. **4**, a block diagram illustrates a content independent data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **4** is similar to the data compression system of FIG. **2** except that the embodiment of FIG. **4** includes an enhanced metric functionality for selecting an optimal encoding technique. In particular, each of the encoders E**1** . . . En in the encoder module **30** is tagged with a corresponding one of user-selected encoder desirability factors **70**. Encoder desirability is defined as an a priori user specified factor that takes into account any number of user considerations including, but not limited to, compatibility of the encoded data with existing standards, data error robustness, or any other aggregation of factors that the user wishes to consider for a particular application. Each encoded data block output from the encoder module **30** has a corresponding desirability factor appended thereto. A figure of merit module **80**, operatively coupled to the compression ratio module **50** and the descriptor module **60**, is provided for calculating a figure of merit for each of the encoded data blocks which possess a compression ratio greater than the compression ratio threshold limit. The figure of merit for each encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor. As discussed below in further detail with reference to FIGS. **5***a* and **5***b*, the figure of merit substitutes the a priori user compression threshold limit for selecting and outputting encoded data blocks.

The operation of the data compression system of FIG. **4** will now be discussed in further detail with reference to the flow diagram of FIGS. **5***a* and **5***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **500**). The size of the first data block is then determined by the counter module **10** (step **502**). The data block is then stored in the buffer **20** (step **504**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder in the encoder set E**1** . . . En (step **506**). Each encoded data block processed in the encoder module **30** is tagged with an encoder desirability factor that corresponds the particular encoding technique applied to the encoded data block (step **508**). Upon completion of the encoding of the input data block, an encoded data block with its corresponding desirability factor is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **510**), and the encoded data block size is counted (step **512**).

Next, a compression ratio obtained by each enabled encoder is calculated by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **514**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **516**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **518**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **518**), then the original unencoded input data block is selected for output and a null data compression type descriptor (as discussed above) is appended thereto (step **520**). Accordingly, the original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **522**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **518**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **524**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected for output (step **526**). An appropriate data compression type descriptor is then appended (step **528**) to indicate the data encoding technique applied to the encoded data block. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **530**).

After the encoded data block or the unencoded input data block is output (steps **530** and **522**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **532**). If the input data stream includes additional data blocks (affirmative result in step **532**), then the next successive data block is received (step **534**), its block size is counted (return to step **502**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **532**), data compression of the input data stream is finished (step **536**).

Referring now to FIG. **6**, a block diagram illustrates a data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **6** is similar to the data compression system discussed in detail above with reference to FIG. **2** except that the embodiment of FIG. **6** includes an a priori specified timer that provides real-time or pseudo real-time output data. In particular, an interval timer **90**, operatively coupled to the encoder module **30**, is preloaded with a user specified time value. The role of the interval timer (as will be explained in greater detail below with reference to FIGS. **7***a* and **7***b*) is to limit the processing time for each input data block processed by the encoder module **30** so as to ensure that the real-time, pseudo real-time, or other time critical nature of the data compression processes is preserved.

The operation of the data compression system of FIG. **6** will now be discussed in further detail with reference to the flow diagram of FIGS. **7***a* and **7***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **700**), and its size is determined by the counter module **10** (step **702**). The data block is then stored in buffer **20** (step **704**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **706**) and starts counting towards a user-specified time limit. The input data block is then sent to the encoder module **30** wherein data compression of the data block by each (enabled) encoder E**1** . . . En commences (step **708**). Next, a determination is made as to whether the user specified time expires before the completion of the encoding process (steps **710** and **712**). If the encoding process is completed before or at the expiration of the timer, i.e., each encoder (E**1** through En) completes its respective encoding process (negative result in step **710** and affirmative result in step **712**), then an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **714**).

On the other hand, if the timer expires (affirmative result in **710**), the encoding process is halted (step **716**). Then, encoded data blocks from only those enabled encoders E**1** . . . En that have completed the encoding process are selected and maintained in buffers (step **718**). It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency and natural variation, it is possible that certain encoders may not operate quickly enough and, therefore, do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are buffered (step **714** or **718**), the size of each encoded data block is counted (step **720**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **722**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **724**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **726**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **726**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **728**). The original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **730**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **726**), then the encoded data block having the greatest compression ratio is selected (step **732**). An appropriate data compression type descriptor is then appended (step **734**). The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **736**).

After the encoded data block or the unencoded input data block is output (steps **730** or **736**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **738**). If the input data stream includes additional data blocks (affirmative result in step **738**), the next successive data block is received (step **740**), its block size is counted (return to step **702**) and the data compression process in repeated. This process is iterated for each data block in the input data stream, with each data block being processed within the user-specified time limit as discussed above. Once the final input data block is processed (negative result in step **738**), data compression of the input data stream is complete (step **742**).

Referring now to FIG. **8**, a block diagram illustrates a content independent data compression system according to another embodiment of the present system. The data compression system of FIG. **8** incorporates all of the features discussed above in connection with the system embodiments of FIGS. **2**, **4**, and **6**. For example, the system of FIG. **8** incorporates both the a priori specified timer for providing real-time or pseudo real-time of output data, as well as the enhanced metric for selecting an optimal encoding technique. Based on the foregoing discussion, the operation of the system of FIG. **8** is understood by those skilled in the art.

Referring now to FIG. **9**, a block diagram illustrates a data compression system according to a preferred embodiment of the present invention. The system of FIG. **9** contains many of the features of the previous embodiments discussed above. However, this embodiment advantageously includes a cascaded encoder module **30***c* having an encoding architecture comprising a plurality of sets of serially cascaded encoders Em,n, where "m" refers to the encoding path (i.e., the encoder set) and where "n" refers to the number of encoders in the respective path. It is to be understood that each set of serially cascaded encoders can include any number of disparate and/or similar encoders (i.e., n can be any value for a given path m).

The system of FIG. **9** also includes a output buffer module **40***c* which comprises a plurality of buffer/counters B/Cm,n, each associated with a corresponding one of the encoders Em,n. In this embodiment, an input data block is sequentially applied to successive encoders (encoder stages) in the encoder path so as to increase the data compression ratio. For example, the output data block from a first encoder E**1**,**1**, is buffered and counted in B/C**1**,**1**, for subsequent processing by a second encoder E**1**,**2**. Advantageously, these parallel sets of sequential encoders are applied to the input data stream to effect content free lossless data compression. This embodiment provides for multi-stage sequential encoding of data with the maximum number of encoding steps subject to the available real-time, pseudo real-time, or other timing constraints.

As with each previously discussed embodiment, the encoders Em,n may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Encoding techniques are selected based upon their ability to effectively encode different types of input data. A full complement of encoders provides for broad coverage of existing and future data types. The input data blocks may be applied simultaneously to the encoder paths (i.e., the encoder paths may operate in parallel, utilizing task multiplexing on a single central processor, or via dedicated hardware, or by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, an input data block may be sequentially applied to the encoder paths. Moreover, each serially cascaded encoder path may comprise a fixed (predetermined) sequence of encoders or a random sequence of encoders. Advantageously, by simultaneously or sequentially processing input data blocks via a plurality of sets of serially cascaded encoders, content free data compression is achieved.

The operation of the data compression system of FIG. **9** will now be discussed in further detail with reference to the flow diagram of FIGS. **10***a* and **10***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **100**), and its size is determined by the counter module **10** (step **102**). The data block is then stored in buffer **20** (step **104**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **106**) and starts counting towards a user-specified time limit. The input data block is then sent to the cascade encoder module **30**C wherein the input data block is applied to the first encoder (i.e., first encoding stage) in each of the cascaded encoder paths E**1**,**1** . . . Em,**1** (step **108**). Next, a determination is made as to whether the user specified time expires before the completion of the first stage encoding process (steps **110** and **112**). If the first stage encoding process is completed before the expiration of the timer, i.e., each encoder (E**1**,**1** . . . Em,**1**) completes its respective encoding process (negative result in step **110** and affirmative result in step **112**), then an encoded data block is output from each encoder E**1**,**1** . . . Em,**1** and maintained in a corresponding buffer (step **114**). Then for each cascade encoder path, the output of the completed encoding stage is applied to the next successive encoding stage in the cascade path (step **116**). This process (steps **110**, **112**, **114**, and **116**) is repeated until the earlier of the timer expiration (affirmative result in step **110**) or the completion of encoding by each encoder stage in the serially cascaded paths, at which time the encoding process is halted (step **118**).

Then, for each cascade encoder path, the buffered encoded data block output by the last encoder stage that completes the encoding process before the expiration of the timer is selected for further processing (step **120**). Advantageously, the interim stages of the multi-stage data encoding process are preserved. For example, the results of encoder E**1**,**1** are preserved even after encoder E**1**,**2** begins encoding the output of encoder E**1**,**1**. If the interval timer expires after encoder E**1**,**1** completes its respective encoding process but before encoder E**1**,**2** completes its respective encoding process, the encoded data block from encoder E**1**,**1** is complete and is utilized for calculating the compression ratio for the corresponding encoder path. The incomplete encoded data block from encoder E**1**,**2** is either discarded or ignored.

It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders in the cascade encoder paths complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency, natural variation and the sequential application of the cascaded encoders, it is possible that certain encoders may not operate quickly enough and therefore do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are selected (step **120**), the size of each encoded data block is counted (step **122**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each encoder (step **124**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **126**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **128**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **128**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **130**). The original unencoded data block and its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **132**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **128**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **134**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected (step **136**). An appropriate data compression type descriptor is then appended (step **138**) to indicate the data encoding technique applied to the encoded data block. For instance, the data type compression descriptor can indicate that the encoded data block was processed by either a single encoding type, a plurality of sequential encoding types, and a plurality of random encoding types. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **140**).

After the unencoded data block or the encoded data input data block is output (steps **132** and **140**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **142**). If the input data stream includes additional data blocks (affirmative result in step **142**), then the next successive data block is received (step **144**), its block size is counted (return to step **102**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **142**), data compression of the input data stream is finished (step **146**).

Referring now to FIG. **11**, a block diagram illustrates a data decompression system according to one embodiment of the present invention. The data decompression system preferably includes an input buffer **1100** that receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **1100** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **1102** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **1104** includes a plurality of decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source. As with the data compression systems discussed above, the decoder module **1104** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time.

The data decompression system also includes an output data buffer **1106** for buffering the decoded data block output from the decoder module **1104**.

The operation of the data decompression system of FIG. **11** will be discussed in further detail with reference to the flow diagram of FIG. **12**. A data stream comprising one or more data blocks of compressed or uncompressed data is input into the data decompression system and the first data block in the stream is received (step **1200**) and maintained in the buffer (step **1202**). As with the data compression systems discussed above, data decompression is performed on a per data block basis. The data compression type descriptor is then extracted from the input data block (step **1204**). A determination is then made as to whether the data compression type descriptor is null (step **1206**). If the data compression type descriptor is determined to be null (affirmative result in step **1206**), then no decoding is applied to the input data block and the original undecoded data block is output (or maintained in the output buffer) (step **1208**).

On the other hand, if the data compression type descriptor is determined to be any value other than null (negative result in step **1206**), the corresponding decoder or decoders are then selected (step **1210**) from the available set of decoders D**1** . . . Dn in the decoding module **1104**. It is to be understood that the data compression type descriptor may mandate the application of: a single specific decoder, an ordered sequence of specific decoders, a random order of specific decoders, a class or family of decoders, a mandatory or optional application of parallel decoders, or any combination or permutation thereof. The input data block is then decoded using the selected decoders (step **1212**), and output (or maintained in the output buffer **1106**) for subsequent data processing, storage, or transmittal (step **1214**). A determination is then made as to whether the input data stream contains additional data blocks to be processed (step **1216**). If the input data stream includes additional data blocks (affirmative result in step **1216**), the next successive data block is received (step **1220**), and buffered (return to step **1202**). Thereafter, the data decompression process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1216**), data decompression of the input data stream is finished (step **1218**).

In other embodiments of the present invention described below, data compression is achieved using a combination of content dependent data compression and content independent data compression. For example, FIGS. **13***a* and **13***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to one embodiment of the present invention, wherein content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The data compression system comprises a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds a priori specified content independent or content dependent minimum compression ratio thresholds. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

A content dependent data recognition module **1300** analyzes the incoming data stream to recognize data types, data structures, data block formats, file substructures, file types, and/or any other parameters that may be indicative of either the data type/content of a given data block or the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1310** module may be employed to hold and/or determine associations between recognized data parameters and appropriate algorithms. Each data block that is recognized by the content data compression module **1300** is routed to a content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**.

A content dependent encoder module **1320** is operatively connected to the content dependent data recognition module **1300** and comprises a set of encoders D**1**, D**2**, D**3** . . . Dm. The encoder set D**1**, D**2**, D**3** . . . Dm may include any number "n" of those lossless or lossy encoding techniques currently well known within the art such as MPEG4, various voice codecs, MPEG3, AC3, AAC, as well as lossless algorithms such as run length, Huffinan, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders and or codecs are preferably selected to provide a broad coverage of existing and future data types.

The content independent encoder module **30**, which is operatively connected to the content dependent data recognition module **1300**, comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Again, it is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder modules (content dependent **1320** and content independent **30**) selectively receive the buffered input data blocks (or unbuffered input data blocks from the counter module **10**) from module **1300** based on the results of recognition. Data compression is performed by the respective encoder modules wherein some or all of the encoders D**1** . . . Dm or E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders D**1** . . . Dm and E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoder set D**1** through Dm of encoder module **1320** and/or the encoder set E**1** through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders D**1** through Dm and E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block. It should be further noted that one or more algorithms may be implemented in dedicated hardware such as an MPEG4 or MP3 encoding integrated circuit.

Buffer/counter modules **1330** and **40** are operatively connected to their respective encoding modules **1320** and **30**, for buffering and counting the size of each of the encoded data blocks output from the respective encoder modules. Specifically, the content dependent buffer/counter **1330** comprises a plurality of buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm, each operatively associated with a corresponding one of the encoders D**1** . . . Dm. Similarly the content independent buffer/counters BCE**1**, BCE**2**, BCE**3** . . . BCEn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **1340**, operatively connected to the content dependent output buffer/counters **1330** and content independent buffer/counters **40** determines the compression ratio obtained for each of the enabled encoders D**1** . . . Dm and or E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn. In addition, the compression ratio module **1340** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn achieves a compression that meets an a priori-specified threshold. As is. understood by those skilled in the art, the threshold limit maybe specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It should be noted that different threshold values may be applied to content dependent and content independent encoded data. Further these thresholds may be adaptively modified based upon enabled encoders in either or both the content dependent or content independent encoder sets, along with any associated parameters. A compression type description module **1350**, operatively coupled to the compression ratio module **1340**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

A mode of operation of the data compression system of FIGS. **13***a* and **13***b* will now be discussed with reference to the flow diagrams of FIGS. **14***a*-**14***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. In general, content independent data compression is applied to a given data block when the content of a data block cannot be identified or is not associated with a specific data compression algorithm. More specifically, referring to FIG. **14***a*, a data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1400**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1402**). The data block is then stored in the buffer **20** (step **1404**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1408**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1410**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1412**), and the encoded data block size is counted (step **1414**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1416**). Each compression ratio is then compared with an apriori-specified compression ratio threshold (step **1418**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

As previously stated the data block stored in the buffer **20** (step **1404**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1434**) the appropriate content dependent algorithms are enabled and initialized (step **1436**), and the data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1438**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1440**), and the encoded data block size is counted (step **1442**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1444**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1448**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

After the encoded data block or the unencoded data input data block is output (steps **1426** and **1436**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1428**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1432**), its block size is counted (return to step **1402**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1428**), data compression of the input data stream is finished (step **1430**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. Further the encoding may be lossy or lossless dependent upon the input data types. Further if the data type is not recognized the default content independent lossless compression is applied. It is not a requirement that this process be deterministic—in fact a certain probability may be applied if occasional data loss is permitted. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

FIGS. **15***a* and **15***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **15***a* and **15***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **15***a* and **15***b* additionally performs content independent data compression on a data block when the compression ratio obtained for the data block using the content dependent data compression does not meet a specified threshold.

A mode of operation of the data compression system of FIGS. **15***a* and **15***b* will now be discussed with reference to the flow diagram of FIGS. **16***a*-**16***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1600**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1602**). The data block is then stored in the buffer **20** (step **1604**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1608**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1610**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1612**), and the encoded data block size is counted (step **1614**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1616**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1618**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1620**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1634**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1636**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1620**), then the encoded data block having the greatest compression ratio is selected (step **1622**). An appropriate data compression type descriptor is then appended (step **1624**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1626**).

As previously stated the data block stored in the buffer **20** (step **1604**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1634**) the appropriate content dependent algorithms are enabled and initialized (step **1636**) and the data is routed to the content dependent encoder module **1620** and compressed by each (enabled) encoder D**1** . . . Dm (step **1638**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1640**), and the encoded data block size is counted (step **1642**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1644**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1648**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1648**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is routed to the content independent encoder module **30** and the process resumes with compression utilizing content independent encoders (step **1610**).

After the encoded data block or the unencoded data input data block is output (steps **1626** and **1636**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1628**). If the input data stream includes additional data blocks (affirmative result in step **1628**), the next successive data block is received (step **1632**), its block size is counted (return to step **1602**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1628**), data compression of the input data stream is finished (step **1630**).

FIGS. **17***a* and **17***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **17***a* and **17***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **17***a* and **17***b* additionally uses a priori estimation algorithms or look-up tables to estimate the desirability of using content independent data compression encoders and/or content dependent data compression encoders and selecting appropriate algorithms or subsets thereof based on such estimation.

More specifically, a content dependent data recognition and or estimation module **1700** is utilized to analyze the incoming data stream for recognition of data types, data strictures, data block formats, file substructures, file types, or any other parameters that may be indicative of the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1710** module may be employed to hold associations between recognized data parameters and appropriate algorithms. If the content data compression module recognizes a portion of the data, that portion is routed to the content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**. It is to be appreciated that process of recognition (modules **1700** and **1710**) is not limited to a deterministic recognition, but may further comprise a probabilistic estimation of which encoders to select for compression from the set of encoders of the content dependent module **1320** or the content independent module **30**. For example, a method may be employed to compute statistics of a data block whereby a determination that the locality of repetition of characters in a data stream is determined is high can suggest a text document, which may be beneficially compressed with a lossless dictionary type algorithm. Further the statistics of repeated characters and relative frequencies may suggest a specific type of dictionary algorithm. Long strings will require a wide dictionary file while a wide diversity of strings may suggest a deep dictionary. Statistics may also be utilized in algorithms such as Huffman where various character statistics will dictate the choice of different Huffinan compression tables. This technique is not limited to lossless algorithms but may be widely employed with lossy algorithms. Header information in frames for video files can imply a specific data resolution. The estimator then may select the appropriate lossy compression algorithm and compression parameters (amount of resolution desired). As shown in previous embodiments of the present invention, desirability of various algorithms and now associated resolutions with lossy type algorithms may also be applied in the estimation selection process.

A mode of operation of the data compression system of FIGS. **17***a* and **17***b* will now be discussed with reference to the flow diagrams of FIGS. **18***a*-**18***d*. The method of FIGS. **18***a*-**18***d* use a priori estimation algorithms or look-up tables to estimate the desirability or probability of using content independent data compression encoders or content dependent data compression encoders, and select appropriate or desirable algorithms or subsets thereof based on such estimates. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1800**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1802**). The data block is then stored in the buffer **20** (step **1804**). The data block is then analyzed on a per block or multi-block basis by the content dependent/content independent data recognition module **1700** (step **1806**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1710** (step **1808**) the data is to the content independent encoder module **30**. An estimate of the best content independent encoders is performed (step **1850**) and the appropriate encoders are enabled and initialized as applicable. The data is then compressed by each (enabled) encoder E**1** . . . En (step **1810**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1812**), and the encoded data block size is counted (step **1814**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1816**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1818**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

As previously stated the data block stored in the buffer **20** (step **1804**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1806**). If the data stream content is recognized or estimated utilizing the recognition list(s) or algorithms(s) module **1710** (affirmative result in step **1808**) the recognized data type/file or block is selected based on a list or algorithm (step **1838**) and an estimate of the desirability of using the associated content dependent algorithms can be determined (step **1840**). For instance, even though a recognized data type may be associated with three different encoders, an estimation of the desirability of using each encoder may result in only one or two of the encoders being actually selected for use. The data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1842**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1844**), and the encoded data block size is counted (step **1846**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1848**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1850**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

After the encoded data block or the unencoded data input data block is output (steps **1826** and **1836**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1828**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1832**), its block size is counted (return to step **1802**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1828**), data compression of the input data stream is finished (step **1830**).

It is to be appreciated that in the embodiments described above with reference to FIGS. **13**-**18**, an a priori specified time limit or any other real-time requirement may be employed to achieve practical and efficient real-time operation.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A system for compressing data comprising;

a processor;

one or more content dependent data compression encoders; and

a single data compression encoder;

wherein the processor is configured:

to analyze data within a data block to identify one or more parameters or attributes of the data wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based solely on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block;

to perform content dependent data compression with the one or more content dependent data compression encoders if the one or more parameters or attributes of the data are identified; and

to perform data compression with the single data compression encoder, if the one or more parameters or attributes of the data are not identified.

2. The system of claim **1**, wherein the data block is received in an uncompressed form, the data block being included in one or more data blocks transmitted in sequence originating from an external source.

3. The system of claim **1**, wherein the data block is received in an uncompressed form, the data block being included in one or more data blocks transmitted in sequence originating from internal source.

4. The system of claim **1** wherein the compressing, is performed in real-time.

5. The system of claim **1**, wherein the content dependent data compression with the one or more content dependent data compression encoders is performed in real-time.

6. The system of claim **1**, wherein the data compression with the single data compression encoder is performed in real-time.

7. The system of claim **1** wherein the compressing is performed in real-time if the parameter or attribute of the data in the data block is not identified.

8. The system of claim **1** wherein the compressing is performed in real-time if the one or more parameters or attributes of the data in the data block is identified.

9. The system of claim **1**, wherein the processor is further configured to associate a data token indicative of the content dependent data compression applied to the data block to create a compressed data block.

10. The system of claim **1**, wherein the processor is further configured to associate a data token indicative of the single data compression encoder applied to the data block to create a compressed data block.

11. The system of claim **1**, wherein the content dependent data compression further comprises associating a plurality of encoders to the one or more parameters or attributes of the data, wherein at least one of the plurality of encoders provides lossy compression and at least another one of the plurality of encoders provides lossless compression.

12. The system of claim **1**, wherein the content dependent data compression is lossy or lossless depending on the one or more parameters or attributes of the data.

13. The system of claim **1**, wherein the content dependent data compression is lossy and an amount of desired resolution of the lossy compression is selected.

14. The system of claim **1**, wherein the single data compression encoder is lossy.

15. The system of claim **1**, wherein a compressed data block is stored.

16. The system of claim **1**, wherein the processor is further configured to output the data block in uncompressed form if the content dependent data compression results in a compressed data block indicative of data expansion.

17. The system of claim **1**, wherein the processor is further configured to output the data block in uncompressed form if the data compression with the single data compression encoder results in a compressed data block indicative of data expansion.

18. The system of claim **1**, wherein a compressed data block is transmitted, received, and decompressed, and wherein a time taken to compress, transmit, receive, and decompress is less than a time to transmit and receive the data block.

19. The system of claim **1**, wherein the content dependent data compression further comprises providing a compressed data block from one of a plurality of encoders, associated with the one or more of the parameters or attributes of the data;

wherein the one of the plurality of encoders has a higher desirability factor for the data block than another of the plurality of encoders.

20. The system of claim **1**, wherein the processor is further configured to output a compressed data block with a token representative of a compression technique used to compress the data block.

21. The system of claim **1**, wherein a compressed data block is the result of a lossy compression technique.

22. The system of claim **1**, wherein a compressed data block is the result of a lossy compression technique and an amount of resolution of the lossy compression technique is selectable.

23. The system of claim **1**, wherein at least one content dependent data compression technique performed by the one or more content dependent data compression encoders is lossy and a data compression technique performed by the single data compression encoder is lossless.

24. A system for compressing data comprising;

a processor;

one or more data compression encoders; and

a default data compression encoder;

wherein the processor is configured:

to analyze data within a data block to identify one or more parameters or attributes of the data wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based solely on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block; and

to compress the data block to provide a compressed data block, wherein if one or more encoders are associated with the one or more parameters or attributes of the data, compressing the data block with at least one of the one or more data compression encoders, otherwise compressing the data block with the default data compression encoder.

25. A computer implemented method comprising:

analyzing, using a processor, data within a data block to identify one or more parameters or attributes of the data within the data block;

determining, using the processor, whether to output the data block in a received form or in a compressed form; and

outputting, using the processor, the data block in the received form or the compressed form based on the determination,

wherein the outputting the data block in the compressed form comprises determining whether to compress the data block with content dependent data compression based on the one or more parameters or attributes of the data within the data block or to compress the data block with a single data compression encoder; and

wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based only on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block.

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US008717203B2

(12) **United States Patent**
Fallon

(10) **Patent No.: US 8,717,203 B2**
(45) **Date of Patent: May 6, 2014**

(54) **DATA COMPRESSION SYSTEMS AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/035,561**

(22) Filed: **Sep. 24, 2013**

(65) **Prior Publication Data**

US 2014/0022098 A1 Jan. 23, 2014

Related U.S. Application Data

(63) Continuation of application No. 13/154,211, filed on Jun. 6, 2011, which is a continuation of application No. 12/703,042, filed on Feb. 9, 2010, now Pat. No. 8,502,707, which is a continuation of application No. 11/651,366, filed on Jan. 8, 2007, now abandoned, which is a continuation of application No. 11/651,365, filed on Jan. 8, 2007, now Pat. No. 7,714,747, said application No. 11/651,366 is a continuation of application No. 10/668,768, filed on Sep. 22, 2003, now Pat. No. 7,161,506, which is a continuation of application No. 10/016,355, filed on Oct. 29, 2001, now Pat. No. 6,624,761, which is a continuation of application No. 09/705,446, filed on Nov. 3, 2000, now Pat. No. 6,309,424, which is a continuation of application No. 09/210,491, filed on Dec. 11, 1998, now Pat. No. 6,195,024.

(51) **Int. Cl.**
H03M 7/34 (2006.01)

(52) **U.S. Cl.**
USPC **341/51**; 341/50; 341/65; 341/67; 341/87; 341/107

(58) **Field of Classification Search**
USPC 341/51, 65, 67, 79, 87, 106, 107
See application file for complete search history.

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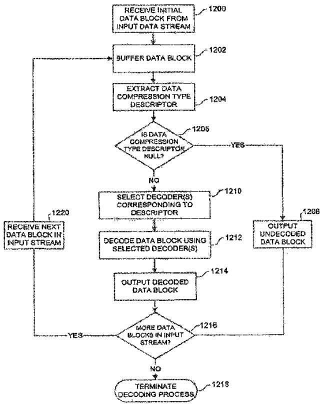
(57) **ABSTRACT**

Systems and methods for providing fast and efficient data compression using a combination of content independent data compression and content dependent data compression. In one aspect, a method for compressing data comprises the steps of: analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types; performing content dependent data compression on the data block, if the data type of the data block is identified; performing content independent data compression on the data block, if the data type of the data block is not identified.

30 Claims, 34 Drawing Sheets



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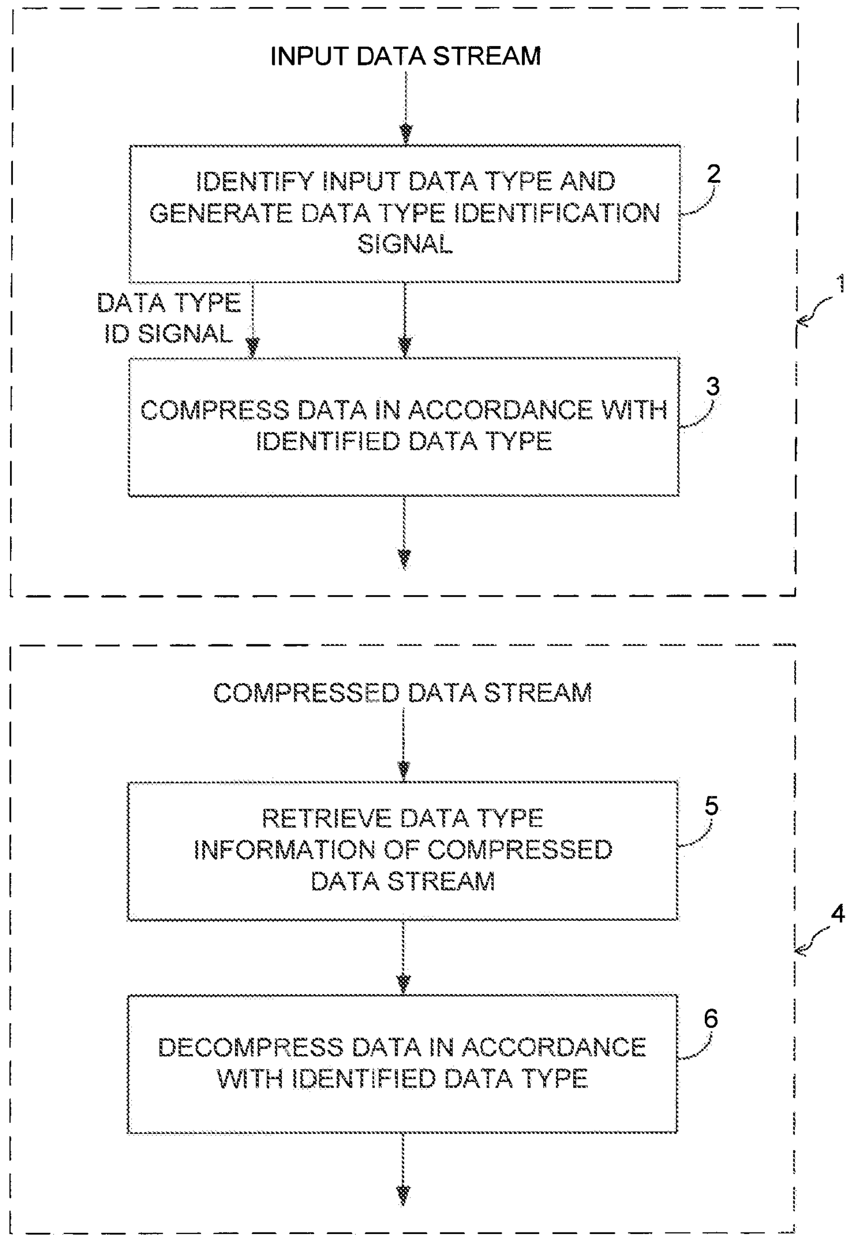


FIG. 1
PRIOR ART

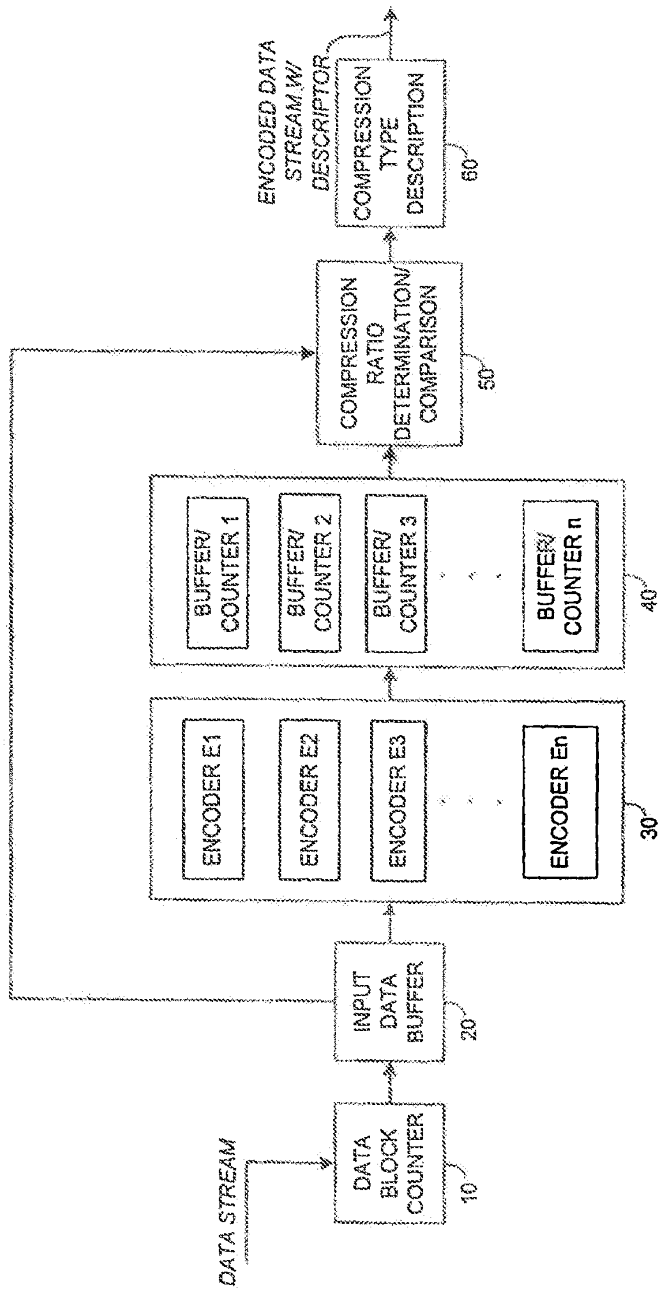

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 2

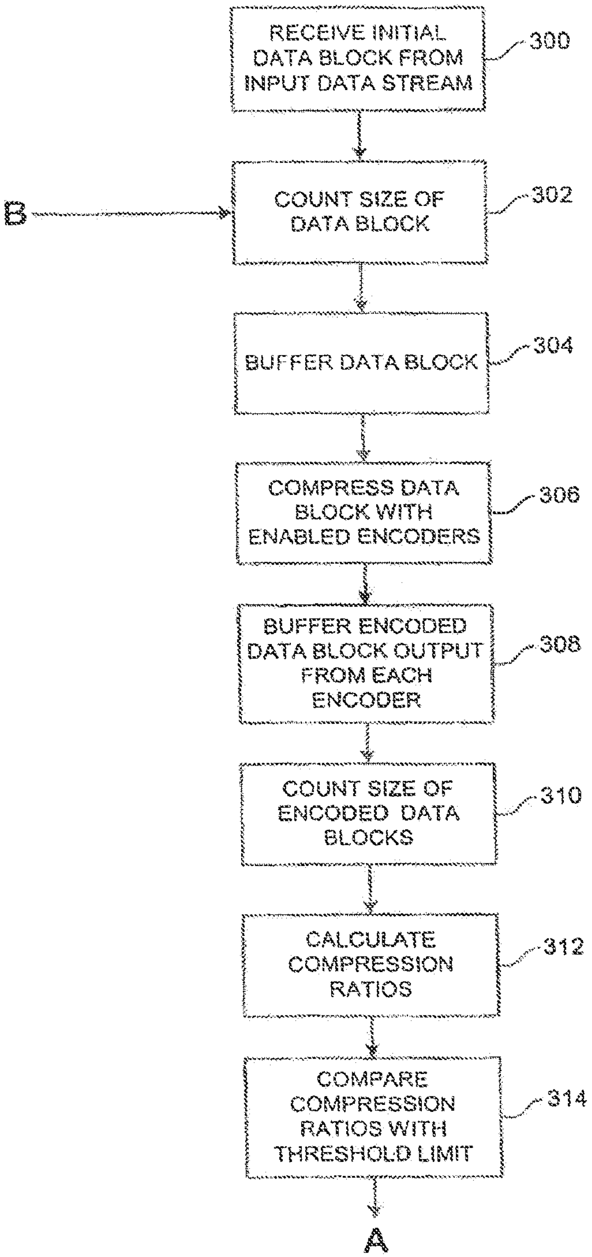

RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
300
B
COUNT SIZE OF DATA BLOCK
302
BUFFER DATA BLOCK
304
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
306
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
308
COUNT SIZE OF ENCODED DATA BLOCKS
310
CALCULATE COMPRESSION RATIOS
312
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
314
A

FIG. 3a

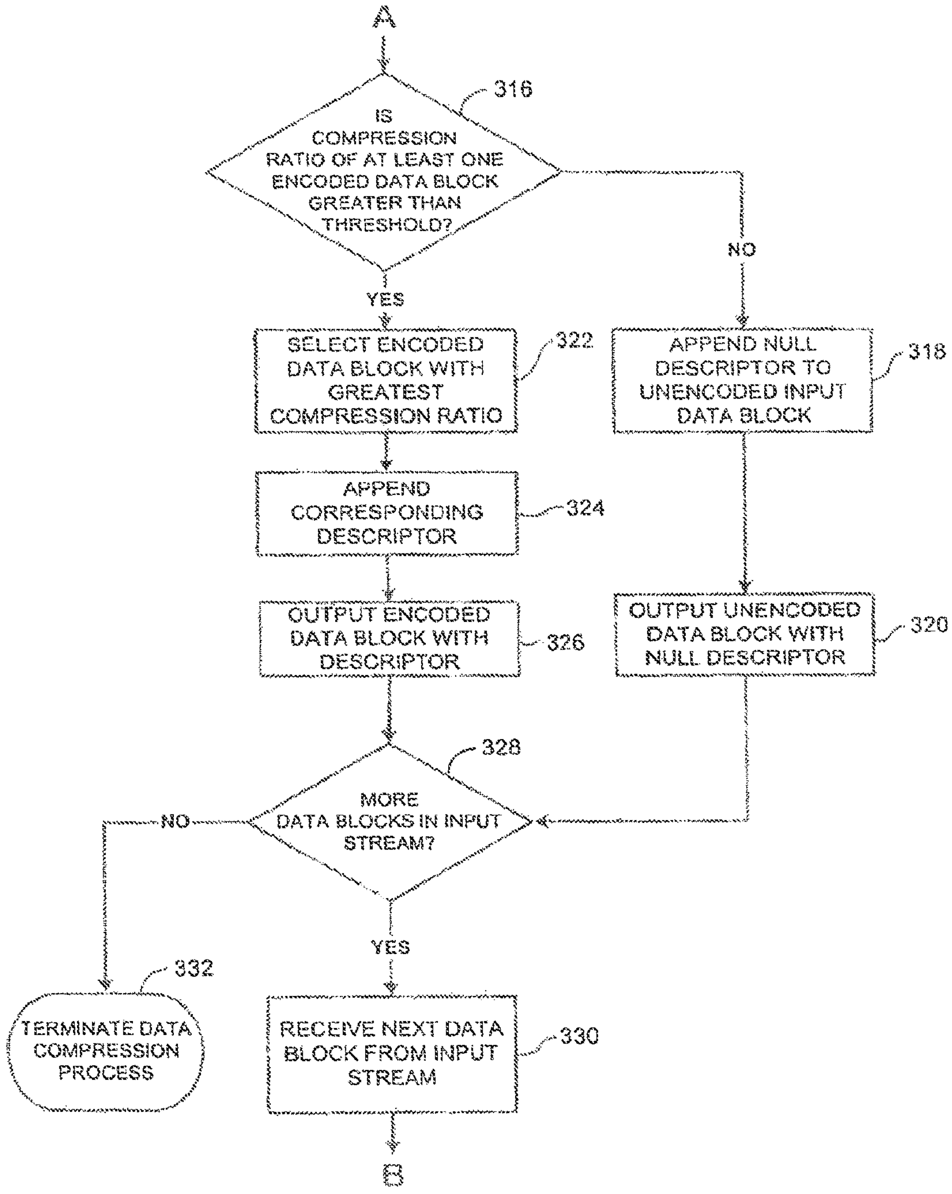

A
316
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
322
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
318
APPEND CORRESPONDING DESCRIPTOR
324
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
326
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
320
328
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
332
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
330
B

FIG. 3b

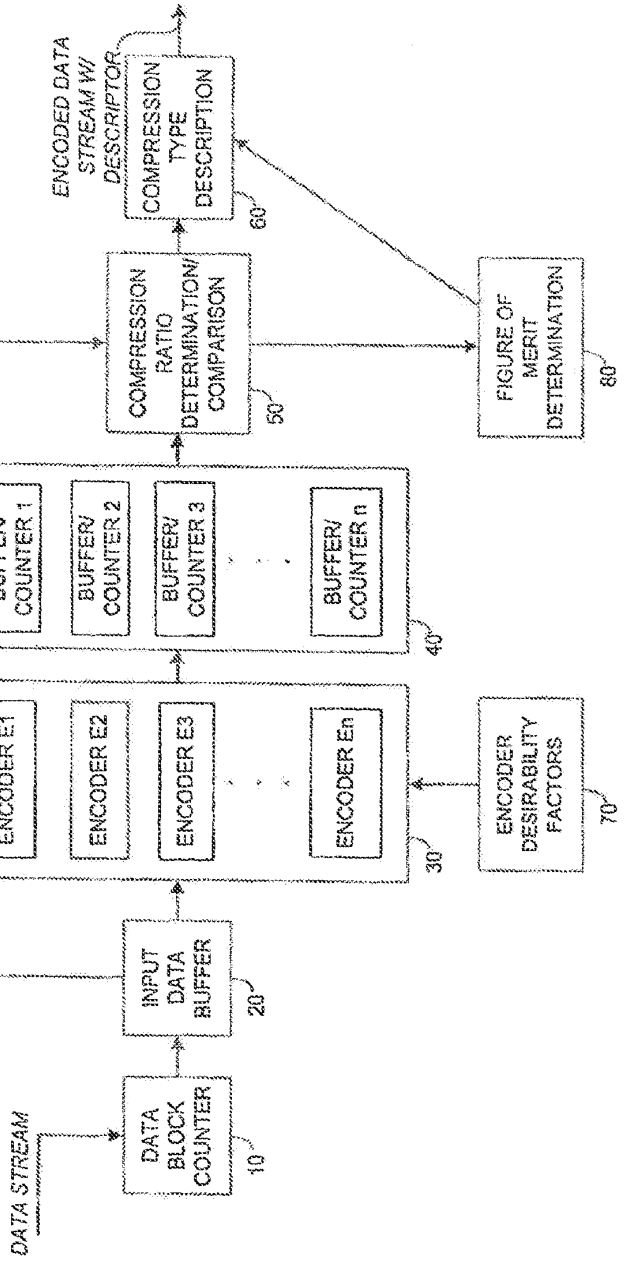

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR
ENCODER DESIRABILITY FACTORS
70
FIGURE OF MERIT DETERMINATION
80

FIG. 4

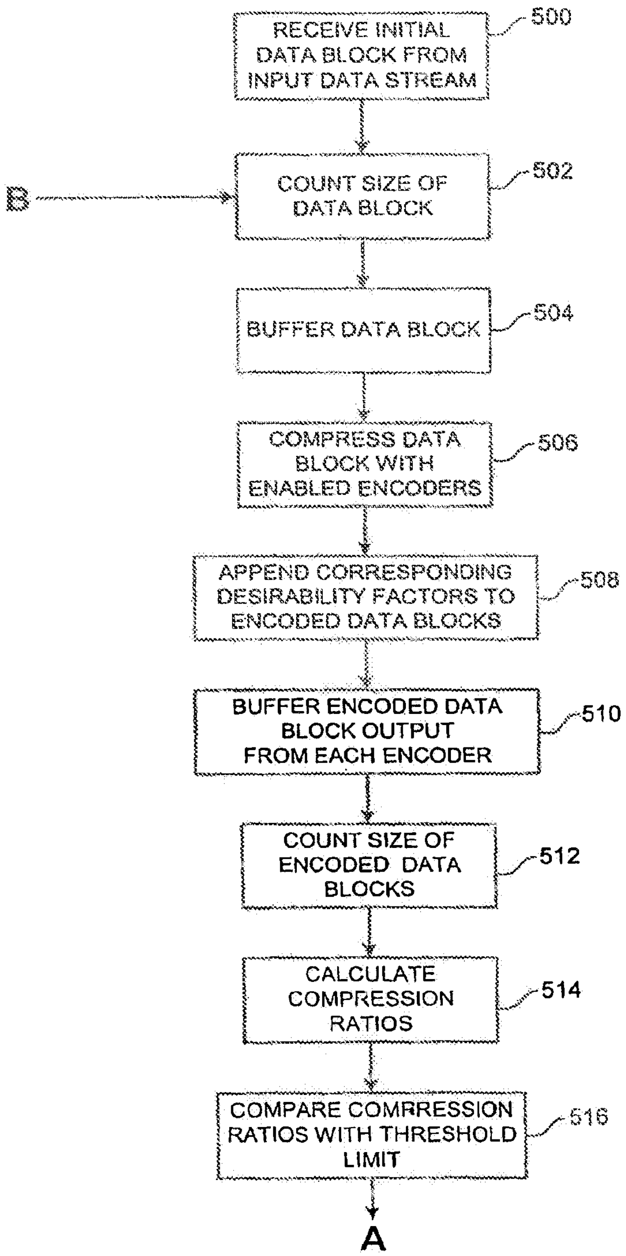

RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
500
COUNT SIZE OF DATA BLOCK
502
B
BUFFER DATA BLOCK
504
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
506
APPEND CORRESPONDING DESIRABILITY FACTORS TO ENCODED DATA BLOCKS
508
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
510
COUNT SIZE OF ENCODED DATA BLOCKS
512
CALCULATE COMPRESSION RATIOS
514
COMPARE COMRRESSION RATIOS WITH THRESHOLD LIMIT
516
A

FIG. 5a

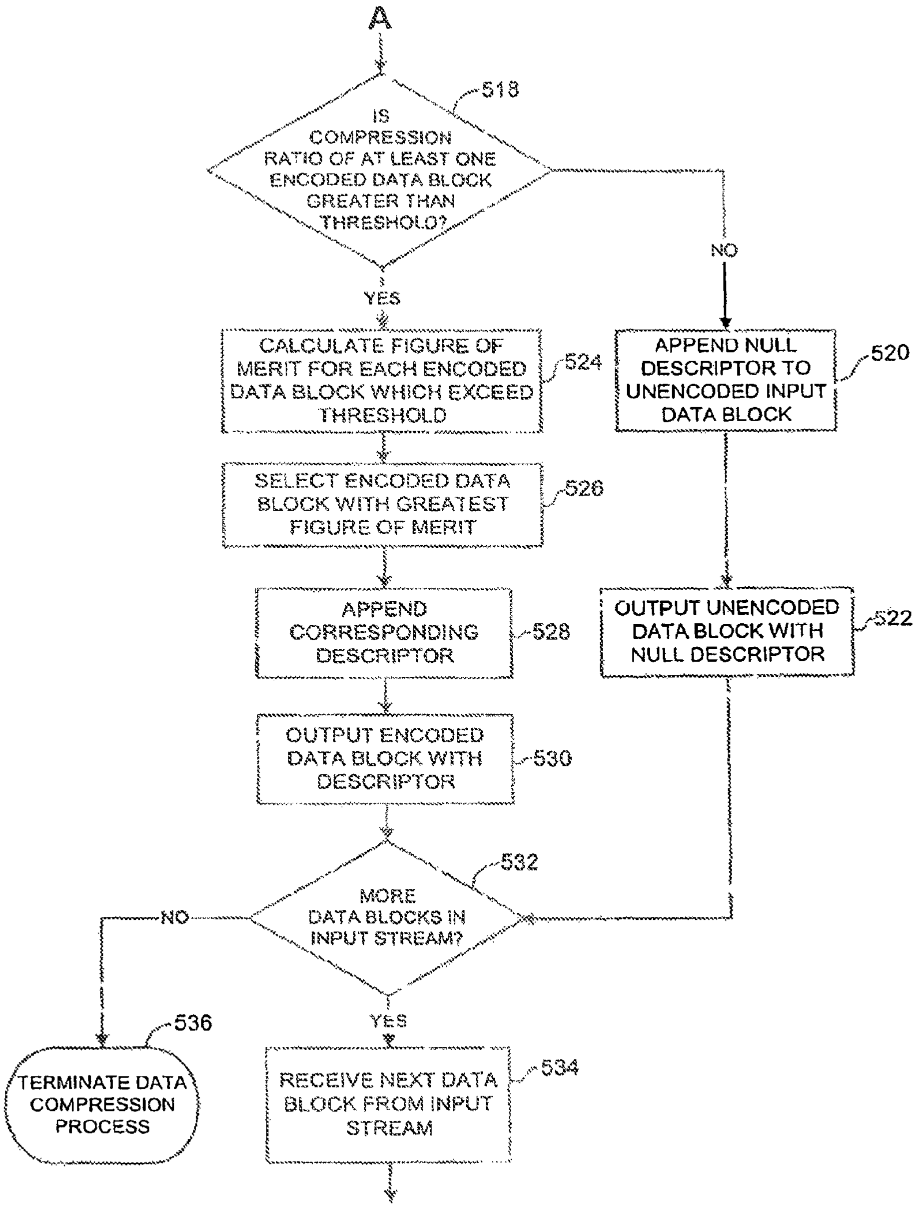

A
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
518
NO
YES
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
524
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
520
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
526
APPEND CORRESPONDING DESCRIPTOR
528
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
522
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
530
MORE DATA BLOCKS IN INPUT STREAM?
532
NO
YES
TERMINATE DATA COMPRESSION PROCESS
536
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
534
B

FIG. 5b

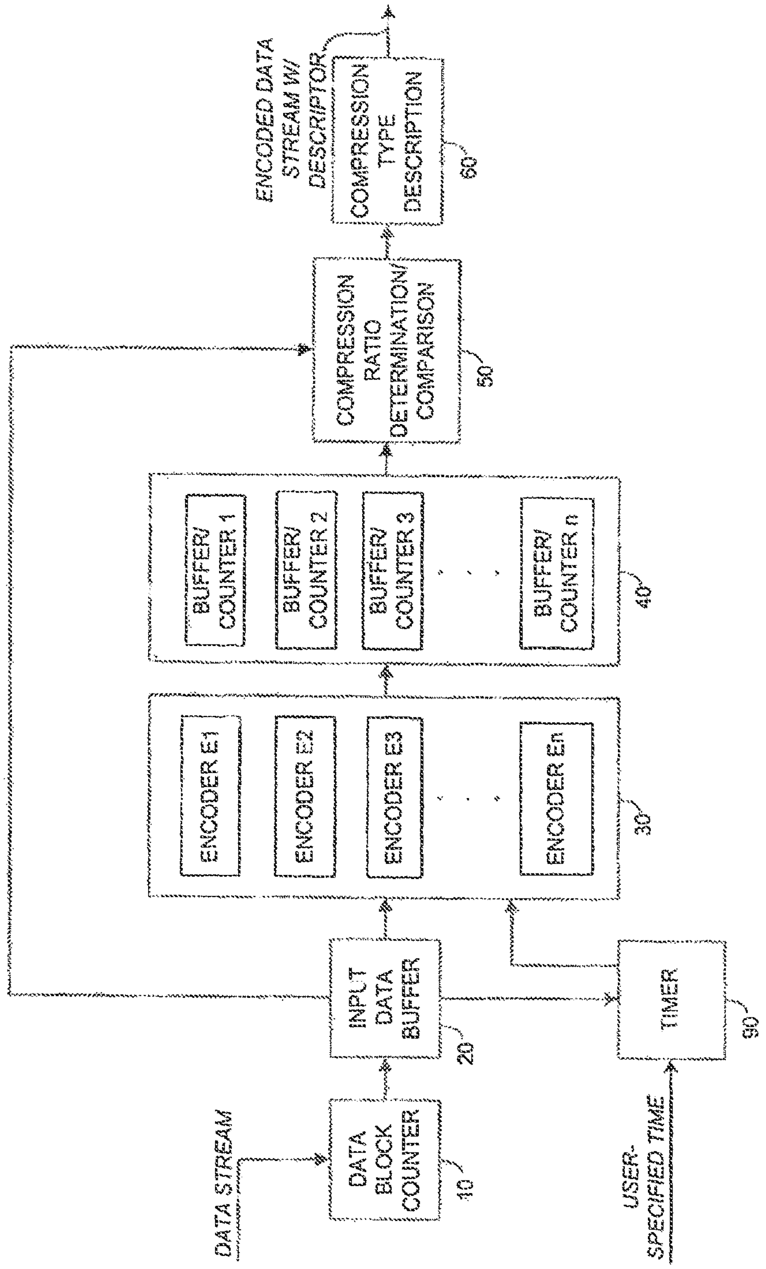

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
. . .
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
. . .
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 6

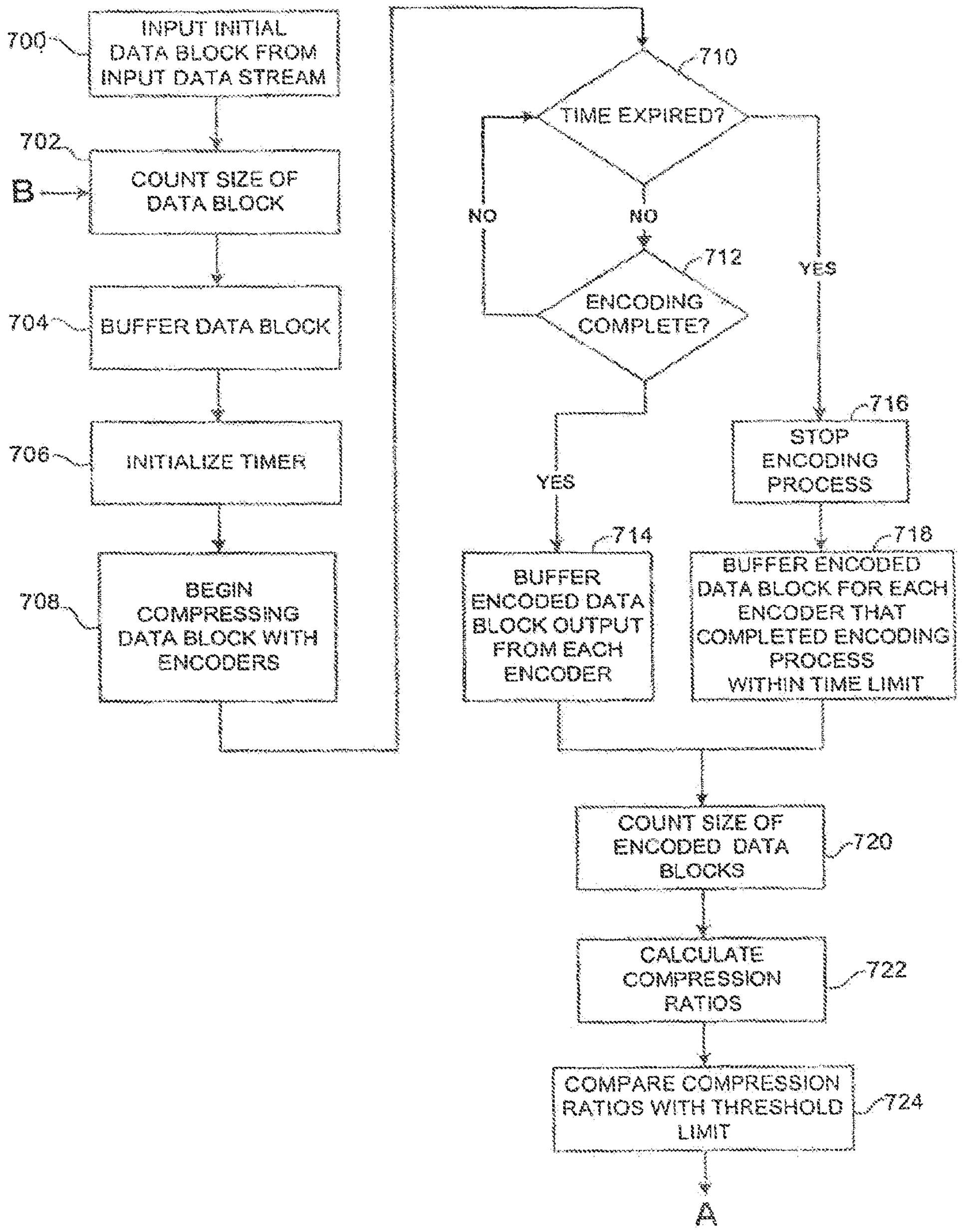

700
INPUT INITIAL DATA BLOCK FROM INPUT DATA STREAM
702
B
COUNT SIZE OF DATA BLOCK
704
BUFFER DATA BLOCK
706
INITIALIZE TIMER
708
BEGIN COMPRESSING DATA BLOCK WITH ENCODERS
710
TIME EXPIRED?
NO
NO
YES
712
ENCODING COMPLETE?
YES
714
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
716
STOP ENCODING PROCESS
718
BUFFER ENCODED DATA BLOCK FOR EACH ENCODER THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
COUNT SIZE OF ENCODED DATA BLOCKS
720
CALCULATE COMPRESSION RATIOS
722
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
724
A

FIG. 7a

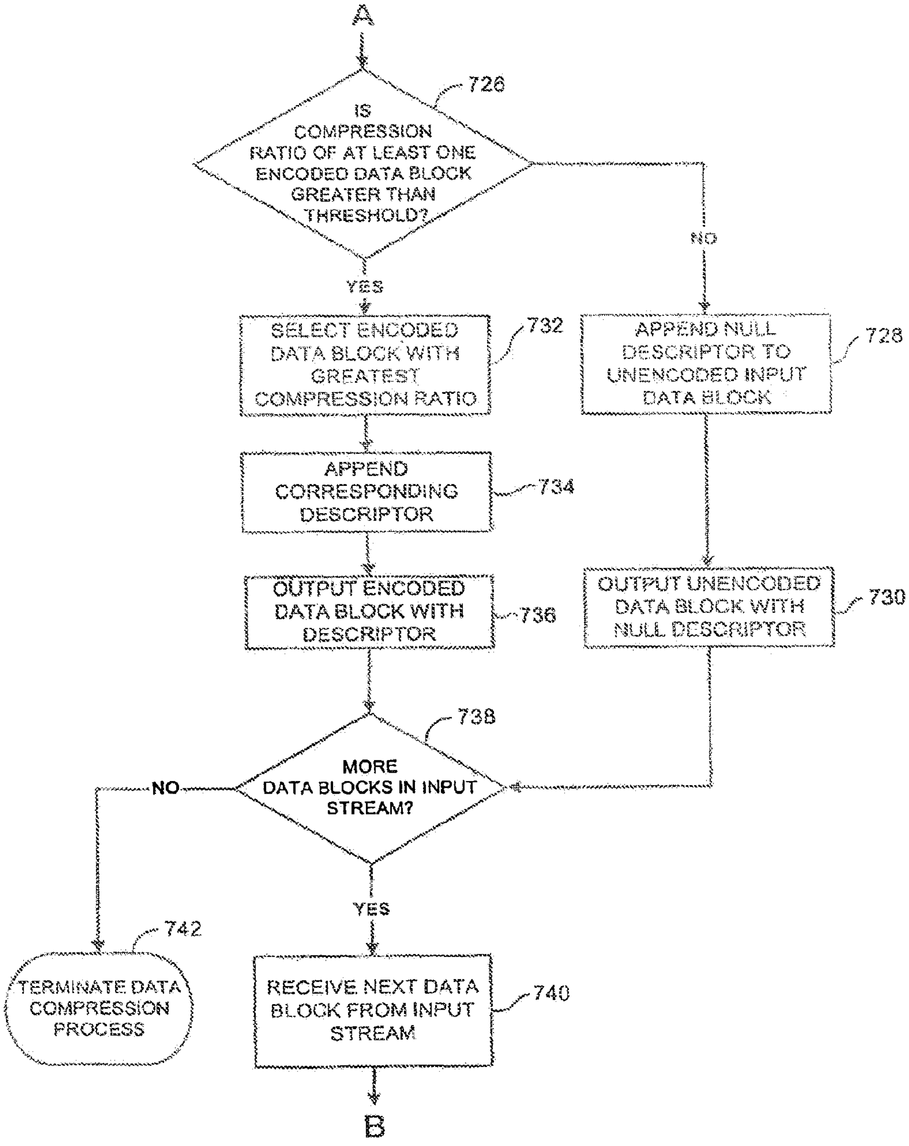

A
726
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
732
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
728
APPEND CORRESPONDING DESCRIPTOR
734
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
736
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
730
738
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
742
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
740
B

FIG. 7b

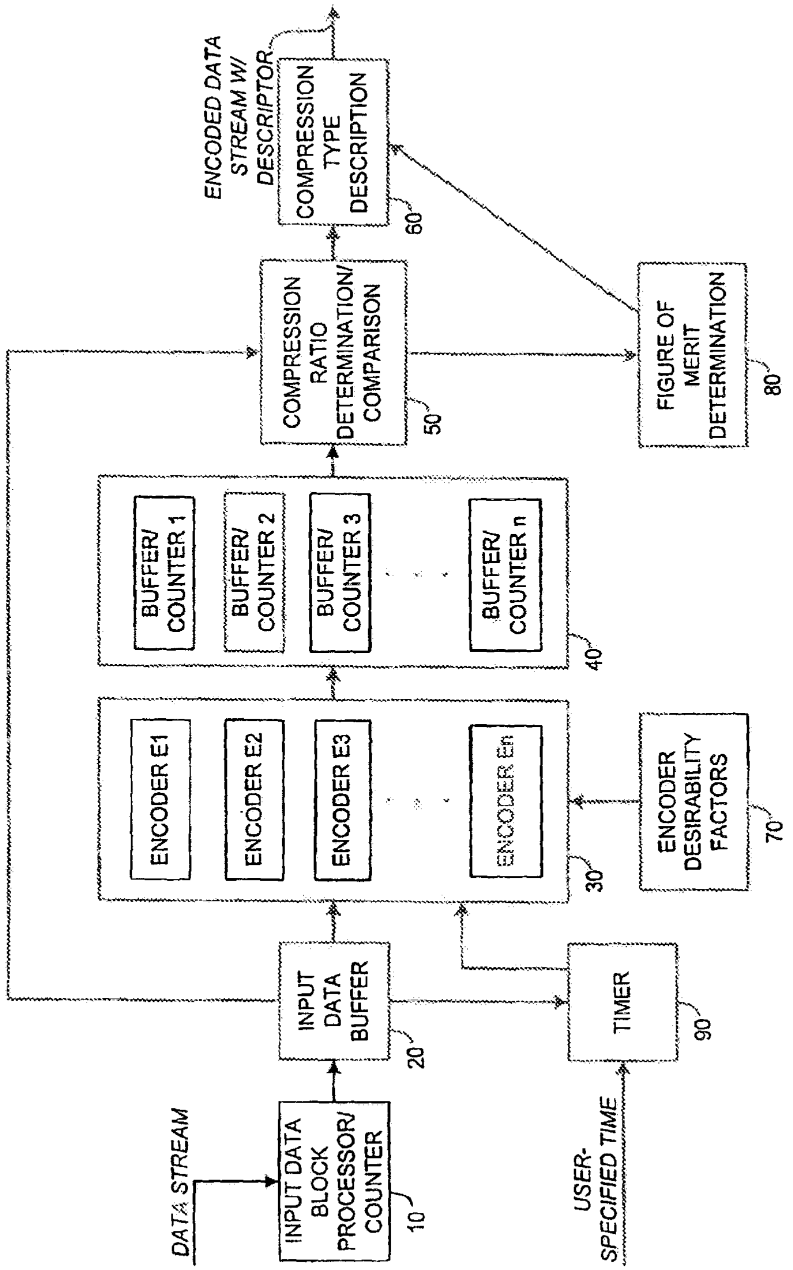

DATA STREAM
INPUT DATA BLOCK PROCESSOR/ COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
. . .
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
. . .
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 8

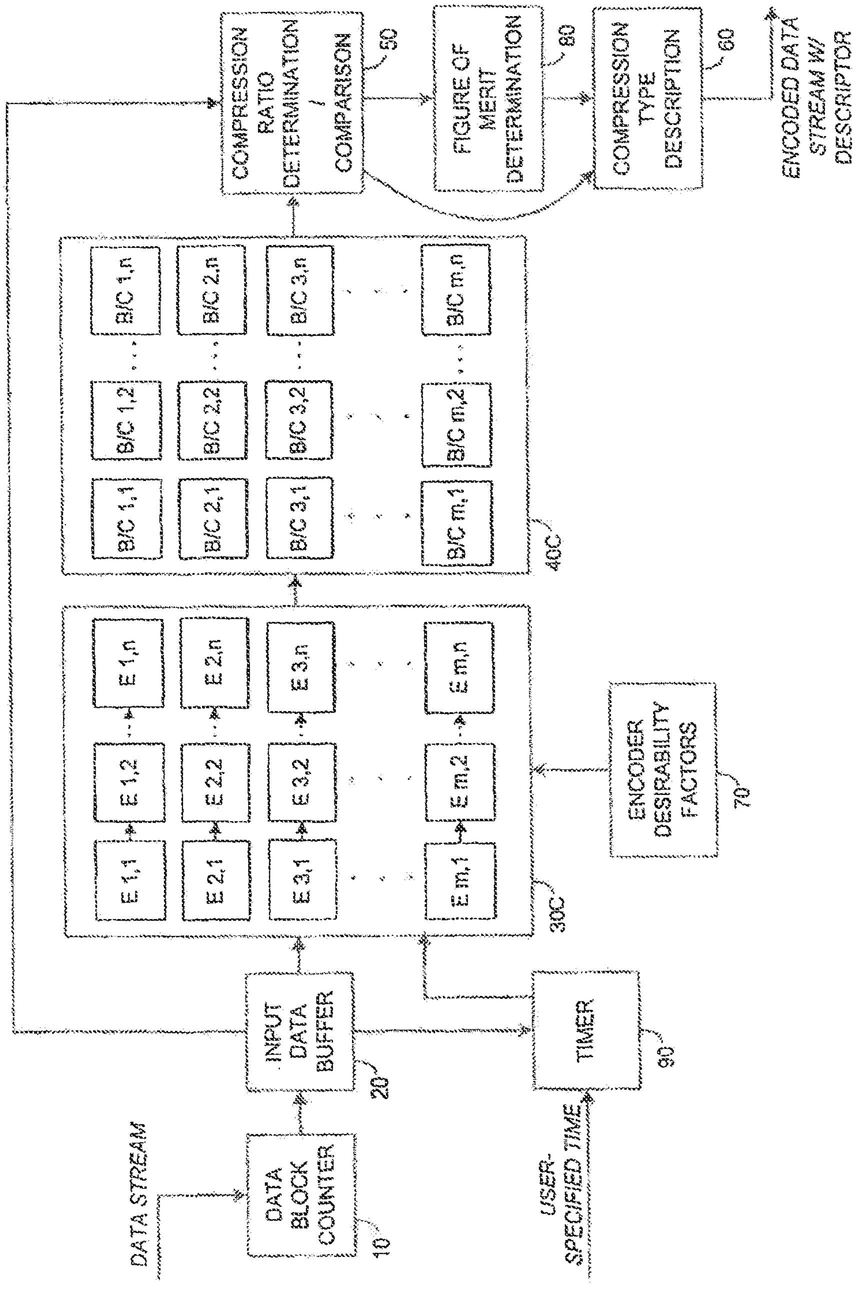

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
E 1,1
E 1,2
E 1,n
E 2,1
E 2,2
E 2,n
E 3,1
E 3,2
E 3,n
E m,1
E m,2
E m,n
30C
ENCODER DESIRABILITY FACTORS
70
B/C 1,1
B/C 1,2
B/C 1,n
B/C 2,1
B/C 2,2
B/C 2,n
B/C 3,1
B/C 3,2
B/C 3,n
B/C m,1
B/C m,2
B/C m,n
40C
COMPRESSION RATIO DETERMINATION / COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 9

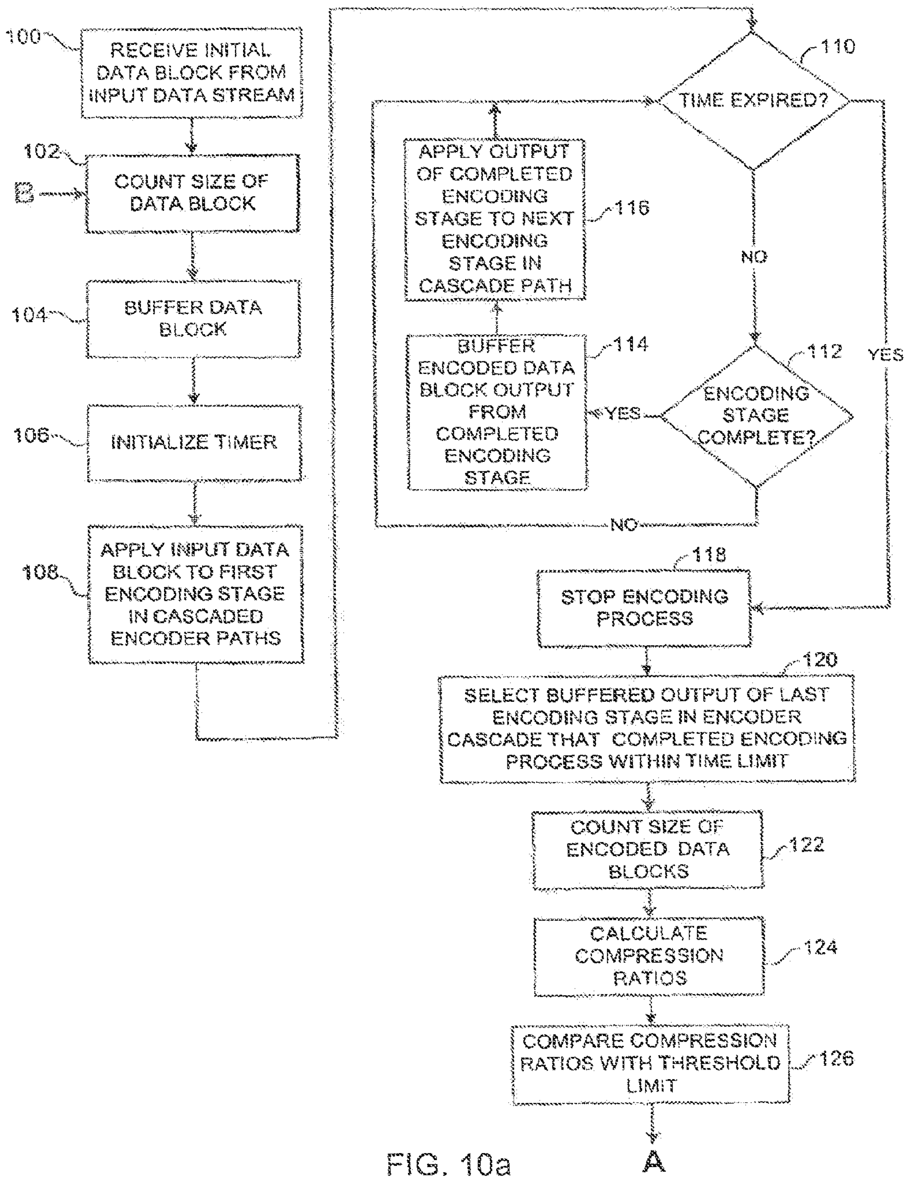

100
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
102
B
COUNT SIZE OF DATA BLOCK
104
BUFFER DATA BLOCK
106
INITIALIZE TIMER
108
APPLY INPUT DATA BLOCK TO FIRST ENCODING STAGE IN CASCADED ENCODER PATHS
110
TIME EXPIRED?
NO
YES
112
ENCODING STAGE COMPLETE?
YES
NO
114
BUFFER ENCODED DATA BLOCK OUTPUT FROM COMPLETED ENCODING STAGE
116
APPLY OUTPUT OF COMPLETED ENCODING STAGE TO NEXT ENCODING STAGE IN CASCADE PATH
118
STOP ENCODING PROCESS
120
SELECT BUFFERED OUTPUT OF LAST ENCODING STAGE IN ENCODER CASCADE THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
122
COUNT SIZE OF ENCODED DATA BLOCKS
124
CALCULATE COMPRESSION RATIOS
126
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
A

FIG. 10a

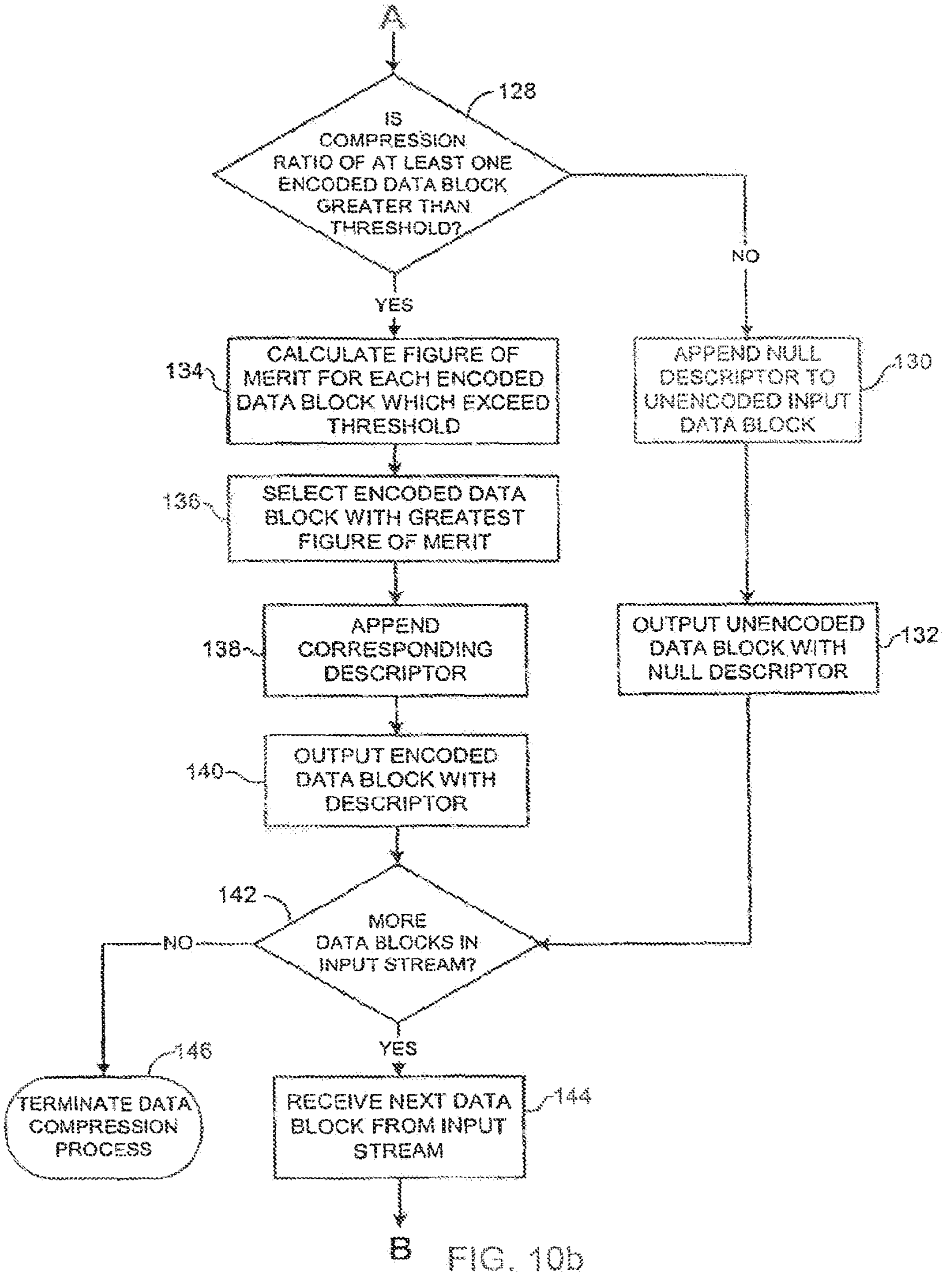

A
128
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
134
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
130
136
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
138
APPEND CORRESPONDING DESCRIPTOR
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
132
140
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
142
NO
MORE DATA BLOCKS IN INPUT STREAM?
YES
146
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
144
B

FIG. 10b

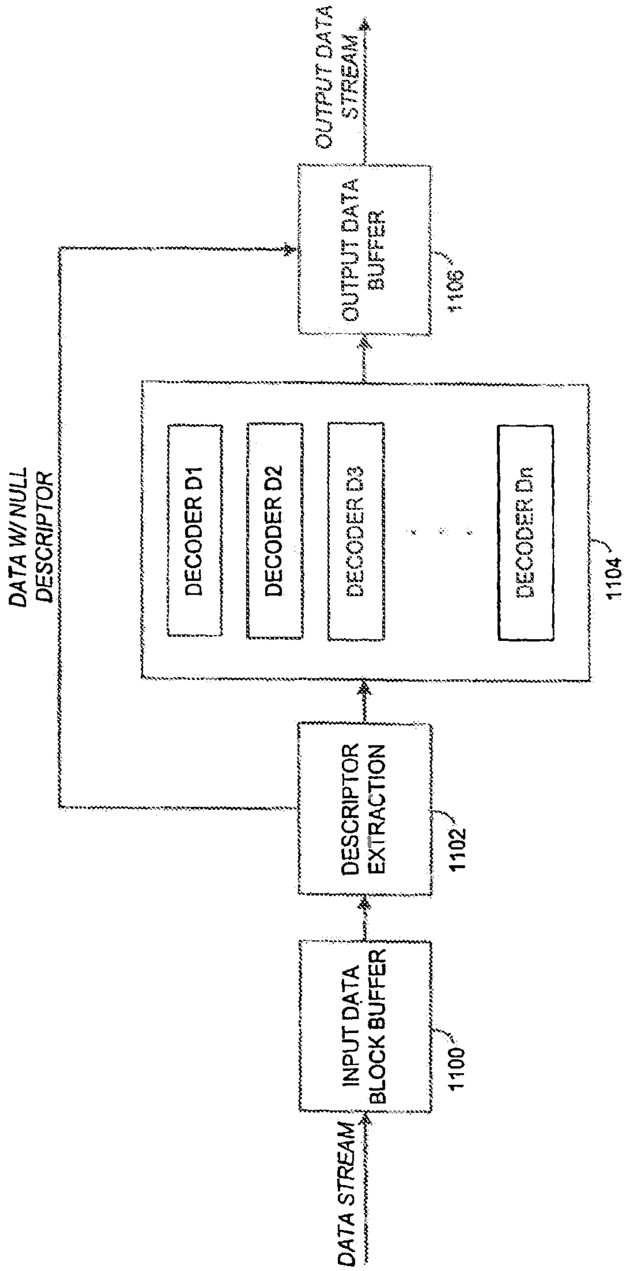

DATA STREAM
INPUT DATA BLOCK BUFFER
1100
DESCRIPTOR EXTRACTION
1102
DATA W/ NULL DESCRIPTOR
DECODER D1
DECODER D2
DECODER D3
DECODER Dn
1104
OUTPUT DATA BUFFER
1106
OUTPUT DATA STREAM

FIG. 11

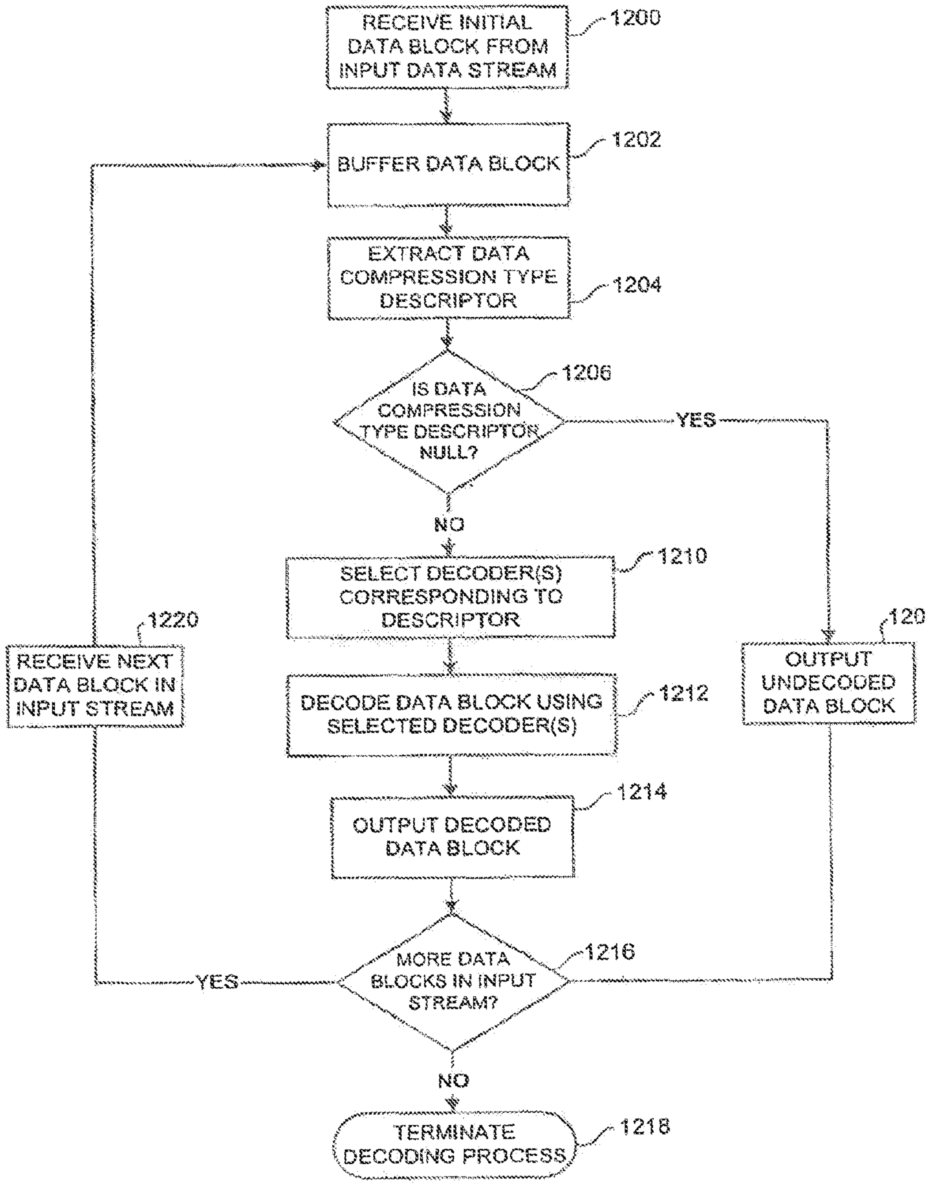
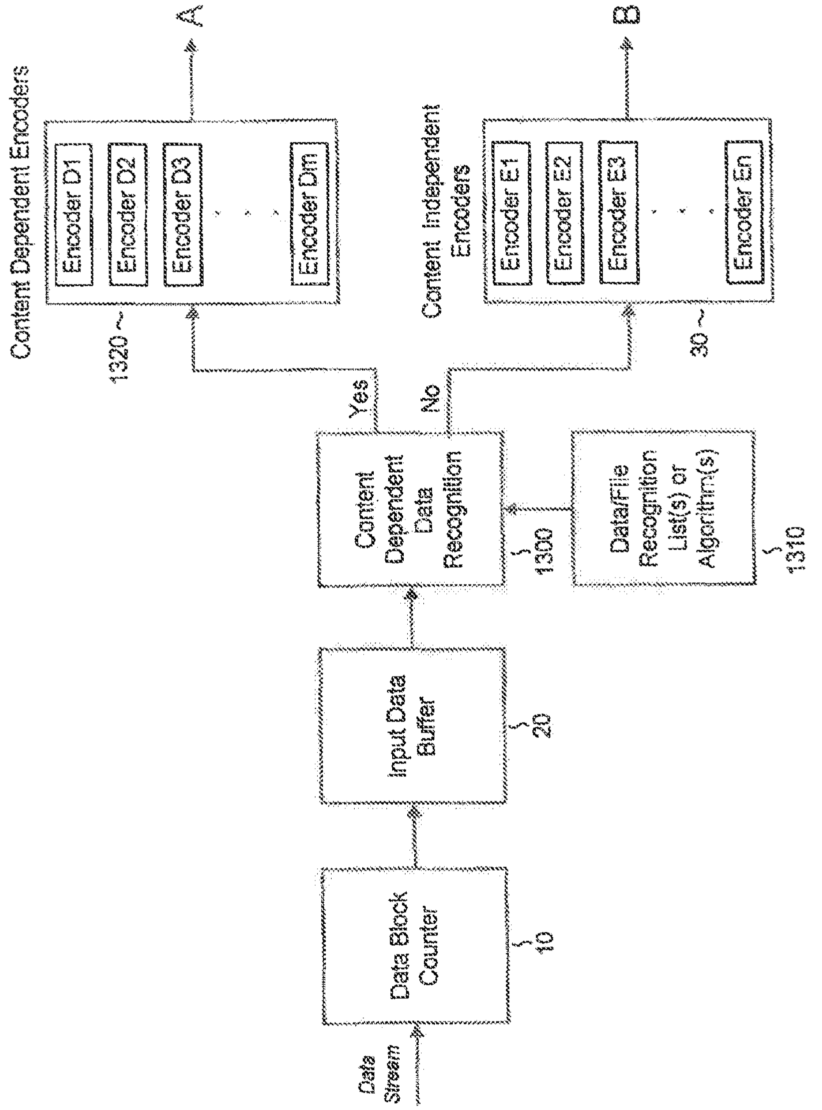

RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
1200
BUFFER DATA BLOCK
1202
EXTRACT DATA COMPRESSION TYPE DESCRIPTOR
1204
IS DATA COMPRESSION TYPE DESCRIPTOR NULL?
1206
YES
NO
SELECT DECODER(S) CORRESPONDING TO DESCRIPTOR
1210
OUTPUT UNDECODED DATA BLOCK
1208
RECEIVE NEXT DATA BLOCK IN INPUT STREAM
1220
DECODE DATA BLOCK USING SELECTED DECODER(S)
1212
OUTPUT DECODED DATA BLOCK
1214
MORE DATA BLOCKS IN INPUT STREAM?
1216
YES
NO
TERMINATE DECODING PROCESS
1218

FIG. 12



Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
Encoder En
B

FIGURE 13A

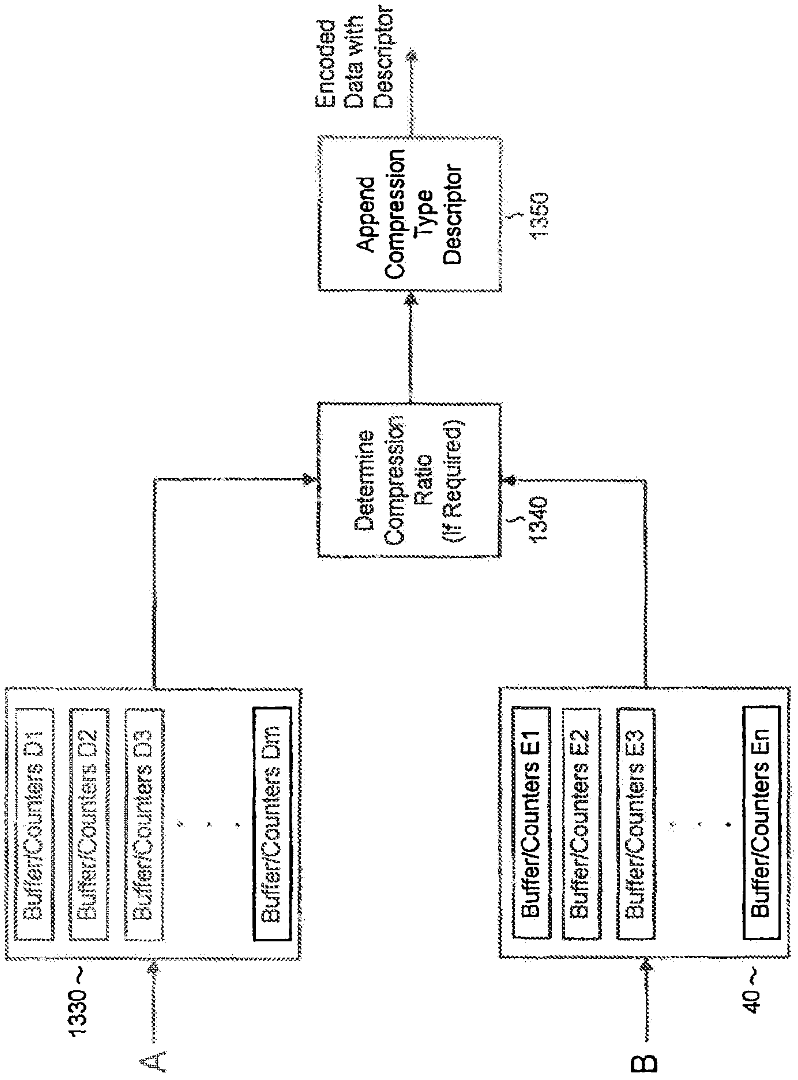

A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
B
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio (If Required)
1340
Append Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 13B

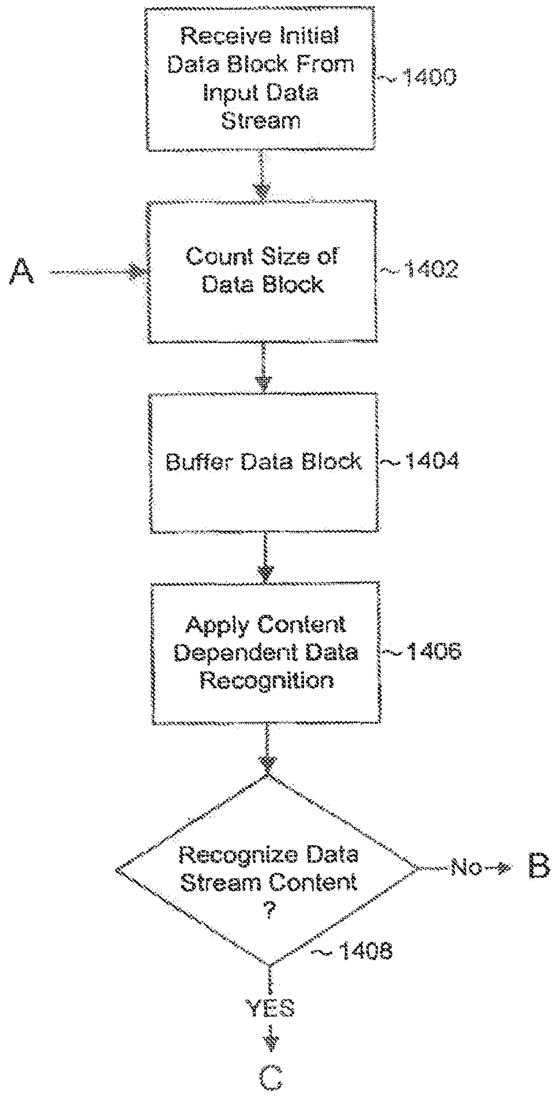

Receive Initial Data Block From Input Data Stream
1400
A
Count Size of Data Block
1402
Buffer Data Block
1404
Apply Content Dependent Data Recognition
1406
Recognize Data Stream Content ?
No
B
1408
YES
C

FIGURE 14A

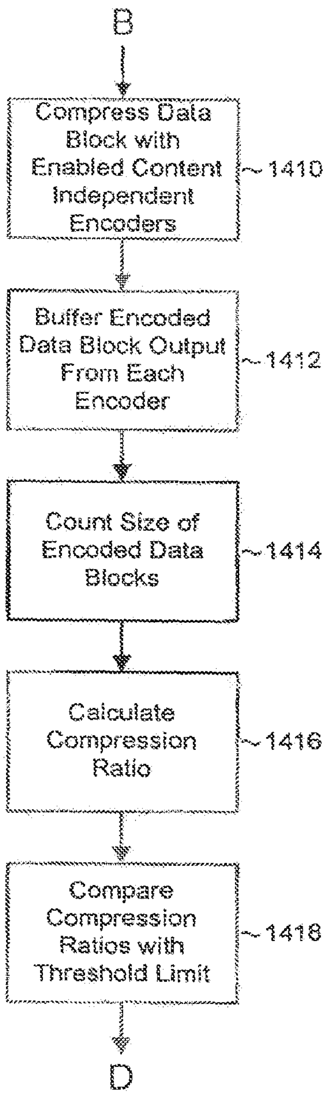

B
Compress Data Block with Enabled Content Independent Encoders
1410
Buffer Encoded Data Block Output From Each Encoder
1412
Count Size of Encoded Data Blocks
1414
Calculate Compression Ratio
1416
Compare Compression Ratios with Threshold Limit
1418
D

FIGURE 14B

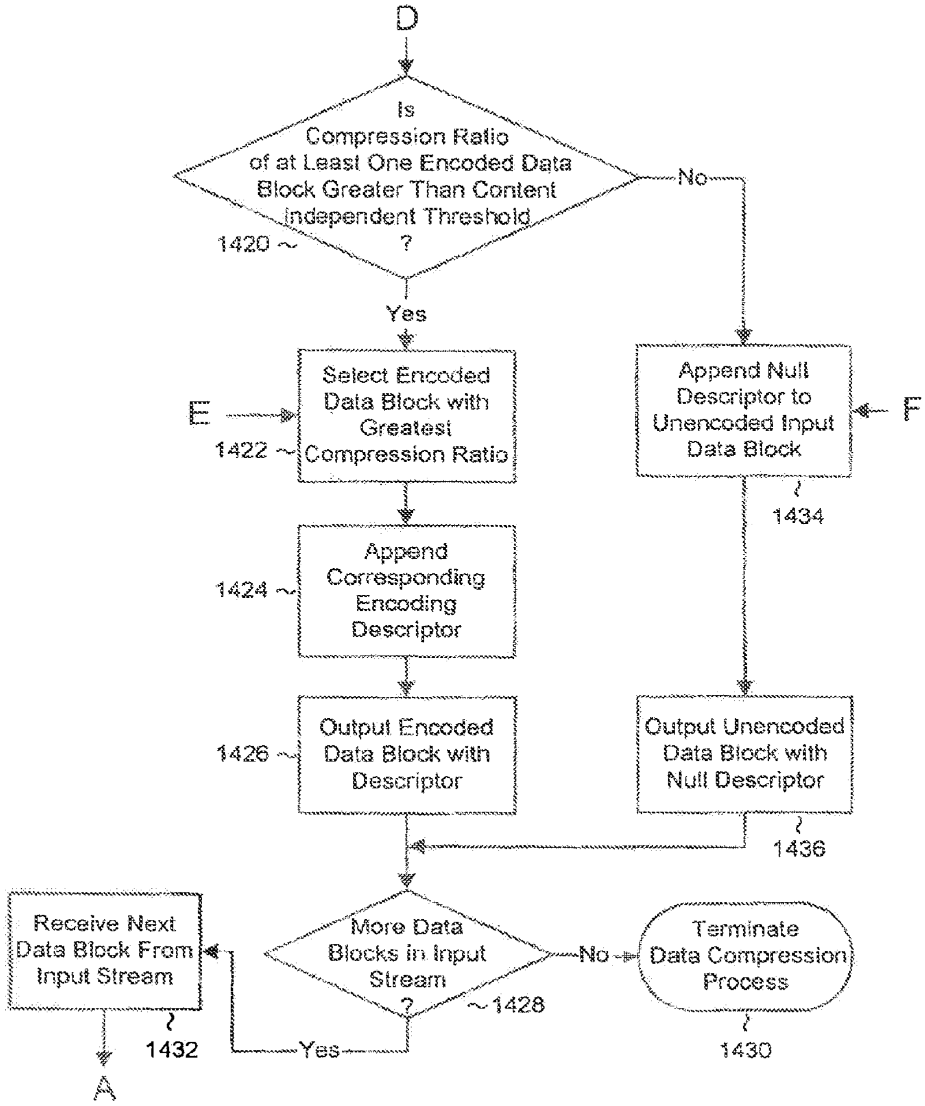

D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1420
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1422
Append Null Descriptor to Unencoded Input Data Block
F
1434
Append Corresponding Encoding Descriptor
1424
Output Encoded Data Block with Descriptor
1426
Output Unencoded Data Block with Null Descriptor
1436
Receive Next Data Block From Input Stream
1432
A
More Data Blocks in Input Stream ?
1428
Yes
No
Terminate Data Compression Process
1430

FIGURE 14C

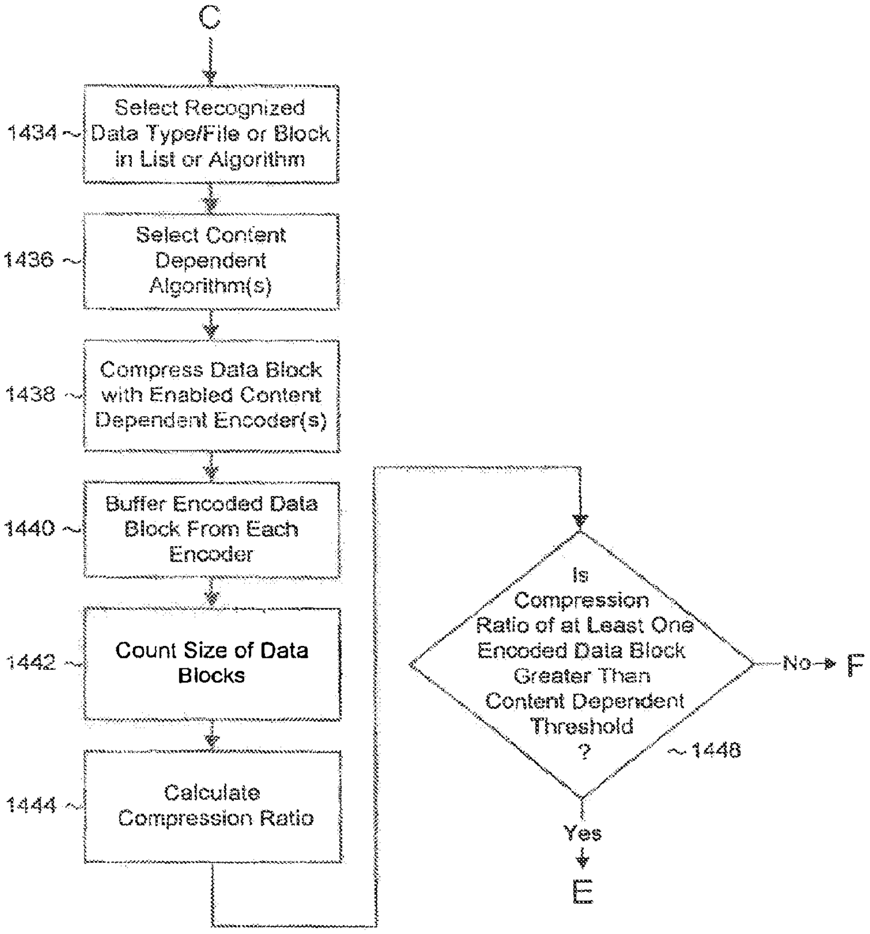

C
1434
Select Recognized Data Type/File or Block in List or Algorithm
1436
Select Content Dependent Algorithm(s)
1438
Compress Data Block with Enabled Content Dependent Encoder(s)
1440
Buffer Encoded Data Block From Each Encoder
1442
Count Size of Data Blocks
1444
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1446
No
F
Yes
E

FIGURE 14D

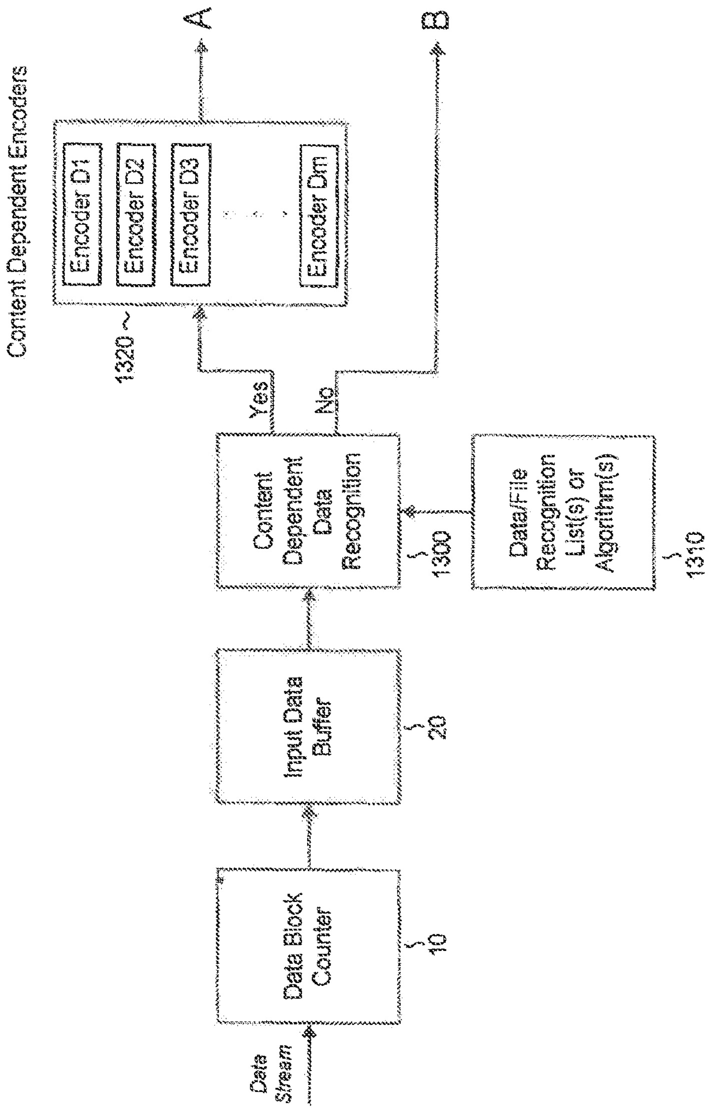

Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
A
B

FIGURE 15A

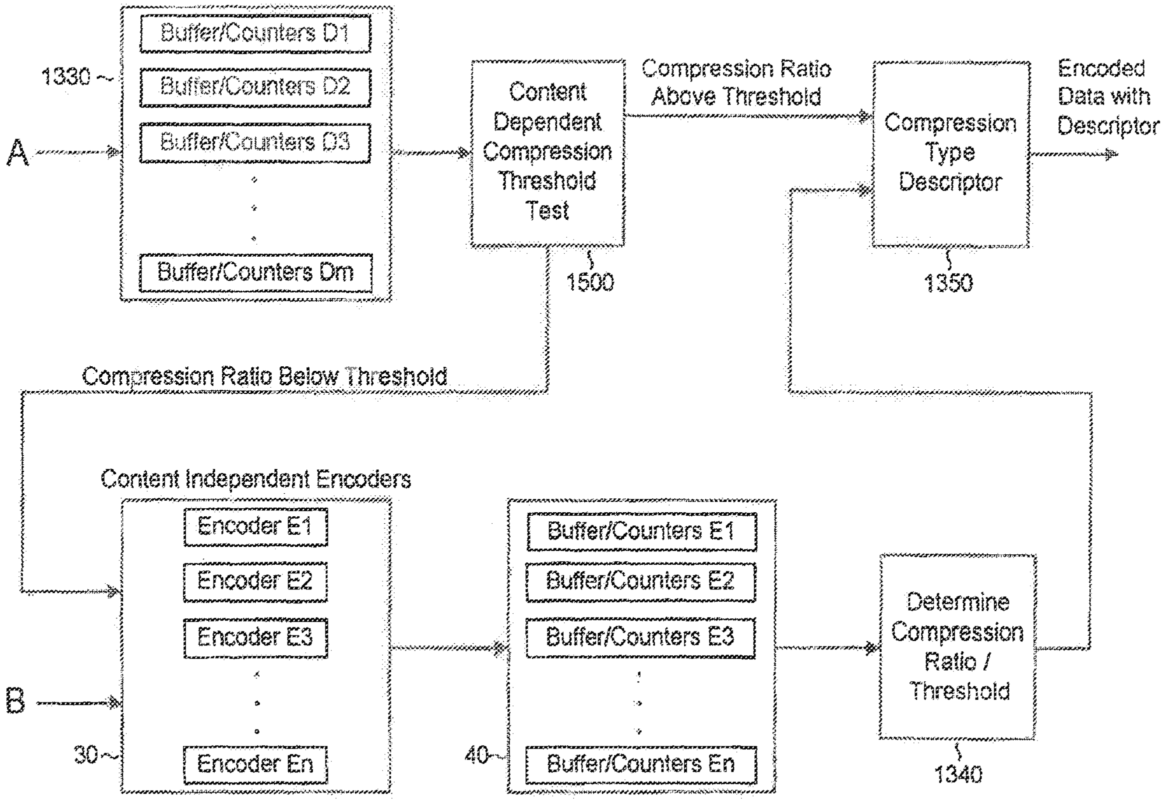

A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
Content Dependent Compression Threshold Test
1500
Compression Ratio Above Threshold
Compression Type Descriptor
1350
Encoded Data with Descriptor
Compression Ratio Below Threshold
Content Independent Encoders
B
30
Encoder E1
Encoder E2
Encoder E3
Encoder En
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio / Threshold
1340

FIGURE 15B

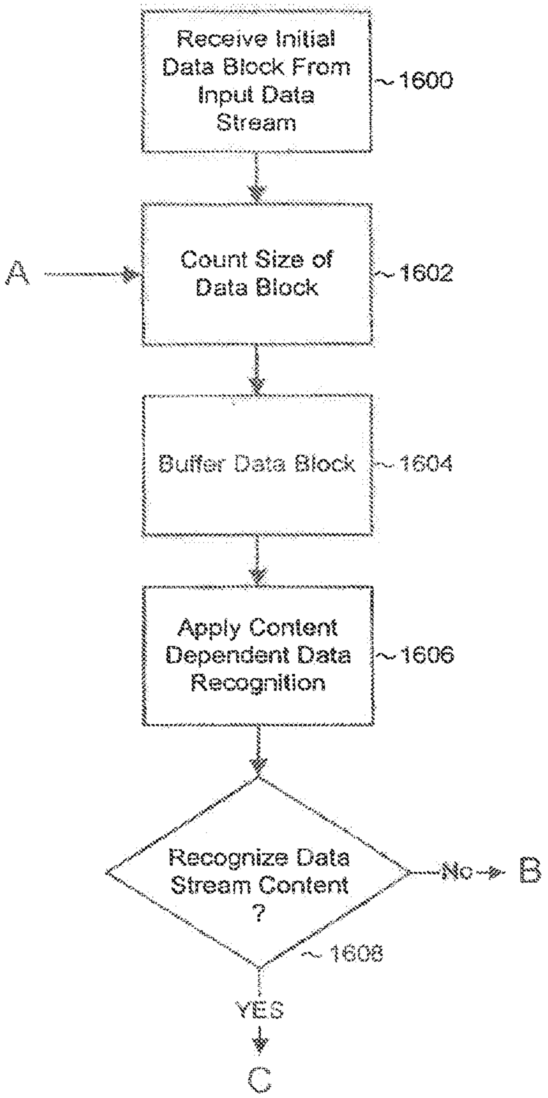

Receive Initial Data Block From Input Data Stream
1600
A
Count Size of Data Block
1602
Buffer Data Block
1604
Apply Content Dependent Data Recognition
1606
Recognize Data Stream Content ?
No
B
1608
YES
C

FIGURE 16A

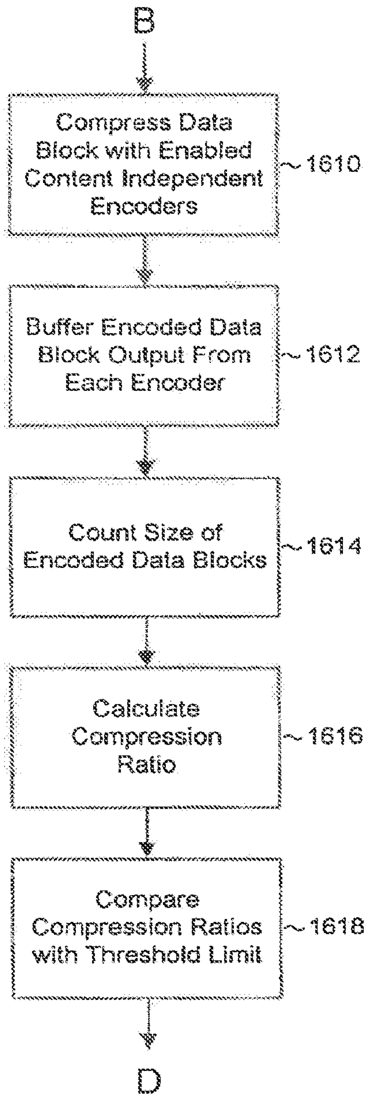

B
Compress Data Block with Enabled Content Independent Encoders
1610
Buffer Encoded Data Block Output From Each Encoder
1612
Count Size of Encoded Data Blocks
1614
Calculate Compression Ratio
1616
Compare Compression Ratios with Threshold Limit
1618
D

FIGURE 16B

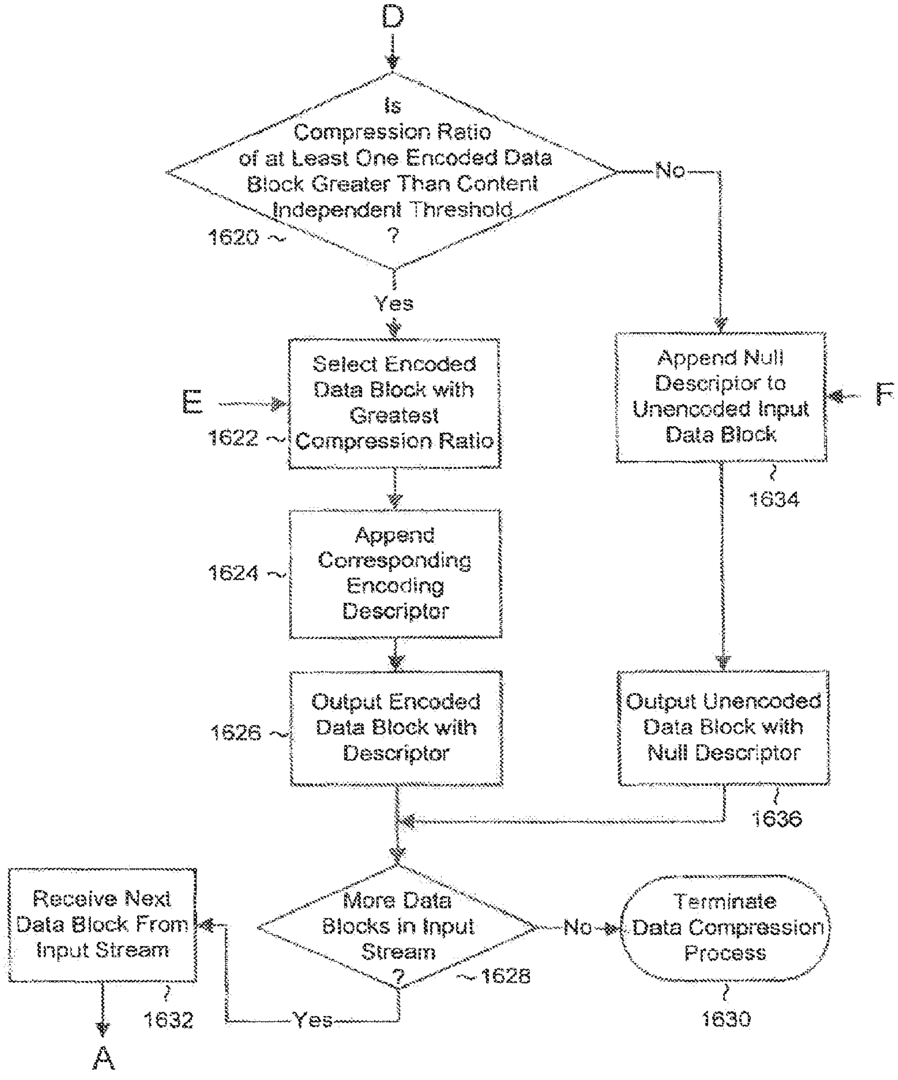

D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1620
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1622
Append Null Descriptor to Unencoded Input Data Block
F
1634
Append Corresponding Encoding Descriptor
1624
Output Encoded Data Block with Descriptor
1626
Output Unencoded Data Block with Null Descriptor
1636
Receive Next Data Block From Input Stream
More Data Blocks in Input Stream ?
1628
No
Terminate Data Compression Process
1632
Yes
1630
A

FIGURE 16C

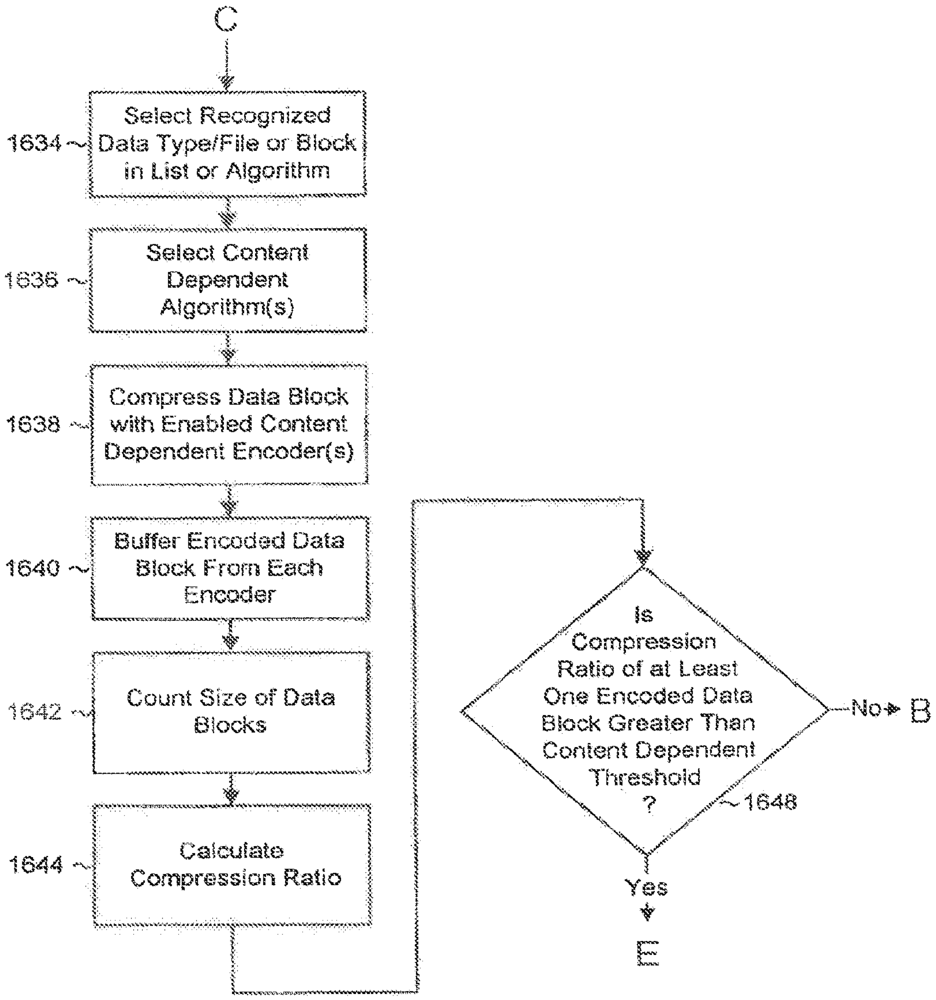

C
1634
Select Recognized Data Type/File or Block in List or Algorithm
1636
Select Content Dependent Algorithm(s)
1638
Compress Data Block with Enabled Content Dependent Encoder(s)
1640
Buffer Encoded Data Block From Each Encoder
1642
Count Size of Data Blocks
1644
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1648
No
B
Yes
E

FIGURE 16D

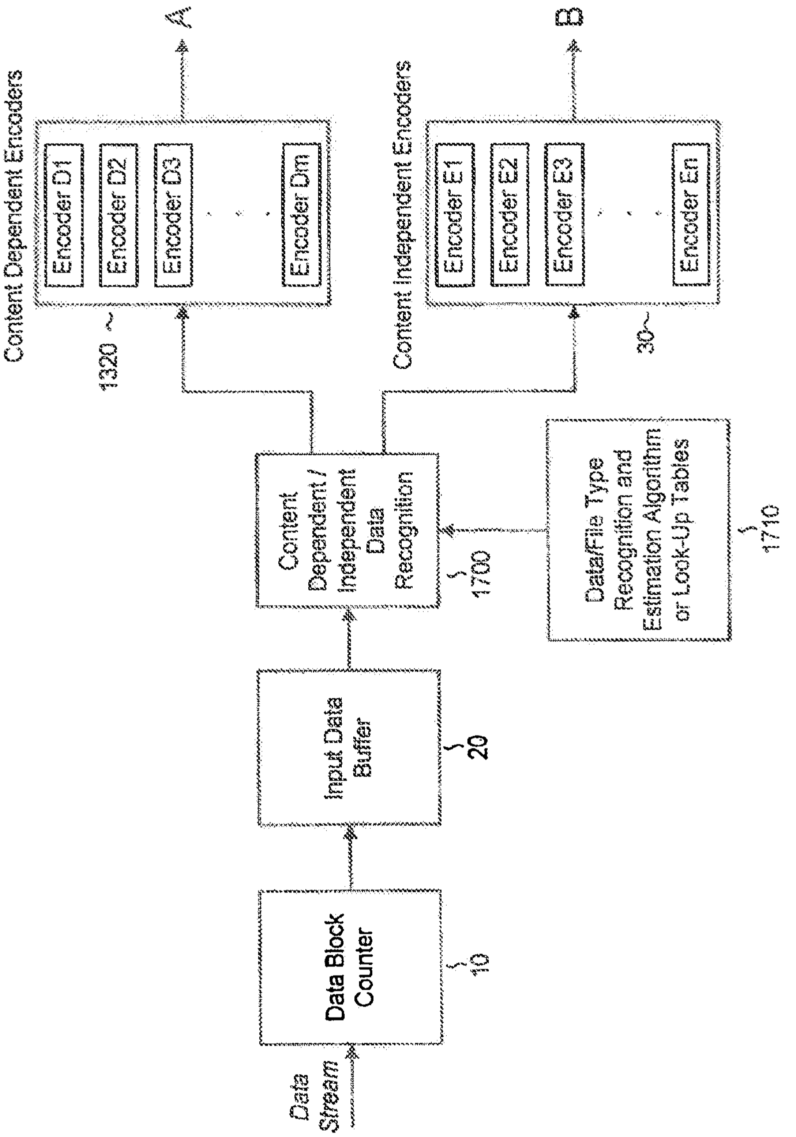

Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent / Independent Data Recognition
1700
Data/File Type Recognition and Estimation Algorithm or Look-Up Tables
1710
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
. . .
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
. . .
Encoder En
B

FIGURE 17A

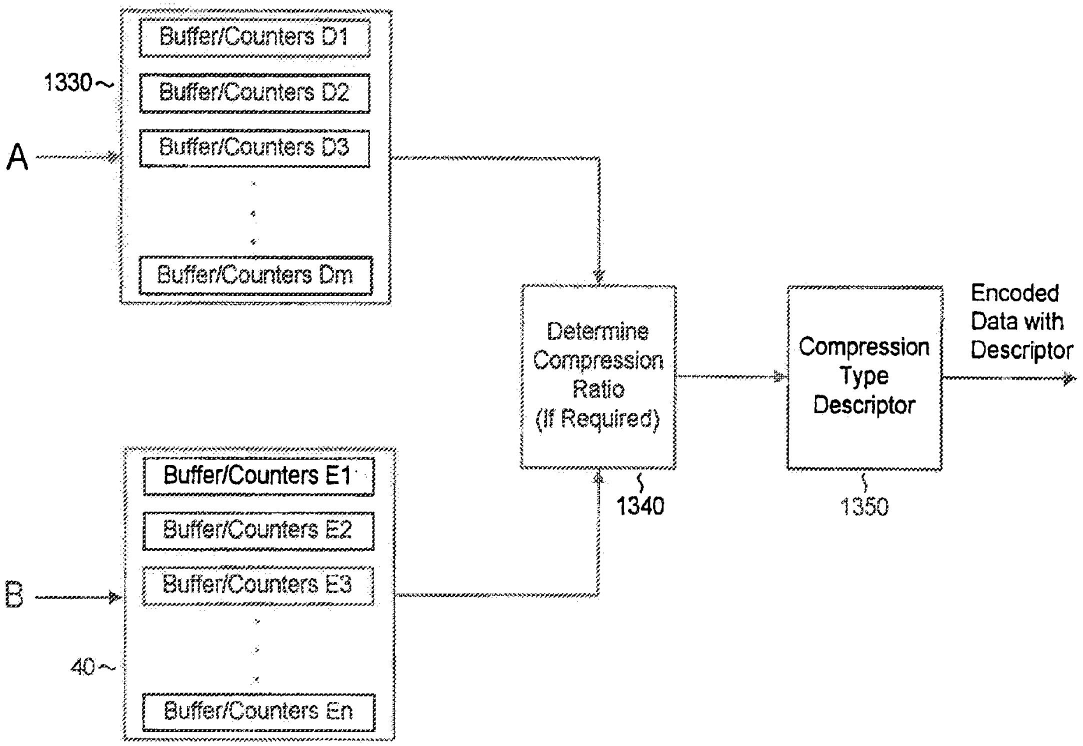

1330
A
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
B
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio (If Required)
1340
Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 17B

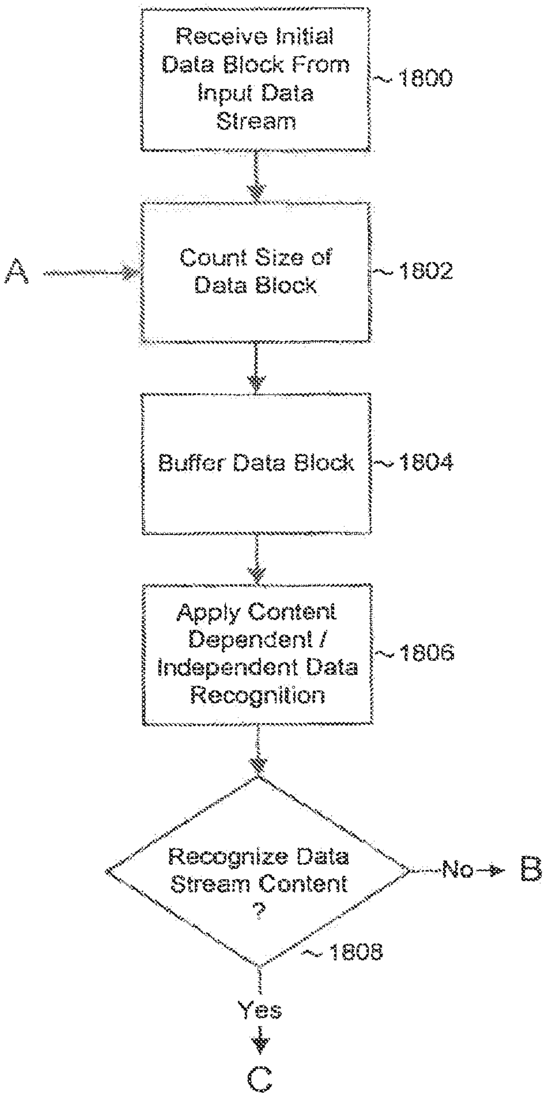

Receive Initial Data Block From Input Data Stream
1800
A
Count Size of Data Block
1802
Buffer Data Block
1804
Apply Content Dependent / Independent Data Recognition
1806
Recognize Data Stream Content ?
No
B
1808
Yes
C

FIGURE 18A

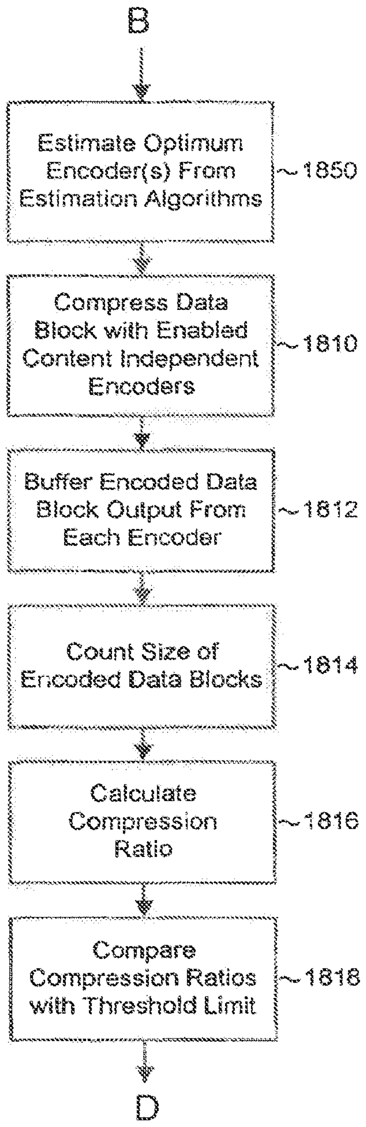

B
Estimate Optimum Encoder(s) From Estimation Algorithms
1850
Compress Data Block with Enabled Content Independent Encoders
1810
Buffer Encoded Data Block Output From Each Encoder
1812
Count Size of Encoded Data Blocks
1814
Calculate Compression Ratio
1816
Compare Compression Ratios with Threshold Limit
1818
D

FIGURE 18B

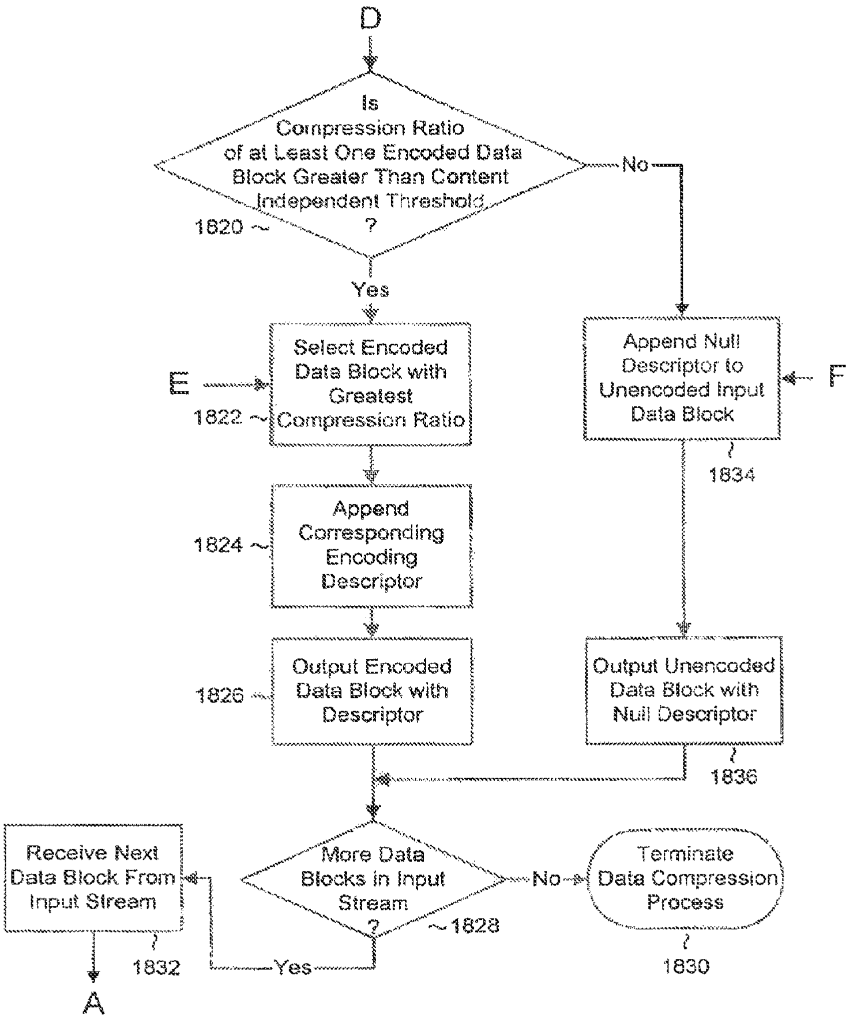

D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1820
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1822
Append Null Descriptor to Unencoded Input Data Block
F
1834
Append Corresponding Encoding Descriptor
1824
Output Encoded Data Block with Descriptor
1826
Output Unencoded Data Block with Null Descriptor
1836
More Data Blocks in Input Stream ?
1828
No
Terminate Data Compression Process
1830
Yes
Receive Next Data Block From Input Stream
1832
A

FIGURE 18C

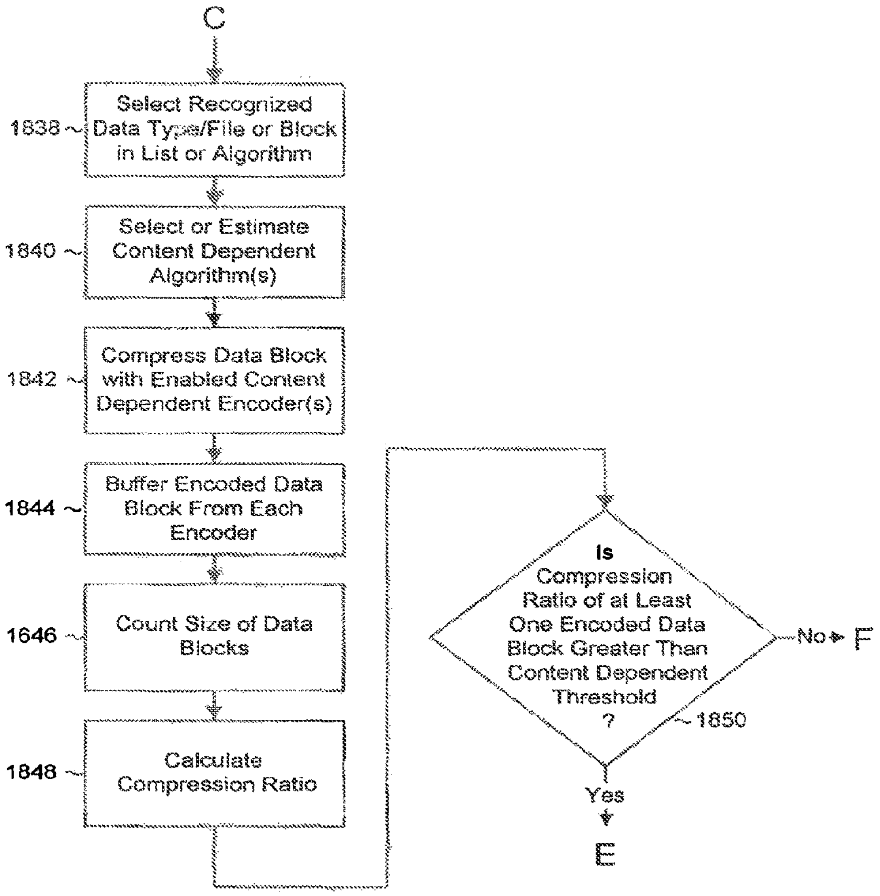

C
1838
Select Recognized Data Type/File or Block in List or Algorithm
1840
Select or Estimate Content Dependent Algorithm(s)
1842
Compress Data Block with Enabled Content Dependent Encoder(s)
1844
Buffer Encoded Data Block From Each Encoder
1646
Count Size of Data Blocks
1848
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1850
No
F
Yes
E

FIGURE 18D

DATA COMPRESSION SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 13/154,211, filed Jun. 6, 2011, which is a Continuation of U.S. patent application Ser. No. 12/703,042, filed Feb. 9, 2010, now U.S. Pat. No. 8,502,707, which is a Continuation of both U.S. patent application Ser. No. 11/651,366, filed Jan. 8, 2007, now abandoned, and U.S. patent application Ser. No. 11/651,365, filed Jan. 8, 2007, now U.S. Pat. No. 7,714,747. Each of application Ser. No. 11/651,366 and application Ser. No. 11/651,365 is a Continuation of U.S. patent application Ser. No. 10/668,768, filed Sep. 22, 2003, now U.S. Pat. No. 7,161,506, which is a Continuation of U.S. patent application Ser. No. 10/016,355, filed Oct. 29, 2001, now U.S. Pat. No. 6,624,761, which is a Continuation-In-Part of U.S. patent application Ser. No. 09/705,446, filed Nov. 3, 2000, now U.S. Pat. No. 6,309,424, which is a Continuation of U.S. patent application Ser. No. 09/210,491, filed Dec. 11, 1998, which is now U.S. Pat. No. 6,195,024. Each of the listed applications are incorporated herein by reference in their entireties.

BACKGROUND

1. Technical Field

The present invention relates generally to a data compression and decompression and, more particularly, to systems and methods for data compression using content independent and content dependent data compression and decompression.

2. Description of Related Art

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video, frequently exists in the natural world as analog information. As is well known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two

types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossless and lossy data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Entropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than the entropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the entropy of a given data set.

There are various problems associated with the use of lossless compression techniques. One fundamental problem encountered with most lossless data compression techniques are their content sensitive behavior. This is often referred to as data dependency. Data dependency implies that the compression ratio achieved is highly contingent upon the content of the data being compressed. For example, database files often have large unused fields and high data redundancies, offering the opportunity to losslessly compress data at ratios of 5 to 1 or more. In contrast, concise software programs have little to no data redundancy and, typically, will not losslessly compress better than 2 to 1.

Another problem with lossless compression is that there are significant variations in the compression ratio obtained when using a single lossless data compression technique for data streams having different data content and data size. This process is known as natural variation.

A further problem is that negative compression may occur when certain data compression techniques act upon many types of highly compressed data. Highly compressed data appears random and many data compression techniques will substantially expand, not compress this type of data.

For a given application, there are many factors that govern the applicability of various data compression techniques. These factors include compression ratio, encoding and decoding processing requirements, encoding and decoding time delays, compatibility with existing standards, and implementation complexity and cost, along with the is adaptability and robustness to variations in input data. A direct relationship exists in the current art between compression ratio and the amount and complexity of processing required. One of the limiting factors in most existing prior art lossless data compression techniques is the rate at which the encoding and decoding processes are performed. Hardware and software implementation tradeoffs are often dictated by encoder and decoder complexity along with cost.

Another problem associated with lossless compression methods is determining the optimal compression technique for a given set of input data and intended application. To combat this problem, there are many conventional content dependent techniques that may be utilized. For instance, file type descriptors are typically appended to file names to describe the application programs that normally act upon the data contained within the file. In this manner data types, data structures, and formats within a given file may be ascertained. Fundamental limitations with this content dependent technique include:

(1) the extremely large number of application programs, some of which do not possess published or documented file formats, data structures, or data type descriptors;

(2) the ability for any data compression supplier or consortium to acquire, store, and access the vast amounts of data required to identify known file descriptors and associated data types, data structures, and formats; and

(3) the rate at which new application programs are developed and the need to update file format data descriptions accordingly.

An alternative technique that approaches the problem of selecting an appropriate lossless data compression technique is disclosed, for example, in U.S. Pat. No. 5,467,087 to Chu entitled "High Speed Lossless Data Compression System" ("Chu"). FIG. **1** illustrates an embodiment of this data compression and decompression technique. Data compression **1** comprises two phases, a data pre-compression phase **2** and a data compression phase **3**. Data decompression **4** of a compressed input data stream is also comprised of two phases, a data type retrieval phase **5** and a data decompression phase **6**. During the data compression process **1**, the data pre-compressor **2** accepts an uncompressed data stream, identifies the data type of the input stream, and generates a data type identification signal. The data compressor **3** selects a data compression method from a preselected set of methods to compress the input data stream, with the intention of producing the best available compression ratio for that particular data type.

There are several limitations associated with the Chu method. One such limitation is the need to unambiguously identify various data types. While these might include such common data types as ASCII, binary, or unicode, there, in fact, exists a broad universe of data types that fall outside the three most common data types. Examples of these alternate data types include: signed and unsigned integers of various lengths, differing types and precision of floating point numbers, pointers, other forms of character text, and a multitude of user defined data types. Additionally, data types may be interspersed or partially compressed, making data type recognition difficult and/or impractical. Another limitation is that given a known data type, or mix of data types within a specific set or subset of input data, it may be difficult and/or impractical to predict which data encoding technique yields the highest compression ratio.

Accordingly, there is a need for a data compression system and method that would address limitations in conventional data compression techniques as described above.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing fast and efficient data compression using a combination of content independent data compression and content dependent data compression. In one aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

performing content independent data compression on the data block, if the data type of the data block is not identified.

In another aspect, the step of performing content independent data compression comprises: encoding the data block with a plurality of encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the encoders; comparing each of the determined compression ratios with a first compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression ratios do not meet the first compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the first compression threshold.

In another aspect, the step of performing content dependent compression comprises the steps of: selecting one or more encoders associated with the identified data type and encoding the data block with the selected encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the selected encoders; comparing each of the determined compression ratios with a second compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression do not meet the second compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the second compression threshold.

In yet another aspect, the step of performing content independent data compression on the data block, if the data type of the data block is not identified, comprises the steps of: estimating a desirability of using of one or more encoder types based one characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of performing content dependent data compression on the data block, if the data type of the data block is identified, comprises the steps of: estimating a desirability of using of one or more encoder types based on characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of analyzing the data block comprises analyzing the data block to recognize one of a data type, data structure, data block format, file substructure, and/or file types. A further step comprises maintaining an association between encoder types and data types, data structures, data block formats, file substructure, and/or file types.

In yet another aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

determining a compression ratio of the compressed data block obtained using the content dependent compression and comparing the compression ratio with a first compression threshold; and

performing content independent data compression on the data block, if the data type of the data block is not identified or if the compression ratio of the compressed data block obtained using the content dependent compression does not meet the first compression threshold.

Advantageously, the present invention employs a plurality of encoders applying a plurality of compression techniques on an input data stream so as to achieve maximum compression in accordance with the real-time or pseudo real-time data rate constraint. Thus, the output bit rate is not fixed and the amount, if any, of permissible data quality degradation is user or data specified.

These and other aspects, features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments, which is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block/flow diagram of a content dependent high-speed lossless data compression and decompression system/method according to the prior art;

FIG. **2** is a block diagram of a content independent data compression system according to one embodiment of the present invention;

FIGS. **3***a* and **3***b* comprise a flow diagram of a data compression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **2**;

FIG. **4** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an enhanced metric for selecting an optimal encoding technique;

FIGS. **5***a* and **5***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **4**;

FIG. **6** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an a priori specified timer that provides real-time or pseudo real-time of output data;

FIGS. **7***a* and **7***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **6**;

FIG. **8** is a block diagram of a content independent data compression system according to another embodiment having an a priori specified timer that provides real-time or pseudo real-time of output data and an enhanced metric for selecting an optimal encoding technique;

FIG. **9** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an encoding architecture comprising a plurality of sets of serially cascaded encoders;

FIGS. **10***a* and **10***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **9**;

FIG. **11** is block diagram of a content independent data decompression system according to one embodiment of the present invention;

FIG. **12** is a flow diagram of a data decompression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **11**;

FIGS. **13***a* and **13***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to an embodiment of the present invention;

FIGS. **14***a*-**14***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to one aspect of the present invention;

FIGS. **15***a* and **15***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention;

FIGS. **16***a*-**16***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention;

FIGS. **17***a* and **17***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention; and

FIGS. **18***a*-**18***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to systems and methods for providing data compression and decompression using content independent and content dependent data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. In particular, the system modules described herein are preferably implemented in software as an application program that is executable by, e.g., a general purpose computer or any machine or device having any suitable and preferred microprocessor architecture. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform also includes an operating system and microinstruction code. The various processes and functions described herein may be either part of the microinstruction code or application programs which are executed via the operating system. In addition, various other peripheral devices may be connected to the computer platform such as an additional data storage device and a printing device.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in which the systems are programmed. It is to be appreciated that special purpose microprocessors may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **2** a block diagram illustrates a content independent data compression system according to one embodiment of the present invention. The data compression system includes a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

An encoder module **30** is operatively connected to the buffer **20** and comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, . . . E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **30** successively receives as input each of the buffered input data blocks (or unbuffered input, data blocks from the counter module **10**). Data compression is performed by the encoder module **30** wherein each of the encoders E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks, It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the is encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block, This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **40** is operatively connected to the encoding module **30** for buffering and counting the size of each of the encoded data blocks output from encoder module **30**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **50**, operatively connected to the output buffer/counter **40**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **50** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **60**, operatively coupled to the compression ratio module **50**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

The operation of the data compression system of FIG. **2** will now be discussed in is further detail with reference to the flow diagram of FIGS. **3***a* and **3***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **300**). As stated above, data compression is performed on a per data block basis. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **302**). The data block is then stored in the buffer **20** (step **304**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **306**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **308**), and the encoded data block size is counted (step **310**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of each encoded data block output from the enabled encoders (step **312**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **314**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art.

After the compression ratios are compared with the threshold, a determination is s made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **316**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **316**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **318**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **320**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **316**), then the encoded data block having the greatest compression ratio is selected (step **322**). An appropriate data compression type descriptor is then appended (step **324**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **326**).

After the encoded data block or the unencoded data input data block is output (steps **326** and **320**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **328**). If the input data stream includes additional data blocks (affirmative result in step **328**), the next successive data block is received (step **330**), its block size is counted (return to step **302**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **328**), data compression of the input data stream is finished (step **322**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

Referring now to FIG. **4**, a block diagram illustrates a content independent data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **4** is similar to the data compression system of FIG. **2** except that the embodiment of FIG. **4** includes an enhanced metric functionality for selecting an optimal encoding technique. In particular, each of the encoders E**1** . . . En in the encoder module **30** is tagged with a corresponding one of user-selected encoder desirability factors **70**. Encoder desirability is defined as an a priori user specified factor that takes into account any number of user considerations including, but not limited to, compatibility of the encoded data with existing standards, data error robustness, or any other aggregation of factors that the user wishes to consider for a particular application. Each encoded data block output from the encoder module **30** has a corresponding desirability factor appended thereto. A figure of merit module **80**, operatively coupled to the compression ratio module **50** and the descriptor module **60**, is provided for calculating a figure of merit for each of the encoded data blocks which possess a compression ratio greater than the compression ratio threshold limit. The figure of merit for each encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor. As discussed below in further detail with reference to FIGS. **5***a* and **5***b*, the figure of merit substitutes the a priori user compression threshold limit for selecting and outputting encoded data blocks.

The operation of the data compression system of FIG. **4** will now be discussed in further detail with reference to the flow diagram of FIGS. **5***a* and **5***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **500**). The size of the first data block is then determined by the counter module **10** (step **502**). The data block is then stored in the buffer **20** (step **504**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder in the encoder set E**1** . . . En (step **506**). Each encoded data block processed in the encoder module **30** is tagged with an encoder desirability factor that corresponds the particular encoding technique applied to the encoded data block (step **508**). Upon completion of the encoding of the input data block, an encoded data block with its corresponding desirability factor is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **510**), and the encoded data block size is counted (step **512**).

Next, a compression ratio obtained by each enabled encoder is calculated by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **514**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **516**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **518**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **518**), then the original unencoded input data block is selected for output and a null data compression type descriptor (as discussed above) is appended thereto (step **520**). Accordingly, the original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **522**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **518**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **524**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected for output (step **526**). An appropriate data compression type descriptor is then appended (step **528**) to indicate the data encoding technique applied to the encoded data block. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **530**).

After the encoded data block or the unencoded input data block is output (steps **530** and **522**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **532**). If the input data stream includes additional data blocks (affirmative result in step **532**), then the next successive data block is received (step **534**), its block size is counted (return to step **502**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **532**), data compression of the input data stream is finished (step **536**).

Referring now to FIG. **6**, a block diagram illustrates a data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **6** is similar to the data compression system discussed in detail above with reference to FIG. **2** except that the embodiment of FIG. **6** includes an a priori specified timer that provides real-time or pseudo real-time output data. In particular, an interval timer **90**, operatively coupled to the encoder module **30**, is preloaded with a user specified time value. The role of the interval timer (as will be explained in greater detail below with reference to FIGS. **7***a* and **7***b*) is to limit the processing time for each input data block processed by the encoder module **30** so as to ensure that the real-time, pseudo real-time, or other time critical nature of the data compression processes is preserved.

The operation of the data compression system of FIG. **6** will now be discussed in further detail with reference to the flow diagram of FIGS. **7***a* and **7***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **700**), and its size is determined by the counter module **10** (step **702**). The data block is then stored in buffer **20** (step **704**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **706**) and starts counting towards a user-specified time limit. The input data block is then sent to the encoder module **30** wherein data compression of the data block by each (enabled) encoder E**1** . . . En commences (step **708**). Next, a determination is made as to whether the user specified time expires before the completion of the encoding process (steps **710** and **712**). If the encoding process is completed before or at the expiration of the timer, i.e., each encoder (E**1** through En) completes its respective encoding process (negative result in step **710** and affirmative result in step **712**), then an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **714**).

On the other hand, if the timer expires (affirmative result in **710**), the encoding process is halted (step **716**). Then, encoded data blocks from only those enabled encoders E**1** . . . En that have completed the encoding process are selected and maintained in buffers (step **718**). It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency and natural variation, it is possible that certain encoders may not operate quickly enough and, therefore, do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are buffered (step **714** or **718**), the size of each encoded data block is counted (step **720**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **722**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **724**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **726**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **726**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **728**). The original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **730**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **726**), then the encoded data block having the greatest compression ratio is selected (step **732**). An appropriate data compression type descriptor is then appended (step **734**). The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **736**).

After the encoded data block or the unencoded input data block is output (steps **730** or **736**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **738**). If the input data stream includes additional data blocks (affirmative result in step **738**), the next successive data block is received (step **740**), its block size is counted (return to step **702**) and the data compression process in repeated. This process is iterated for each data block in the input data stream, with each data block being processed within the user-specified time limit as discussed above. Once the final input data block is processed (negative result in step **738**), data compression of the input data stream is complete (step **742**).

Referring now to FIG. **8**, a block diagram illustrates a content independent data compression system according to another embodiment of the present system. The data compression system of FIG. **8** incorporates all of the features discussed above in connection with the system embodiments of FIGS. **2**, **4**, and **6**. For example, the system of FIG. **8** incorporates both the a priori specified timer for providing real-time or pseudo real-time of output data, as well as the enhanced metric for selecting an optimal encoding technique. Based on the foregoing discussion, the operation of the system of FIG. **8** is understood by those skilled in the art.

Referring now to FIG. **9**, a block diagram illustrates a data compression system according to a preferred embodiment of the present invention. The system of FIG. **9** contains many of the features of the previous embodiments discussed above. However, this embodiment advantageously includes a cascaded encoder module **30***c* having an encoding architecture comprising a plurality of sets of serially cascaded encoders Em,n, where "m" refers to the encoding path (i.e., the encoder set) and where "n" refers to the number of encoders in the respective path. It is to be understood that each set of serially cascaded encoders can include any number of disparate and/or similar encoders (i.e., n can be any value for a given path m).

The system of FIG. **9** also includes a output buffer module **40***c* which comprises a plurality of buffer/counters B/Cm,n, each associated with a corresponding one of the encoders Em,n. In this embodiment, an input data block is sequentially applied to successive encoders (encoder stages) in the encoder path so as to increase the data compression ratio. For example, the output data block from a first encoder E**1**,**1**, is buffered and counted in B/C**1**,**1**, for subsequent processing by a second encoder E**1**,**2**. Advantageously, these parallel sets of sequential encoders are applied to the input data stream to effect content free lossless data compression. This embodiment provides for multi-stage sequential encoding of data with the maximum number of encoding steps subject to the available real-time, pseudo real-time, or other timing constraints.

As with each previously discussed embodiment, the encoders Em,n may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Encoding techniques are selected based upon their ability to effectively encode different types of input data. A full complement of encoders provides for broad coverage of existing and future data types. The input data blocks may be applied simultaneously to the encoder paths (i.e., the encoder paths may operate in parallel, utilizing task multiplexing on a single central processor, or via dedicated hardware, or by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, an input data block may be sequentially applied to the encoder paths. Moreover, each serially cascaded encoder path may comprise a fixed (predetermined) sequence of encoders or a random sequence of encoders. Advantageously, by simultaneously or sequentially processing input data blocks via a plurality of sets of serially cascaded encoders, content free data compression is achieved.

The operation of the data compression system of FIG. **9** will now be discussed in further detail with reference to the flow diagram of FIGS. **10***a* and **10***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **100**), and its size is determined by the counter module **10** (step **102**). The data block is then stored in buffer **20** (step **104**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **106**) and starts counting towards a user-specified time limit. The input data block is then sent to the cascade encoder module **30**C wherein the input data block is applied to the first encoder (i.e., first encoding stage) in each of the cascaded encoder paths E**1**,**1** . . . Em,**1** (step **108**). Next, a determination is made as to whether the user specified time expires before the completion of the first stage encoding process (steps **110** and **112**). If the first stage encoding process is completed before the expiration of the timer, i.e., each encoder (E**1**,**1** . . . Em,**1**) completes its respective encoding process (negative result in step **110** and affirmative result in step **112**), then an encoded data block is output from each encoder E**1**,**1** . . . Em,**1** and maintained in a corresponding buffer (step **114**). Then for each cascade encoder path, the output of the completed encoding stage is applied to the next successive encoding stage in the cascade path (step **116**). This process (steps **110**, **112**, **114**, and **116**) is repeated until the earlier of the timer expiration (affirmative result in step **110**) or the completion of encoding by each encoder stage in the serially cascaded paths, at which time the encoding process is halted (step **118**).

Then, for each cascade encoder path, the buffered encoded data block output by the last encoder stage that completes the encoding process before the expiration of the timer is selected for further processing (step **120**). Advantageously, the interim stages of the multi-stage data encoding process are preserved. For example, the results of encoder E**1**,**1** are preserved even after encoder E**1**,**2** begins encoding the output of encoder E**1**,**1**. If the interval timer expires after encoder E**1**,**1** completes its respective encoding process but before encoder E**1**,**2** completes its respective encoding process, the encoded data block from encoder E**1**,**1** is complete and is utilized for calculating the compression ratio for the corresponding encoder path. The incomplete encoded data block from encoder E**1**,**2** is either discarded or ignored.

It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders in the cascade encoder paths complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency, natural variation and the sequential application of the cascaded encoders, it is possible that certain encoders may not operate quickly enough and therefore do not comply with the timing constraints of the end use. Accordingly, the time limit, ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are selected (step **120**), the size of each encoded data block is counted (step **122**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each encoder (step **124**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **126**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **128**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **128**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **130**). The original unencoded data block and its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **132**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **128**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **134**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected (step **136**). An appropriate data compression type descriptor is then appended (step **138**) to indicate the data encoding technique applied to the encoded data block. For instance, the data type compression descriptor can indicate that the encoded data block was processed by either a single encoding type, a plurality of sequential encoding types, and a plurality of random encoding types. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **140**).

After the unencoded data block or the encoded data input data block is output (steps **132** and **140**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **142**). If the input data stream includes additional data blocks (affirmative result in step **142**), then the next successive data block is received (step **144**), its block size is counted (return to step **102**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **142**), data compression of the input data stream is finished (step **146**).

Referring now to FIG. **11**, a block diagram illustrates a data decompression system according to one embodiment of the present invention. The data decompression system preferably includes an input buffer **1100** that receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **1100** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **1102** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **1104** includes a plurality of decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source. As with the data compression systems discussed above, the decoder module **1104** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time.

The data decompression system also includes an output data buffer **1106** for buffering the decoded data block output from the decoder module **1104**.

The operation of the data decompression system of FIG. **11** will be discussed in further detail with reference to the flow diagram of FIG. **12**. A data stream comprising one or more data blocks of compressed or uncompressed data is input into the data decompression system and the first data block in the stream is received (step **1200**) and maintained in the buffer (step **1202**). As with the data compression systems discussed above, data decompression is performed on a per data block basis. The data compression type descriptor is then extracted from the input data block (step **1204**). A determination is then made as to whether the data compression type descriptor is null (step **1206**). If the data compression type descriptor is determined to be null (affirmative result in step **1206**), then no decoding is applied to the input data block and the original undecoded data block is output (or maintained in the output buffer) (step **1208**).

On the other hand, if the data compression type descriptor is determined to be any value other than null (negative result in step **1206**), the corresponding decoder or decoders are then selected (step **1210**) from the available set of decoders D**1** . . . Dn in the decoding module **1104**. It is to be understood that the data compression type descriptor may mandate the application of: a single specific decoder, an ordered sequence of specific decoders, a random order of specific decoders, a class or family of decoders, a mandatory or optional application of parallel decoders, or any combination or permutation thereof. The input data block is then decoded using the selected decoders (step **1212**), and output (or maintained in the output buffer **1106**) for subsequent data processing, storage, or transmittal (step **1214**). A determination is then made as to whether the input data stream contains additional data blocks to be processed (step **1216**). If the input data stream includes additional data blocks (affirmative result in step **1216**), the next successive data block is received (step **1220**), and buffered (return to step **1202**). Thereafter, the data decompression process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1216**), data decompression of the input data stream is finished (step **1218**).

In other embodiments of the present invention described below, data compression is achieved using a combination of content dependent data compression and content independent data compression. For example, FIGS. **13***a* and **13***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to one embodiment of the present invention, wherein content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The data compression system comprises a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds a priori specified content independent or content dependent minimum compression ratio thresholds. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

A content dependent data recognition module **1300** analyzes the incoming data stream to recognize data types, data structures, data block formats, file substructures, file types, and/or any other parameters that may be indicative of either the data type/content of a given data block or the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1310** module may be employed to hold and/or determine associations between recognized data parameters and appropriate algorithms. Each data block that is recognized by the content data compression module **1300** is routed to a content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**.

A content dependent encoder module **1320** is operatively connected to the content dependent data recognition module **1300** and comprises a set of encoders D**1**, D**2**, D**3** . . . Dm. The encoder set D**1**, D**2**, D**3** . . . Dm may include any number “n” of those lossless or lossy encoding techniques currently well known within the art such as MPEG4, various voice codecs, MPEG3, AC3, AAC, as well as lossless algorithms such as run length, Huffinan, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders and or codecs are preferably selected to provide a broad coverage of existing and future data types.

The content independent encoder module **30**, which is operatively connected to the content dependent data recognition module **1300**, comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number “n” of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Again, it is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder modules (content dependent **1320** and content independent **30**) selectively receive the buffered input data blocks (or unbuffered input data blocks from the counter module **10**) from module **1300** based on the results of recognition. Data compression is performed by the respective encoder modules wherein some or all of the encoders D**1** . . . Dm or E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders D**1** . . . Dm and E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoder set D1 through Dm of encoder module **1320** and/or the encoder set E1 through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders D**1** through Dm and E**1** through Fn may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E1 may comprise two parallel Huffman encoders for parallel processing of an input data block. It should be further noted that one or more algorithms may be implemented in dedicated hardware such as an MPEG4 or MP3 encoding integrated circuit.

Buffer/counter modules **1330** and **40** are operatively connected to their respective encoding modules **1320** and **30**, for buffering and counting the size of each of the encoded data blocks output from the respective encoder modules. Specifically, the content dependent buffer/counter **1330** comprises a plurality of buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm, each operatively associated with a corresponding one of the encoders D**1** . . . Dm. Similarly the content independent buffer/counters BCE**1**, BCE**2**, BCE**3** . . . BCEn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **1340**, operatively connected to the content dependent output buffer/counters **1330** and content independent buffer/counters **40** determines the compression ratio obtained for each of the enabled encoders D**1** . . . Dm and or E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn. In addition, the compression ratio module **1340** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn achieves a compression that meets an a priori-specified threshold. As is. understood by those skilled in the art, the threshold limit maybe specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It should be noted that different threshold values may be applied to content dependent and content independent encoded data. Further these thresholds may be adaptively modified based upon enabled encoders in either or both the content dependent or content independent encoder sets, along with any associated parameters. A compression type description module **1350**, operatively coupled to the compression ratio module **1340**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

A mode of operation of the data compression system of FIGS. **13***a* and **13***b* will now be discussed with reference to the flow diagrams of FIGS. **14***a*-**14***d* which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. In general, content independent data compression is applied to a given data block when the content of a data block cannot be identified or is not associated with a specific data compression algorithm. More specifically, referring to FIG. **14***a*, a data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1400**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1402**). The data block is then stored in the buffer **20** (step **1404**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1408**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1410**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1412**), and the encoded data block size is counted (step **1414**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1416**). Each compression ratio is then compared with an apriori-specified compression ratio threshold (step **1418**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

As previously stated the data block stored in the buffer **20** (step **1404**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1434**) the appropriate content dependent algorithms are enabled and initialized (step **1436**), and the data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1438**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1440**), and the encoded data block size is counted (step **1442**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1444**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1448**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

After the encoded data block or the unencoded data input data block is output (steps **1426** and **1436**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1428**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1432**), its block size is counted (return to step **1402**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1428**), data compression of the input data stream is finished (step **1430**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. Further the encoding may be lossy or lossless dependent upon the input data types. Further if the data type is not recognized the default content independent lossless compression is applied. It is not a requirement that this process be deterministic—in fact a certain probability may be applied if occasional data loss is permitted. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

FIGS. **15***a* and **15***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **15***a* and **15***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **15***a* and **15***b* additionally performs content independent data compression on a data block when the compression ratio obtained for the data block using the content dependent data compression does not meet a specified threshold.

A mode of operation of the data compression system of FIGS. **15***a* and **15***b* will now be discussed with reference to the flow diagram of FIGS. **16***a*-**16***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1600**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1602**). The data block is then stored in the buffer **20** (step **1604**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1608**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1610**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1612**), and the encoded data block size is counted (step **1614**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1616**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1618**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1620**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1634**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1636**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1620**), then the encoded data block having the greatest compression ratio is selected (step **1622**). An appropriate data compression type descriptor is then appended (step **1624**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1626**).

As previously stated the data block stored in the buffer **20** (step **1604**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1634**) the appropriate content dependent algorithms are enabled and initialized (step **1636**) and the data is routed to the content dependent encoder module **1620** and compressed by each (enabled) encoder D**1** . . . Dm (step **1638**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1640**), and the encoded data block size is counted (step **1642**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1644**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1648**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1648**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is routed to the content independent encoder module **30** and the process resumes with compression utilizing content independent encoders (step **1610**).

After the encoded data block or the unencoded data input data block is output (steps **1626** and **1636**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1628**). If the input data stream includes additional data blocks (affirmative result in step **1628**), the next successive data block is received (step **1632**), its block size is counted (return to step **1602**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1628**), data compression of the input data stream is finished (step **1630**).

FIGS. **17***a* and **17***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **17***a* and **17***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data Nock cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **17***a* and **17***b* additionally uses a priori estimation algorithms or look-up tables to estimate the desirability of using content independent data compression encoders and/or content dependent data compression encoders and selecting appropriate algorithms or subsets thereof based on such estimation.

More specifically, a content dependent data recognition and or estimation module **1700** is utilized to analyze the incoming data stream for recognition of data types, data strictures, data block formats, file substructures, file types, or any other parameters that may be indicative of the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1710** module may be employed to hold associations between recognized data parameters and appropriate algorithms. If the content data compression module recognizes a portion of the data, that portion is routed to the content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**. It is to be appreciated that process of recognition (modules **1700** and **1710**) is not limited to a deterministic recognition, but may further comprise a probabilistic estimation of which encoders to select for compression from the set of encoders of the content dependent module **1320** or the content independent module **30**. For example, a method may be employed to compute statistics of a data block whereby a determination that the locality of repetition of characters in a data stream is determined is high can suggest a text document, which may be beneficially compressed with a lossless dictionary type algorithm. Further the statistics of repeated characters and relative frequencies may suggest a specific type of dictionary algorithm. Long strings will require a wide dictionary file while a wide diversity of strings may suggest a deep dictionary. Statistics may also be utilized in algorithms such as Huffman where various character statistics will dictate the choice of different Huffinan compression tables. This technique is not limited to lossless algorithms but may be widely employed with lossy algorithms. Header information in frames for video files can imply a specific data resolution. The estimator then may select the appropriate lossy compression algorithm and compression parameters (amount of resolution desired). As shown in previous embodiments of the present invention, desirability of various algorithms and now associated resolutions with lossy type algorithms may also be applied in the estimation selection process.

A mode of operation of the data compression system of FIGS. **17***a* and **17***b* will now be discussed with reference to the flow diagrams of FIGS. **18***a*-**18***d*. The method of FIGS. **18***a*-**18***d* use a priori estimation algorithms or look-up tables to estimate the desirability or probability of using content independent data compression encoders or content dependent data compression encoders, and select appropriate or desirable algorithms or subsets thereof based on such estimates. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1800**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1802**). The data block is then stored in the buffer **20** (step **1804**). The data block is then analyzed on a per block or multi-block basis by the content dependent/content independent data recognition module **1700** (step **1806**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1710** (step **1808**) the data is to the content independent encoder module **30**. An estimate of the best content independent encoders is performed (step **1850**) and the appropriate encoders are enabled and initialized as applicable. The data is then compressed by each (enabled) encoder E**1** . . . En (step **1810**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1812**), and the encoded data block size is counted (step **1814**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1816**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1818**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

As previously stated the data block stored in the buffer **20** (step **1804**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1806**). If the data stream content is recognized or estimated utilizing the recognition list(s) or algorithms(s) module **1710** (affirmative result in step **1808**) the recognized data type/file or block is selected based on a list or algorithm (step **1838**) and an estimate of the desirability of using the associated content dependent algorithms can be determined (step **1840**). For instance, even though a recognized data type may be associated with three different encoders, an estimation of the desirability of using each encoder may result in only one or two of the encoders being actually selected for use. The data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1842**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1844**), and the encoded data block size is counted (step **1846**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1848**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1850**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

After the encoded data block or the unencoded data input data block is output (steps **1826** and **1836**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1828**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1832**), its block size is counted (return to step **1802**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1828**), data compression of the input data stream is finished (step **1830**).

It is to be appreciated that in the embodiments described above with reference to FIGS. **13-18**, an a priori specified time limit or any other real-time requirement may be employed to achieve practical and efficient real-time operation.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A method of decompressing in a data decompression engine one or more compressed data blocks included in one or more data packets, the one or more data packets being transmitted in sequence from one of an internal or an external source to the data decompression engine, wherein a data packet from among the one or more data packets comprises a header containing control information followed by one or more compressed data blocks of the data packet,the method comprising:

applying a plurality of decompression techniques to the one or more compressed data blocks using the data decompression engine;

identifying one or more associated recognizable data tokens of the data packet;

wherein the one or more associated recognizable data tokens identifies a selected compression encoder used to compress the one or more compressed data blocks associated with the data packet; and

wherein the selected compression encoder was selected based on content of a data block on which a compression algorithm was applied to provide the compressed data block;

applying one or more decompression decoders to the compressed data block corresponding to the data packet based on the one or more associated recognizable data tokens;

decompressing the compressed data block with an appropriate decompression decoder if the one or more associated recognizable data tokens indicates that the data block was encoded utilizing content dependent data compression; and

decompressing the compressed data block with an appropriate decompression decoder if the one or more associated recognizable data tokens indicates that the data block was encoded utilizing content independent data compression.

2. The method of claim **1**, wherein the decompressing is performed by an entity different than the compression encoder performing the compression.

3. The method of claim **1**, wherein the one or more recognizable data tokens include values corresponding to one or more decoding techniques to be applied by the one or more decompression decoders.

4. The method of claim **1**, wherein the step of decompressing the compressed data block with the appropriate decompression decoder, when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content independent data compression occurs prior to the step of decompressing the compressed data block with the appropriate decompression decoder, when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content dependent data compression.

5. The method of claim **1**, wherein:

the applying the one or more data compression decoders includes applying a plurality of data compression decoders; and

the applying the one or more decompression decoders further includes applying a plurality of the one or more decompression decoders to decompress a plurality of compressed data blocks from among the one or more compressed data blocks corresponding to the data packet.

6. The method of claim **5**, wherein the applying the one or more decompression decoders further includes:

applying a plurality of the one or more decompression decoders to decompress a plurality of the one or more data packets to provide a plurality of decompressed data packets.

7. The method of claim **6**, further comprising:

generating one or more decompressed data blocks in sequence from the plurality of decompressed data packets.

8. The method of claim **1**, wherein the method of decompressing the one or more compressed data blocks is performed in real-time.

9. The method of claim **1**, wherein the one or more decompression decoders and their associated compression encoders utilize techniques to permit data that was selected and compressed by the selected compression encoder to be fully recovered when decompressed by the one or more decompression decoders.

10. The method of claim **1**, wherein the one or more decompression decoders and their associated compression encoders utilize lossy techniques.

11. The method of claim **1**, wherein the appropriate decompression decoder selected when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content independent data compression applies a different decompression algorithm than the appropriate decompression decoder selected when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content dependent data compression.

12. The method of claim **1**, wherein the appropriate decompression decoder selected when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content independent data compression applies the same decompression algorithm than the appropriate decompression decoder selected when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content dependent data compression.

13. The method of claim **1**, wherein the appropriate decompression decoder selected when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content independent data compression is the same decompression decoder as the appropriate decompression decoder selected when the one or more recognizable data tokens indicate that the compressed data block was encoded utilizing content dependent data compression.

14. A system for decompressing, one or more compressed data blocks included in one or more data packets using a data decompression engine, the one or more data packets being transmitted in sequence from a source that is internal or external to the data decompression engine, wherein a data packet from among the one or more data packets comprises a header containing control information followed by one or more compressed data blocks of the data packet the system comprising:

a data decompression processor configured to analyze the data packet to identify one or more recognizable data tokens associated with the data packet, the one or more recognizable data identifying a selected encoder used to compress one or more data blocks to provide the one or more compressed data blocks, the encoder being selected based on content of the one or more data blocks on which a compression algorithm was applied;

one or more decompression decoders configured to decompress a compressed data block from among the one or more compressed data blocks associated with the data packet based on the one or more recognizable data tokens; wherein:

the one or more decompression decoders are further configured to decompress the compressed data block utilizing content dependent data decompression to provide a first decompressed data block when the one or more recognizable data tokens indicate that the data block was encoded utilizing content dependent data compression; and

the one or more decompression decoders are further configured to decompress the compressed data block utilizing content independent data decompression to provide a second decompressed data block when the one or more recognizable data tokens indicate that the data block was encoded utilizing content independent data compression; and

an output interface, coupled to the data decompression engine, configured to output a decompressed data packet including the first or the second decompressed data block.

15. The system of claim **14**, wherein the one or more decompression decoders are separate from the selected encoder used to compress the one or more data blocks.

16. The system of claim **14**, wherein the one or more recognizable data tokens include values corresponding to one or more applied decoding techniques utilized by the one or more decompression decoders.

17. The system of claim **14**, wherein the one or more decompression decoders are further configured to decompress the compressed data block utilizing one or more appropriate decoders for the data block encoded with content independent data compression prior to further decoding the data block utilizing one or more appropriate decoders for the data block encoded with content dependent data compression.

18. The system of claim **14**, wherein the one or more decompression decoders are further configured to decompress a subset of the one or more compressed data blocks corresponding to the data packet.

19. The system of claim **18**, wherein the one or more decompression decoders are further configured to decompress a subset of the one or more data packets.

20. The system of claim **14**, wherein the one or more decompression decoders are further configured to decompress the compressed data block in real-time.

21. A method of compressing a plurality of data blocks residing in data packets, the data packets being transmitted in sequence from a source that is internal or external to a source of the compression method, the one or more compressed data packets including one or more compressed data blocks, wherein a data packet from among the one or more data packets comprises a header containing control information followed by one or more compressed data blocks of the data packet, the method comprising:

applying a plurality of compression techniques to the plurality of data blocks using a data compression engine;

analyzing content of a data block from among the plurality of data blocks to determine any characteristic, attribute, or parameter of the data block, wherein the analyzing of the data within the data block excludes analyzing based on a descriptor that is indicative of the characteristic, attribute, or parameter of the data block;

selecting one or more encoders based on the characteristic, attribute, or parameter of the data block and a file, wherein the file indicates the characteristic, attribute, or parameter of the data block and their associated encoders;

compressing the data block with the selected one or more encoders utilizing content dependent data compression when the characteristic, attribute, or parameter of the data residing within the data block is recognized as associated with an encoder utilizing content dependent data compression;

compressing the data block with the selected one or more encoders utilizing content independent data compression when the characteristic, attribute, or parameter of the data residing within the data block is not recognized as associated with an encoder utilizing content dependent data compression; and

providing a recognizable data token which identifies the selected one or more encoders utilized for compression of the data block in the one or more data blocks transmitted in sequence.

22. The method of claim **21**, wherein a plurality of the one or more encoders are applied to compress the plurality of data blocks.

23. The method of claim **21**, further comprising:

transmitting one or more data packets in sequence from outputs of the one or more encoders.

24. The method of claim **21**, wherein the data blocks contain financial data.

25. The method of claim **21**, wherein the method of compressing the plurality of data blocks is performed in real-time.

26. The method of claim **21**, wherein the encoders are lossy, and wherein the compression permits the compressed data block to be recovered in full when decompressed.

27. A system for compressing a plurality of data blocks that are compressed and placed into the payload portion of a data packet from among one or more data packets, the data packets

being transmitted in sequence from a source that is internal or external to the compression system, wherein the data packet comprises a header containing control information followed by the plurality of compressed data blocks of the data packet, the system comprising:

a data compression processor configured to analyze content of a data block to determine any characteristic, attribute, or parameter of the data block, where in the analyizing of the data within the data block excludes analyzing based on a descriptor that is indicative of the any characteristic attribute or parameter of the data block;

one or more compression encoders configured to be selected based on the characteristic, attribute, or parameter of the data block and a file, wherein the file indicates the characteristic, attribute, or parameter of the data block and their associated compression encoders; wherein:

the data block is compressed by the selected one or more compression encoders utilizing content dependent data compression when the characteristic, attribute, or parameter of the data block is recognized as being associated with an encoder utilizing content dependent data compression; and

the data block is compressed by the selected one or more compression encoders utilizing content independent data compression when the characteristic, attribute, or parameter of the data block is not recognized as being associated with an encoder utilizing content dependent data compression; and

an output interface, coupled to the data compression processor, configured to output a recognizable data token identifying the selected one or more compression encoders, the recognizable data token including any recognizable data token representative of one or more values in the compressed data packet.

28. The system of claim **27**, wherein the one or more compression encoders are further configured to compress a plurality of data blocks associated with the compressed data packet.

29. The system of claim **28**, wherein the one or more compression encoders are further configured to output a plurality of compressed data blocks.

30. The system of claim **27**, wherein the one or more compression encoders are further configured to compress the data blocks in real-time.

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US008933825B2

(12) **United States Patent**
Fallon

(10) **Patent No.: US 8,933,825 B2**
(45) **Date of Patent: Jan. 13, 2015**

(54) **DATA COMPRESSION SYSTEMS AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/251,453**

(22) Filed: **Apr. 11, 2014**

(65) **Prior Publication Data**

US 2014/0218220 A1 Aug. 7, 2014

Related U.S. Application Data

(63) Continuation of application No. 14/035,561, filed on Sep. 24, 2013, now Pat. No. 8,717,203, which is a continuation of application No. 13/154,211, filed on Jun. 6, 2011, now Pat. No. 8,643,513, which is a

(Continued)

(51) **Int. Cl.**

H03M 7/34	(2006.01)
H03M 7/30	(2006.01)
G06T 9/00	(2006.01)

(52) **U.S. Cl.**
CPC ***H03M 7/3059*** (2013.01); ***H03M 7/30*** (2013.01); ***G06T 9/00*** (2013.01)
USPC **341/51**; 341/65; 341/67; 341/75; 341/79; 341/107

(58) **Field of Classification Search**
CPC ... H03M 7/30; H03M 7/3059; H03M 7/3084; H03M 7/3088; H03M 7/40; H04L 65/607; G06T 9/005; G06Q 40/04; H04N 19/00121; H04N 19/00951; H04N 1/41; H04N 19/00018; H04N 19/0006; H04N 19/0009
USPC 341/50, 51, 67, 75, 79, 106, 107
See application file for complete search history.

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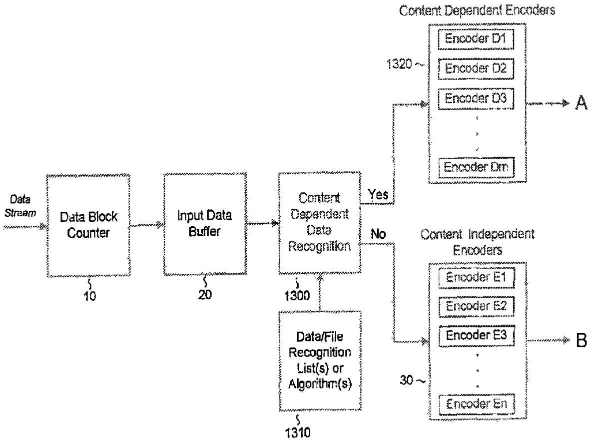
(57) **ABSTRACT**

Data compression using a combination, of content independent data compression and content dependent data compression. In one aspect, a method for compressing data comprises: determining whether or not a parameter or attribute of data within a data block is identified for the data block wherein the determining is not based solely on a descriptor that is indicative of the parameter or attribute of the data within the data block; and compressing the data block with at least one encoder associated with the parameter or attribute of the data within the data block to provide a compressed data block.

30 Claims, 34 Drawing Sheets



Related U.S. Application Data

continuation of application No. 12/703,042, filed on Feb. 9, 2010, now Pat. No. 8,502,707, which is a continuation of application No. 11/651,366, filed on Jan. 8, 2007, now abandoned, and a continuation of application No. 11/651,365, filed on Jan. 8, 2007, now Pat. No. 7,714,747, said application No. 11/651,366 is a continuation of application No. 10/668,768, filed on Sep. 22, 2003, now Pat. No. 7,161,506, said application No. 11/651,365 is a continuation of application No. 10/668,768, filed on Sep. 22, 2003, now Pat. No. 7,161,506, which is a continuation of application No. 10/016,355, filed on Oct. 29, 2001, now Pat. No. 6,624,761, which is a continuation-in-part of application No. 09/705,446, filed on Nov. 3, 2000, now Pat. No. 6,309,424, which is a continuation of application No. 09/210,491, filed on Dec. 11, 1998, now Pat. No. 6,195,024.

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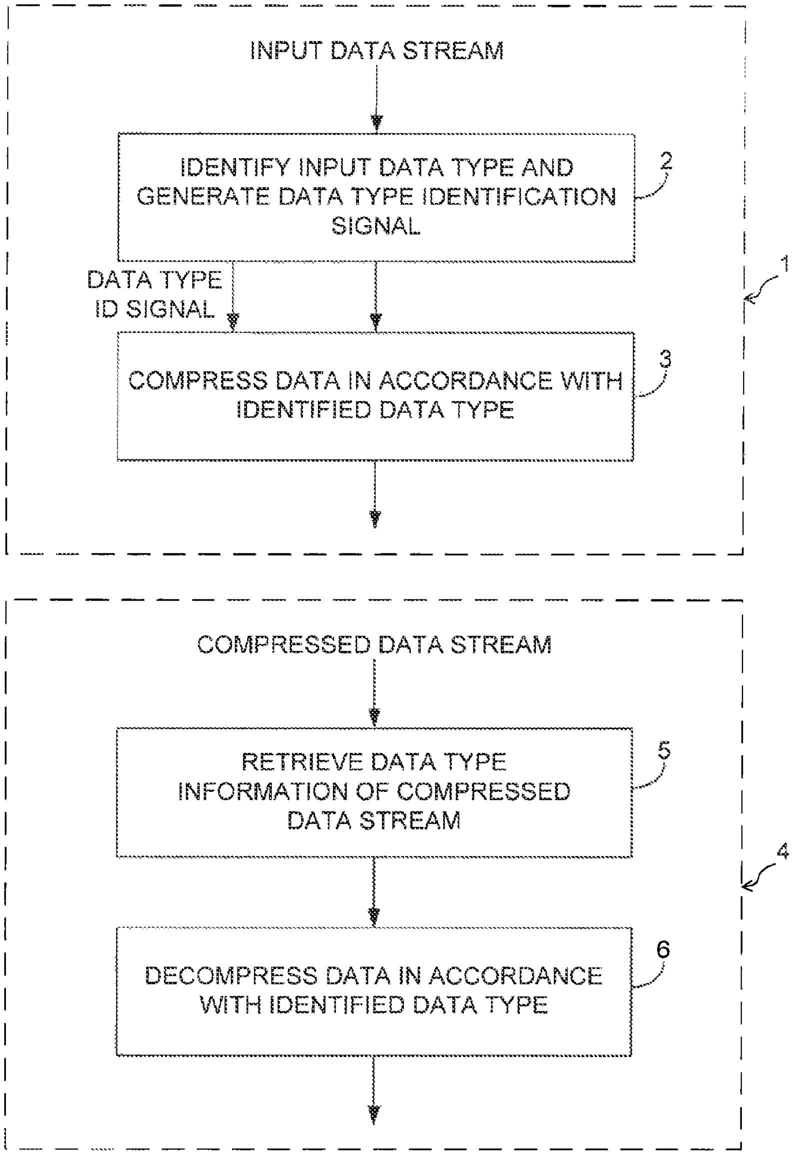

FIG. 1
PRIOR ART

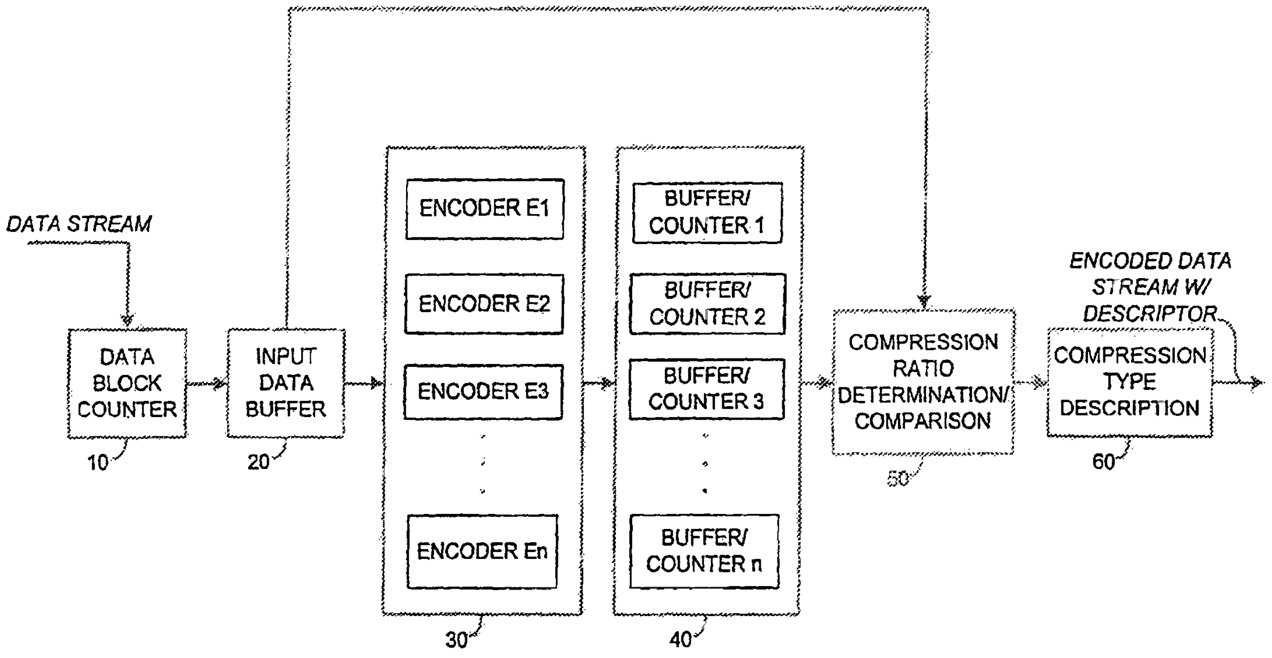
DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 2

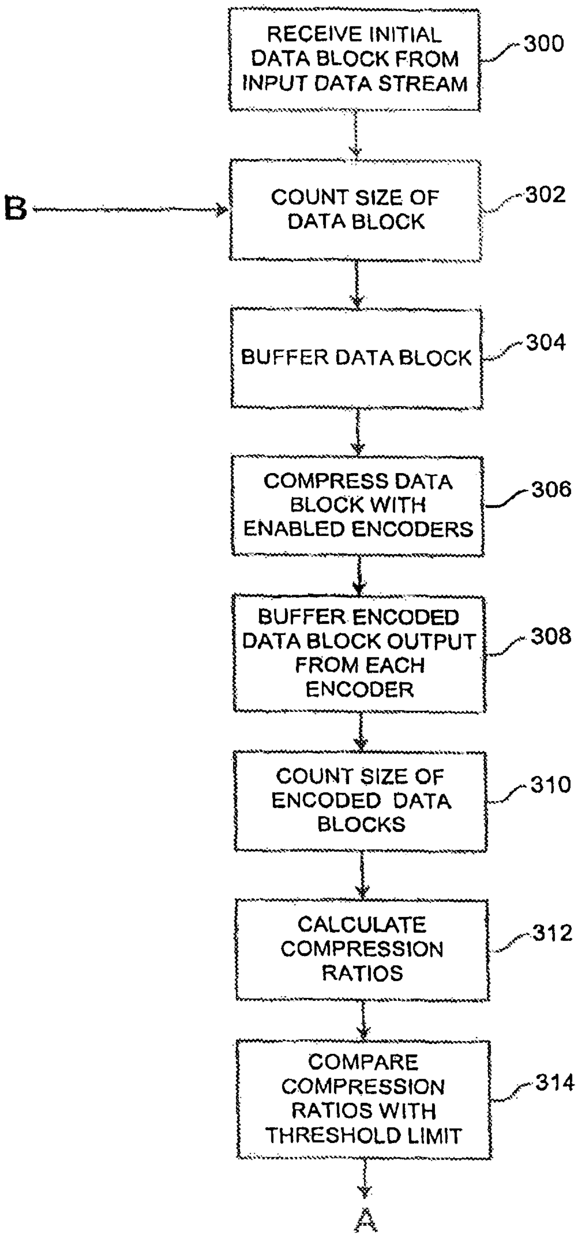
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
300
B
COUNT SIZE OF DATA BLOCK
302
BUFFER DATA BLOCK
304
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
306
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
308
COUNT SIZE OF ENCODED DATA BLOCKS
310
CALCULATE COMPRESSION RATIOS
312
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
314
A

FIG. 3a

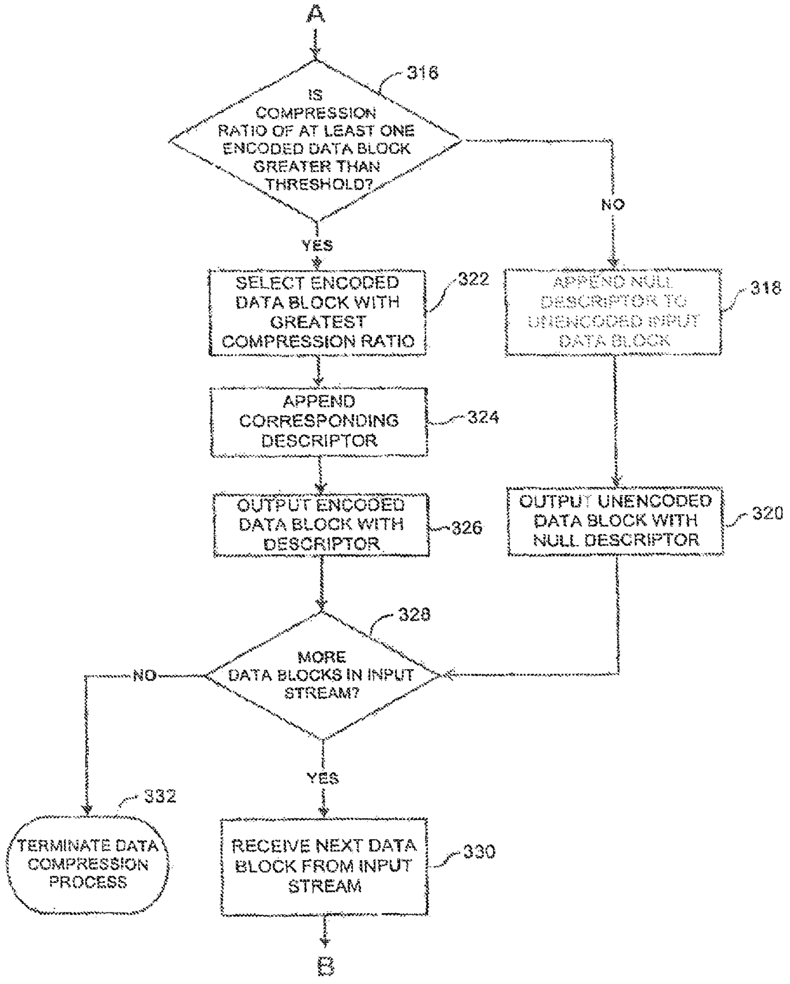
A
316
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
322
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
318
APPEND CORRESPONDING DESCRIPTOR
324
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
326
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
320
328
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
332
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
330
B

FIG. 3b

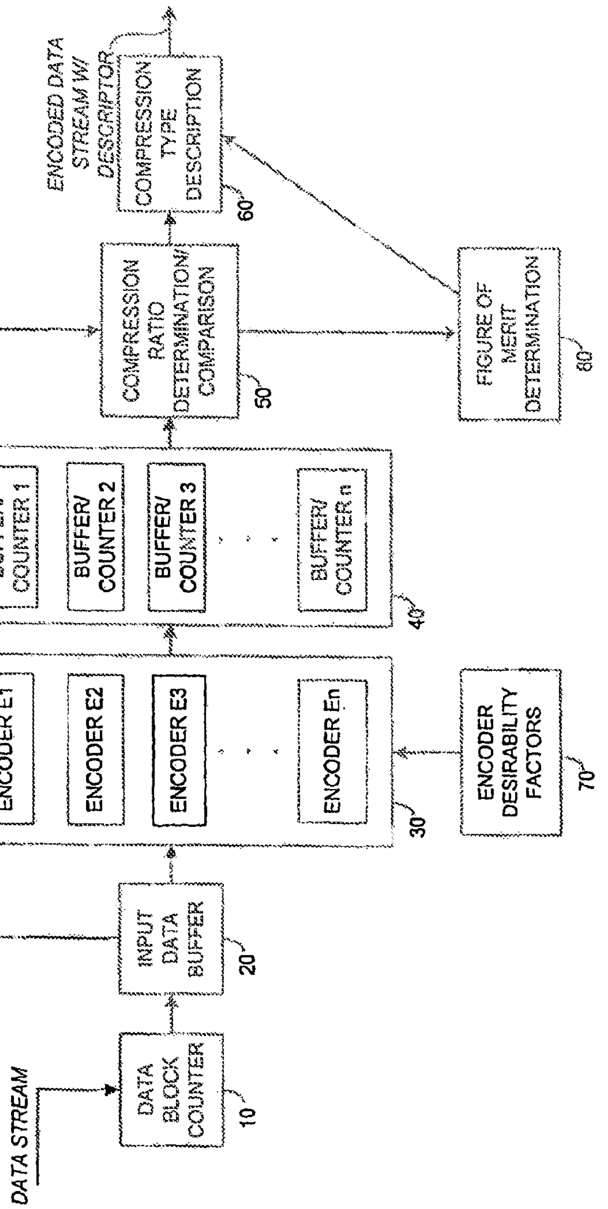
DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 4

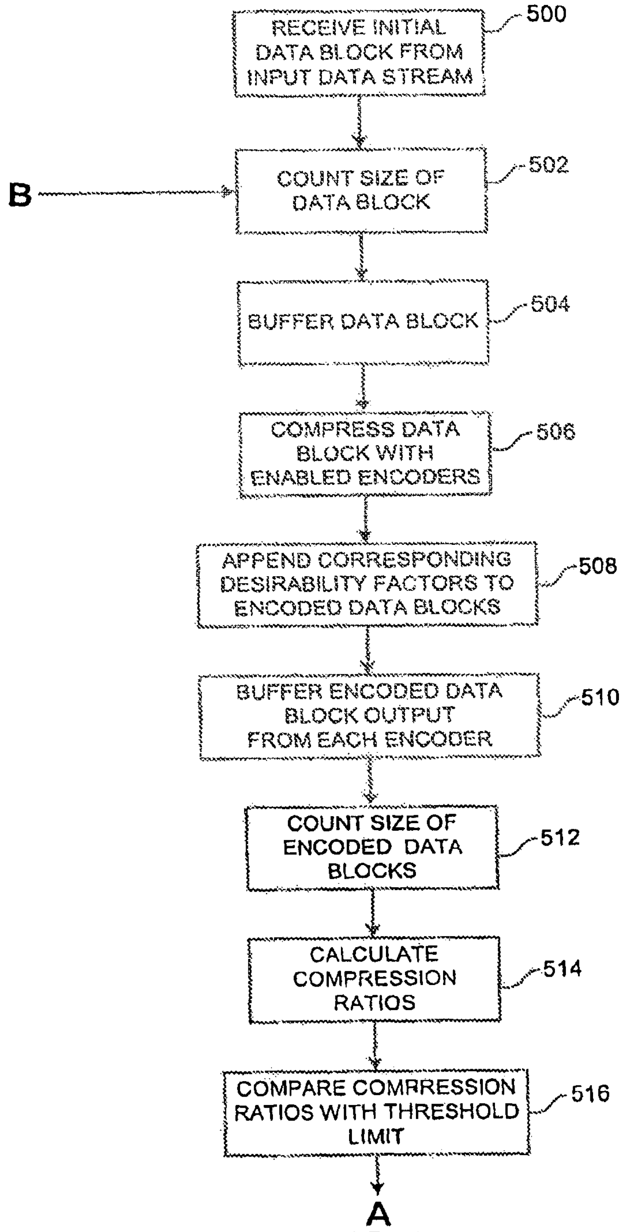
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
500
B
COUNT SIZE OF DATA BLOCK
502
BUFFER DATA BLOCK
504
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
506
APPEND CORRESPONDING DESIRABILITY FACTORS TO ENCODED DATA BLOCKS
508
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
510
COUNT SIZE OF ENCODED DATA BLOCKS
512
CALCULATE COMPRESSION RATIOS
514
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
516
A

FIG. 5a

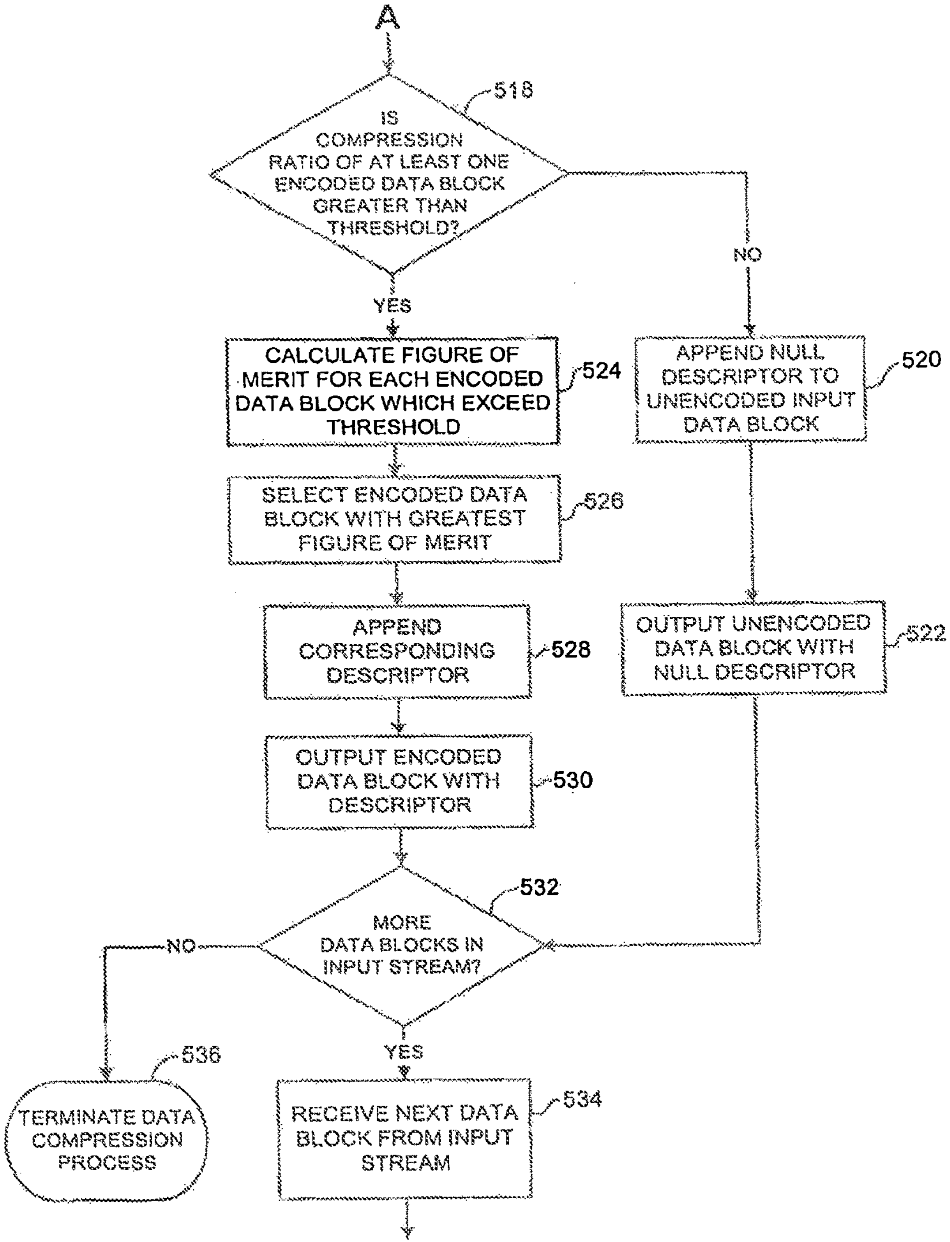
A
518
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
524
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
520
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
526
APPEND CORRESPONDING DESCRIPTOR
528
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
522
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
530
MORE DATA BLOCKS IN INPUT STREAM?
532
NO
YES
536
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
534
B

FIG. 5b

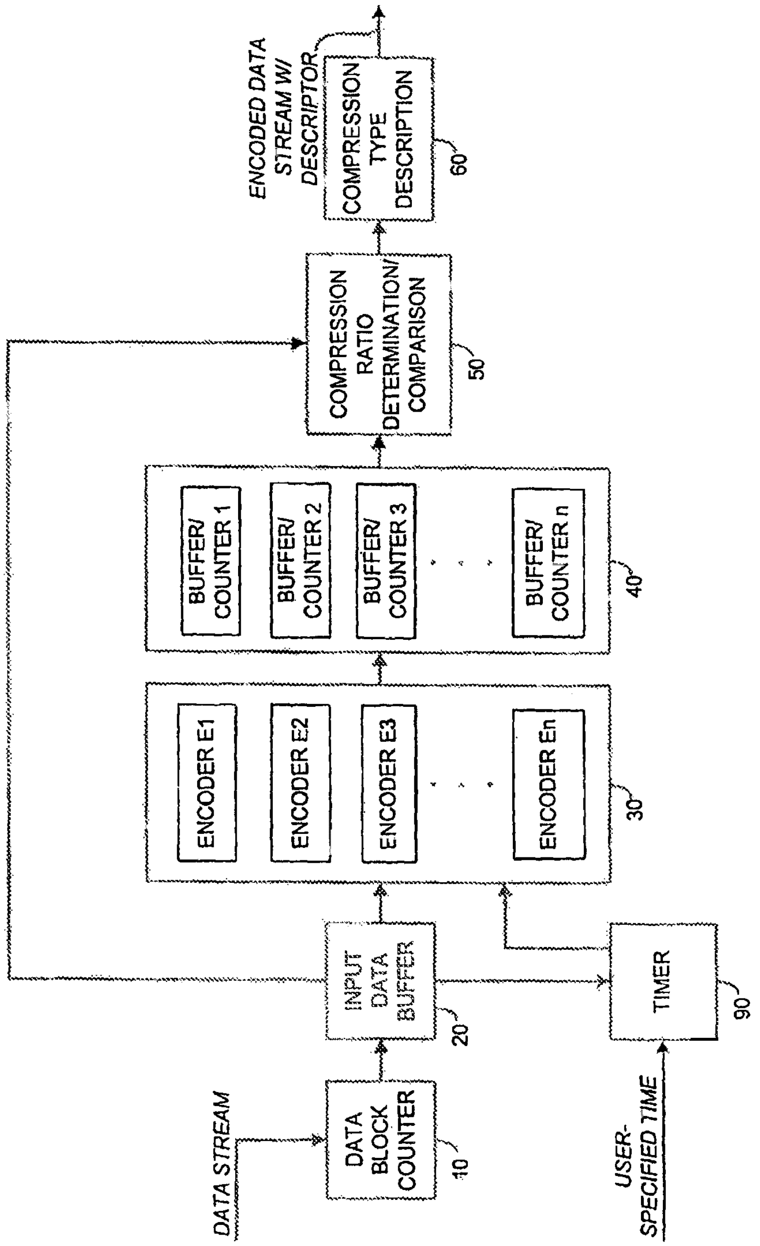
DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 6

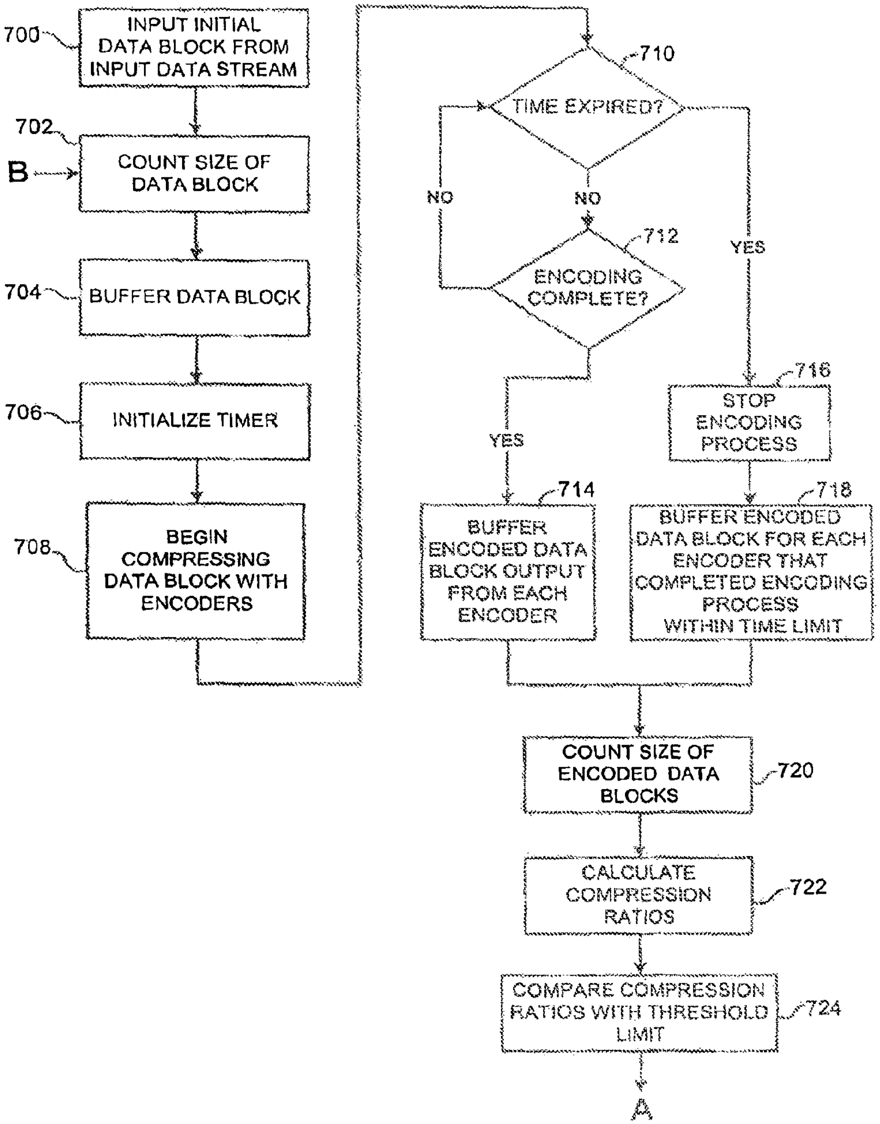
700
INPUT INITIAL DATA BLOCK FROM INPUT DATA STREAM
702
B
COUNT SIZE OF DATA BLOCK
704
BUFFER DATA BLOCK
706
INITIALIZE TIMER
708
BEGIN COMPRESSING DATA BLOCK WITH ENCODERS
710
TIME EXPIRED?
NO
NO
YES
712
ENCODING COMPLETE?
YES
714
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
716
STOP ENCODING PROCESS
718
BUFFER ENCODED DATA BLOCK FOR EACH ENCODER THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
COUNT SIZE OF ENCODED DATA BLOCKS
720
CALCULATE COMPRESSION RATIOS
722
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
724
A

FIG. 7a

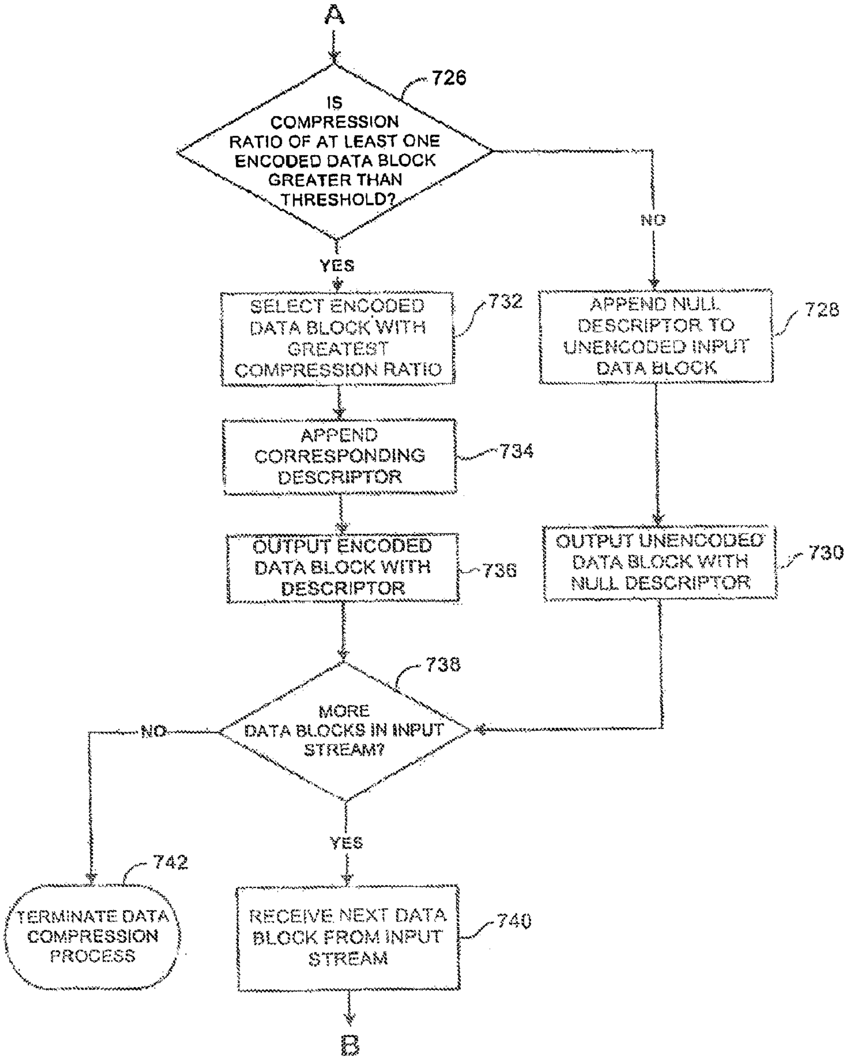
A
726
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
732
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
728
APPEND CORRESPONDING DESCRIPTOR
734
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
736
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
730
738
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
742
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
740
B

FIG. 7b

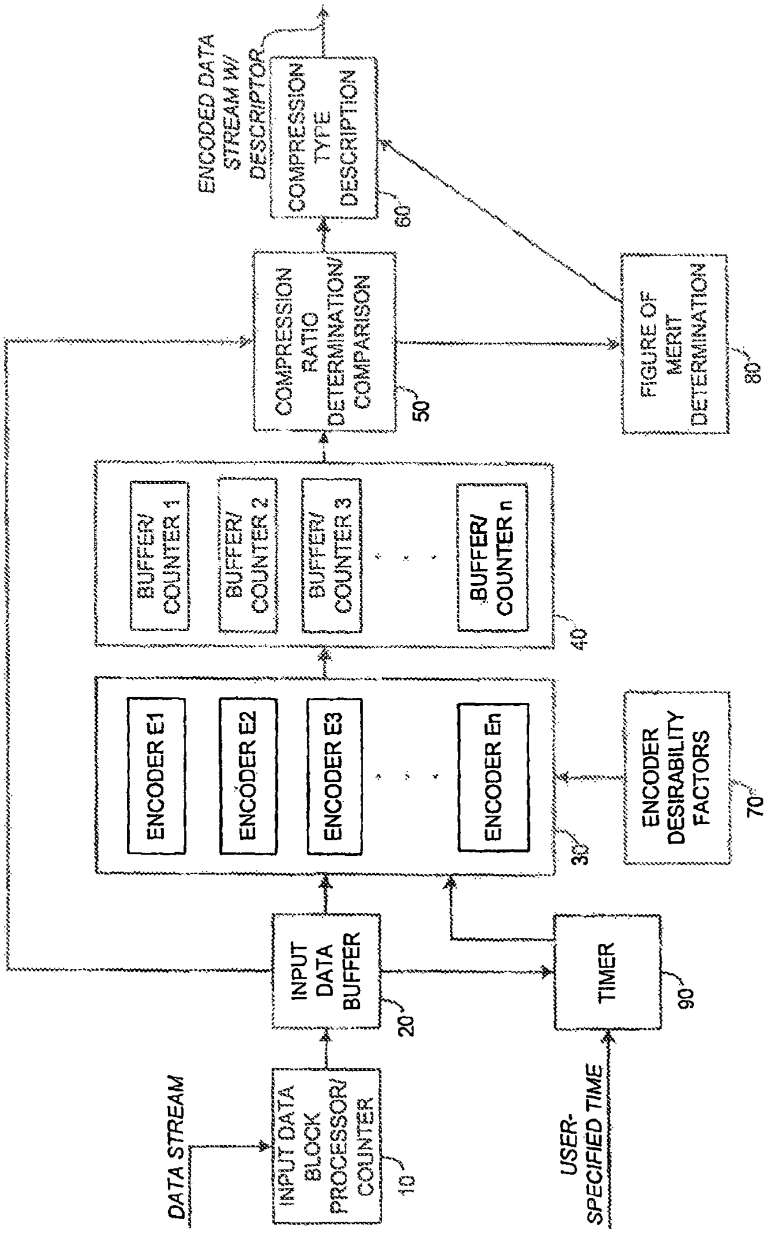
DATA STREAM
INPUT DATA BLOCK PROCESSOR/ COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 8

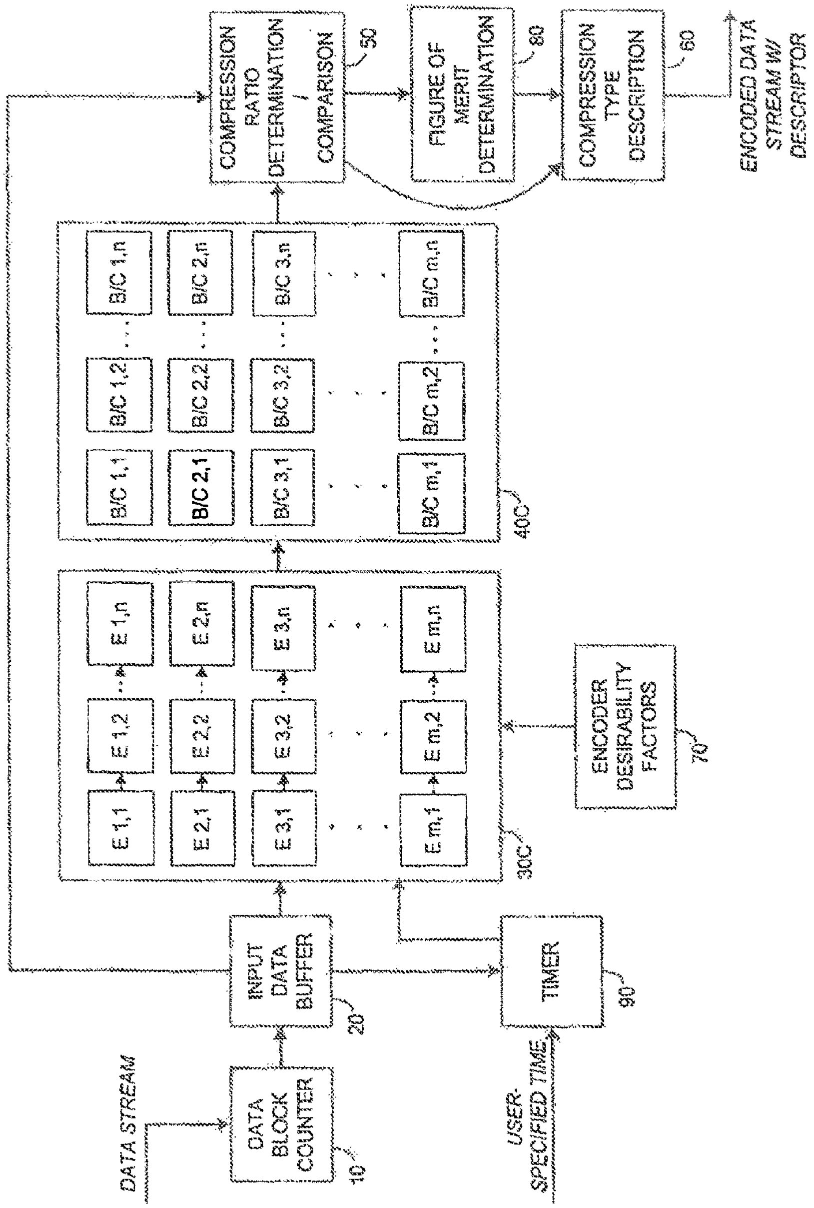
DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
E 1,1
E 1,2
E 1,n
E 2,1
E 2,2
E 2,n
E 3,1
E 3,2
E 3,n
E m,1
E m,2
E m,n
30C
ENCODER DESIRABILITY FACTORS
70
B/C 1,1
B/C 1,2
B/C 1,n
B/C 2,1
B/C 2,2
B/C 2,n
B/C 3,1
B/C 3,2
B/C 3,n
B/C m,1
B/C m,2
B/C m,n
40C
COMPRESSION RATIO DETERMINATION / COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 9

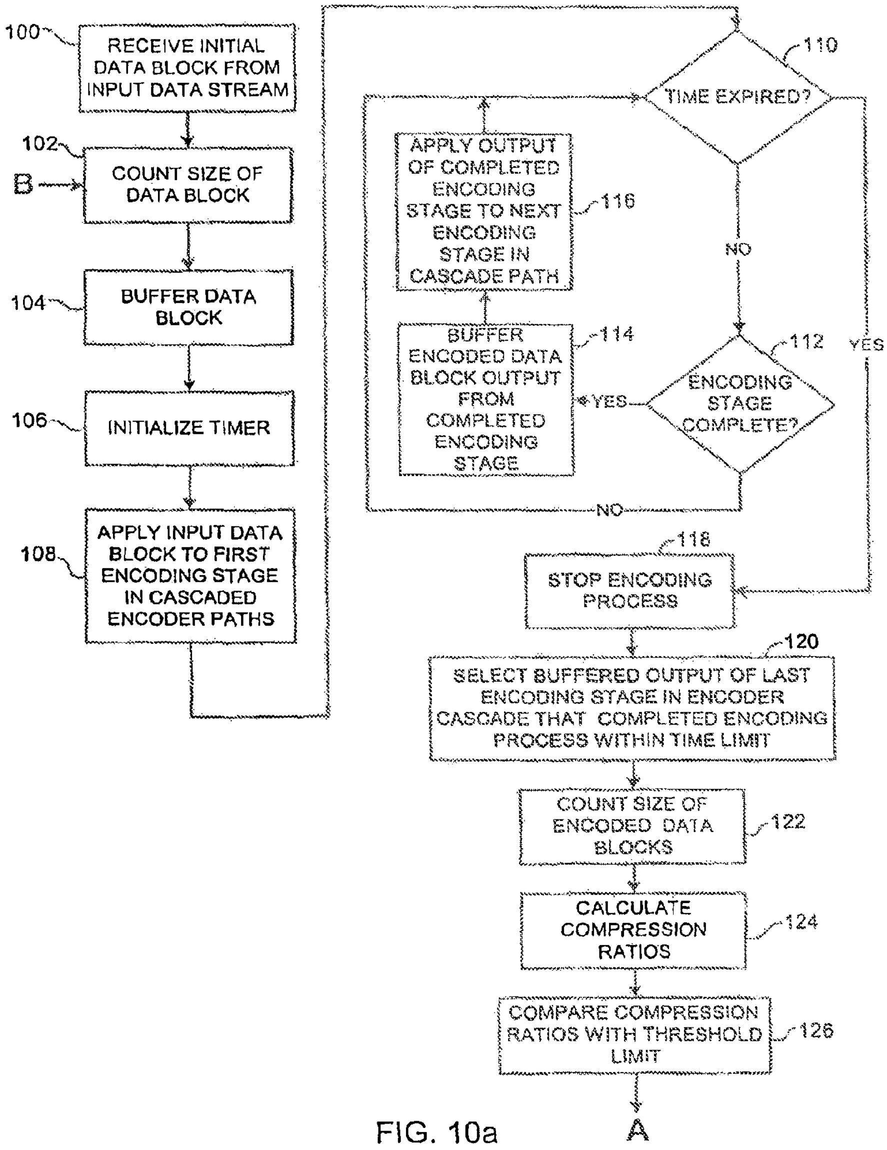
100
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
102
B
COUNT SIZE OF DATA BLOCK
104
BUFFER DATA BLOCK
106
INITIALIZE TIMER
108
APPLY INPUT DATA BLOCK TO FIRST ENCODING STAGE IN CASCADED ENCODER PATHS
110
TIME EXPIRED?
APPLY OUTPUT OF COMPLETED ENCODING STAGE TO NEXT ENCODING STAGE IN CASCADE PATH
116
NO
BUFFER ENCODED DATA BLOCK OUTPUT FROM COMPLETED ENCODING STAGE
114
112
YES
YES
ENCODING STAGE COMPLETE?
NO
118
STOP ENCODING PROCESS
120
SELECT BUFFERED OUTPUT OF LAST ENCODING STAGE IN ENCODER CASCADE THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
COUNT SIZE OF ENCODED DATA BLOCKS
122
CALCULATE COMPRESSION RATIOS
124
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
126
A

FIG. 10a

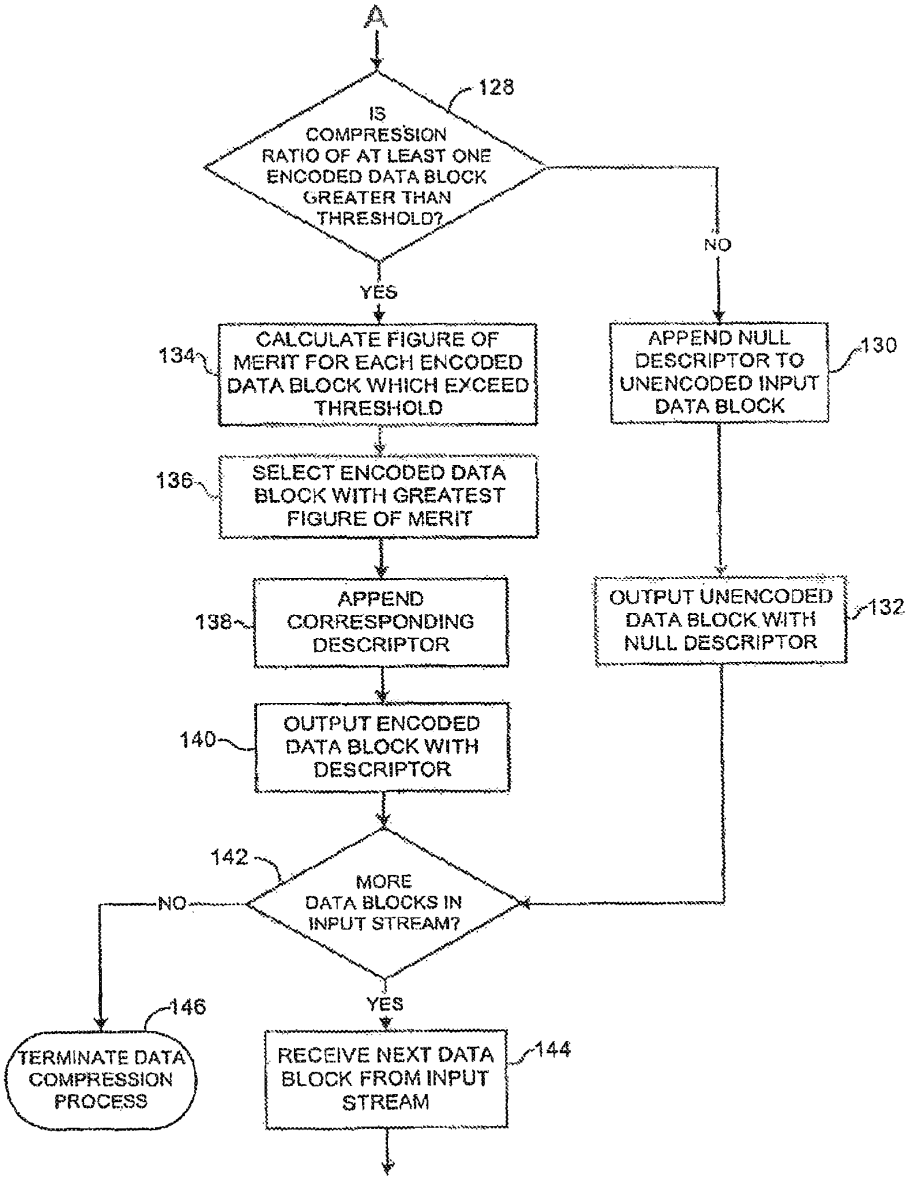
A
128
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
YES
NO
134
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
130
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
136
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
138
APPEND CORRESPONDING DESCRIPTOR
132
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
140
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
142
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
146
TERMINATE DATA COMPRESSION PROCESS
144
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
B

FIG. 10b

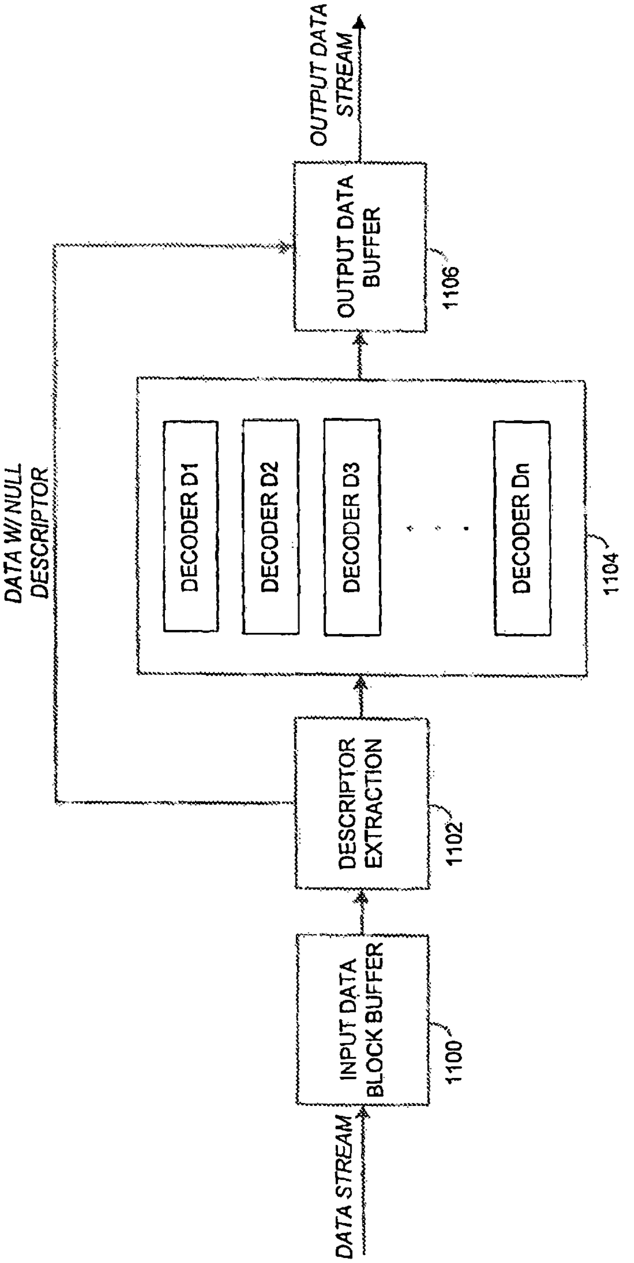
DATA STREAM
INPUT DATA BLOCK BUFFER
1100
DESCRIPTOR EXTRACTION
1102
DATA W/ NULL DESCRIPTOR
DECODER D1
DECODER D2
DECODER D3
DECODER Dn
1104
OUTPUT DATA BUFFER
1106
OUTPUT DATA STREAM

FIG. 11

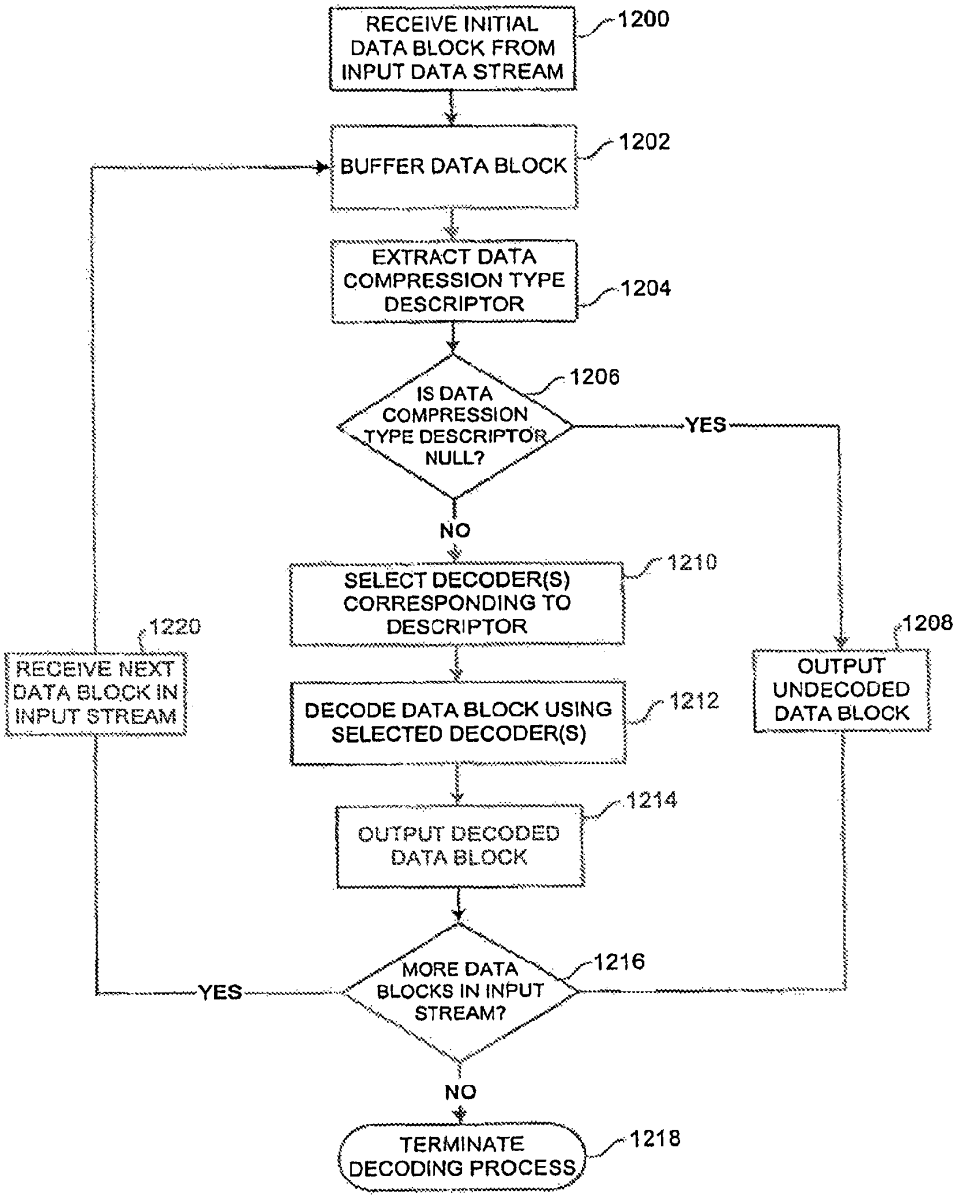
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
1200
BUFFER DATA BLOCK
1202
EXTRACT DATA COMPRESSION TYPE DESCRIPTOR
1204
IS DATA COMPRESSION TYPE DESCRIPTOR NULL?
1206
YES
NO
SELECT DECODER(S) CORRESPONDING TO DESCRIPTOR
1210
OUTPUT UNDECODED DATA BLOCK
1208
RECEIVE NEXT DATA BLOCK IN INPUT STREAM
1220
DECODE DATA BLOCK USING SELECTED DECODER(S)
1212
OUTPUT DECODED DATA BLOCK
1214
MORE DATA BLOCKS IN INPUT STREAM?
1216
YES
NO
TERMINATE DECODING PROCESS
1218

FIG. 12

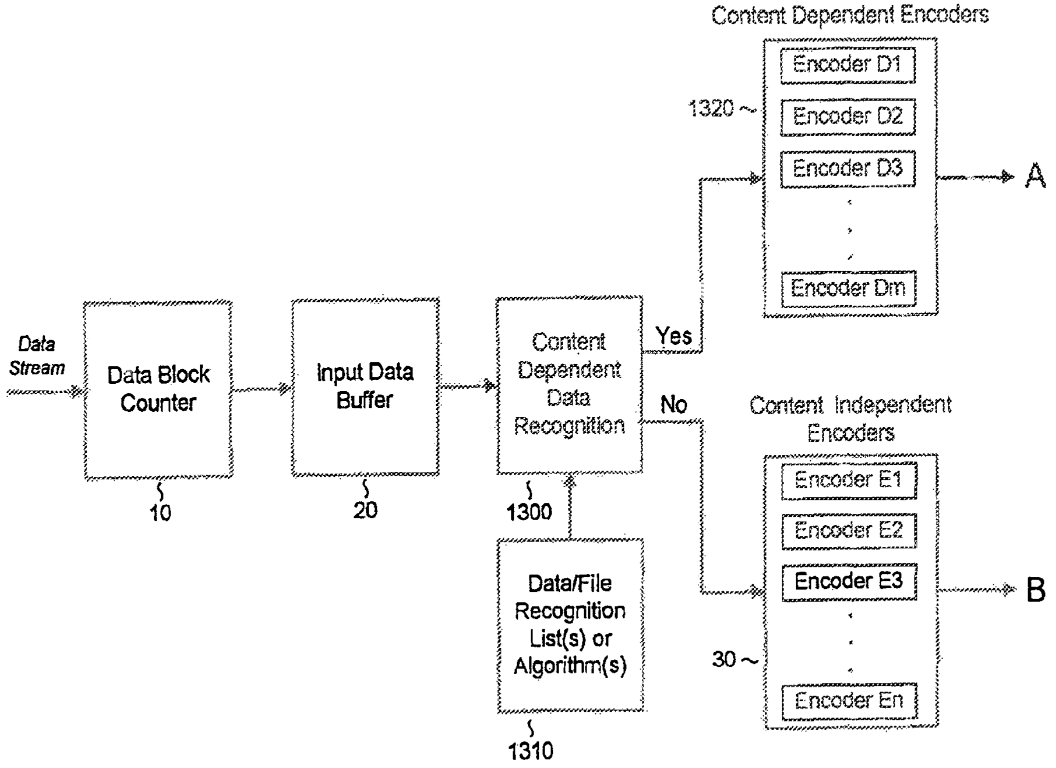
Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
Encoder En
B

FIGURE 13A

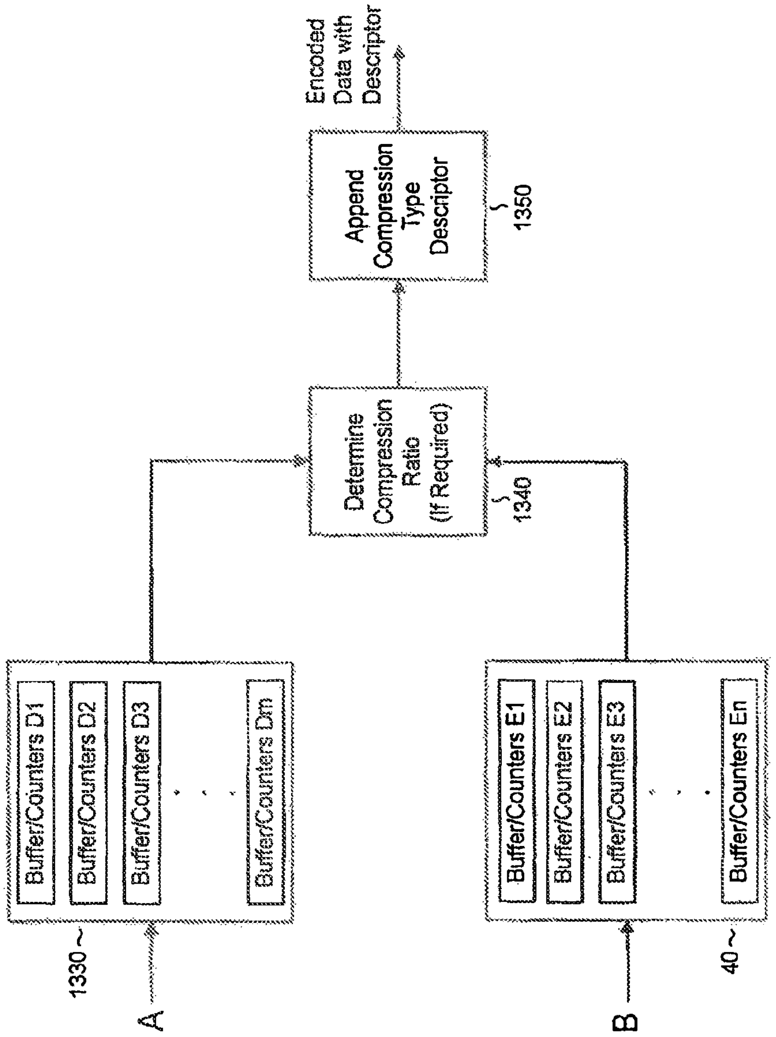
A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
B
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio (If Required)
1340
Append Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 13B

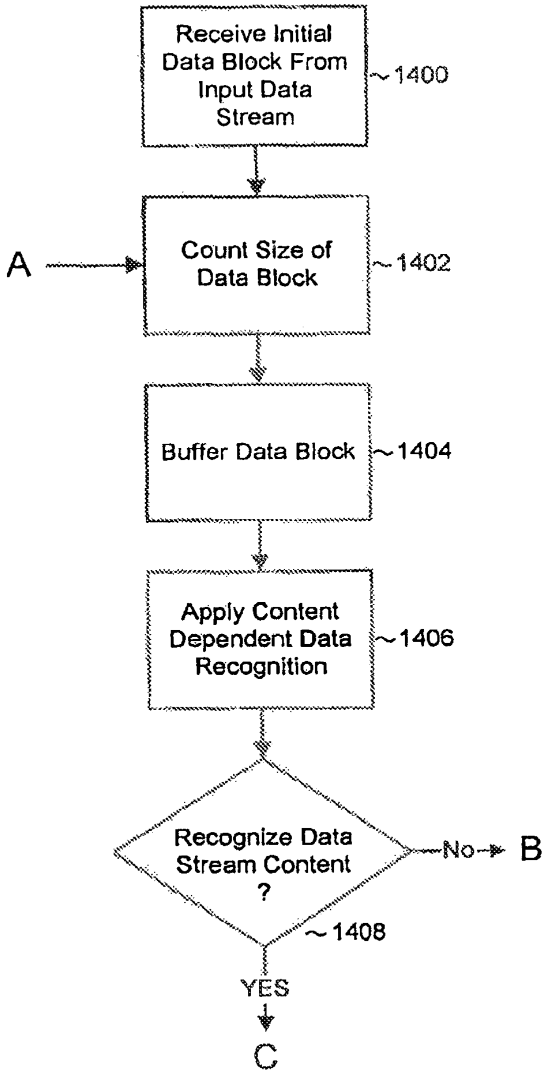
Receive Initial Data Block From Input Data Stream
1400
A
Count Size of Data Block
1402
Buffer Data Block
1404
Apply Content Dependent Data Recognition
1406
Recognize Data Stream Content ?
No
B
1408
YES
C

FIGURE 14A

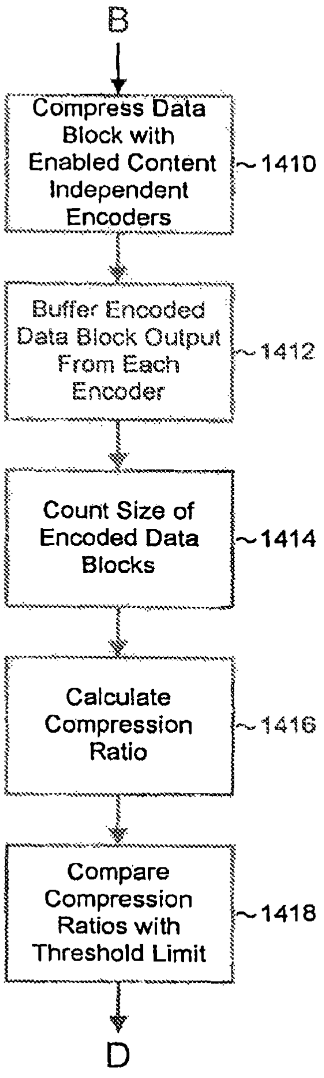
B
Compress Data Block with Enabled Content Independent Encoders
1410
Buffer Encoded Data Block Output From Each Encoder
1412
Count Size of Encoded Data Blocks
1414
Calculate Compression Ratio
1416
Compare Compression Ratios with Threshold Limit
1418
D

FIGURE 14B

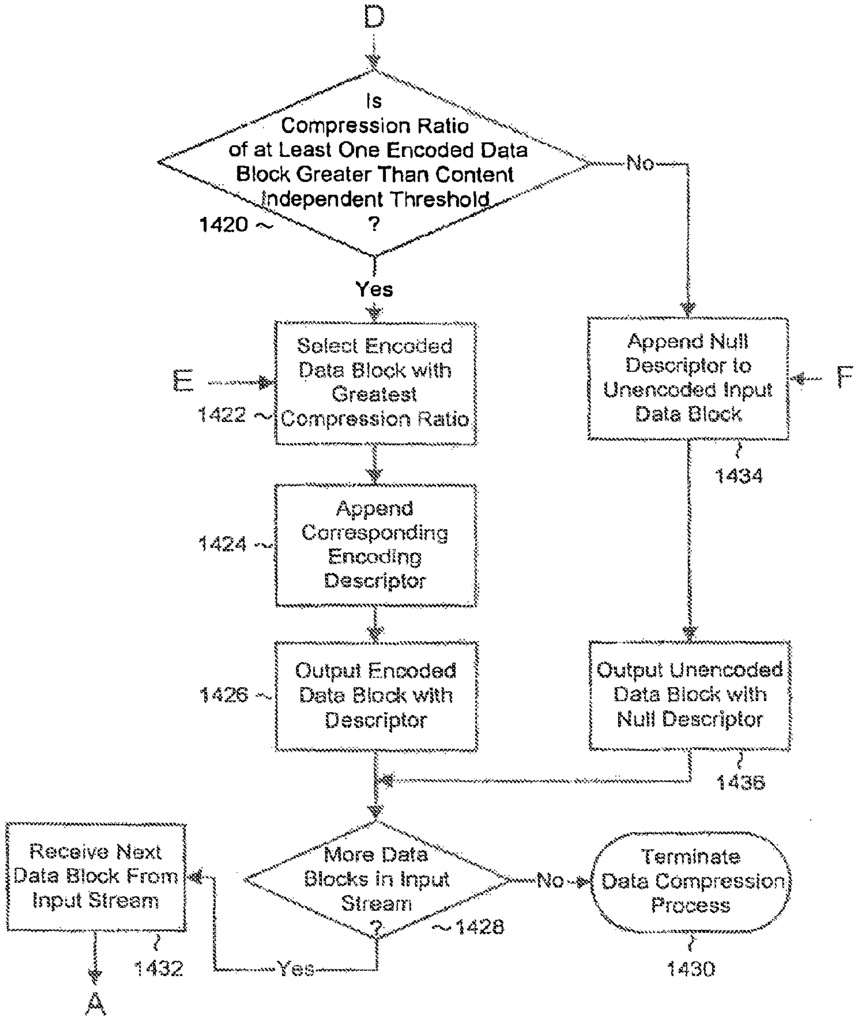
D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1420
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1422
Append Null Descriptor to Unencoded Input Data Block
F
1434
Append Corresponding Encoding Descriptor
1424
Output Encoded Data Block with Descriptor
1426
Output Unencoded Data Block with Null Descriptor
1436
Receive Next Data Block From Input Stream
1432
A
More Data Blocks in Input Stream ?
1428
Yes
No
Terminate Data Compression Process
1430

FIGURE 14C

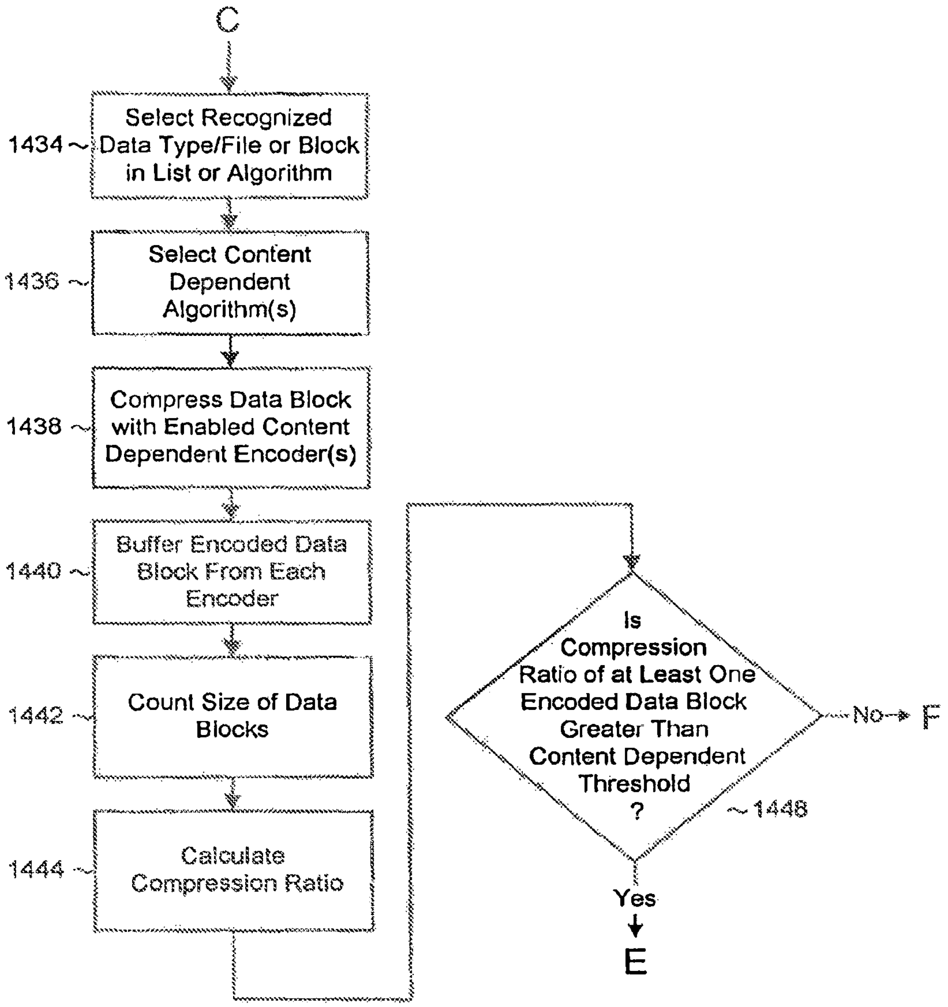
C
1434
Select Recognized Data Type/File or Block in List or Algorithm
1436
Select Content Dependent Algorithm(s)
1438
Compress Data Block with Enabled Content Dependent Encoder(s)
1440
Buffer Encoded Data Block From Each Encoder
1442
Count Size of Data Blocks
1444
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1448
No
F
Yes
E

FIGURE 14D

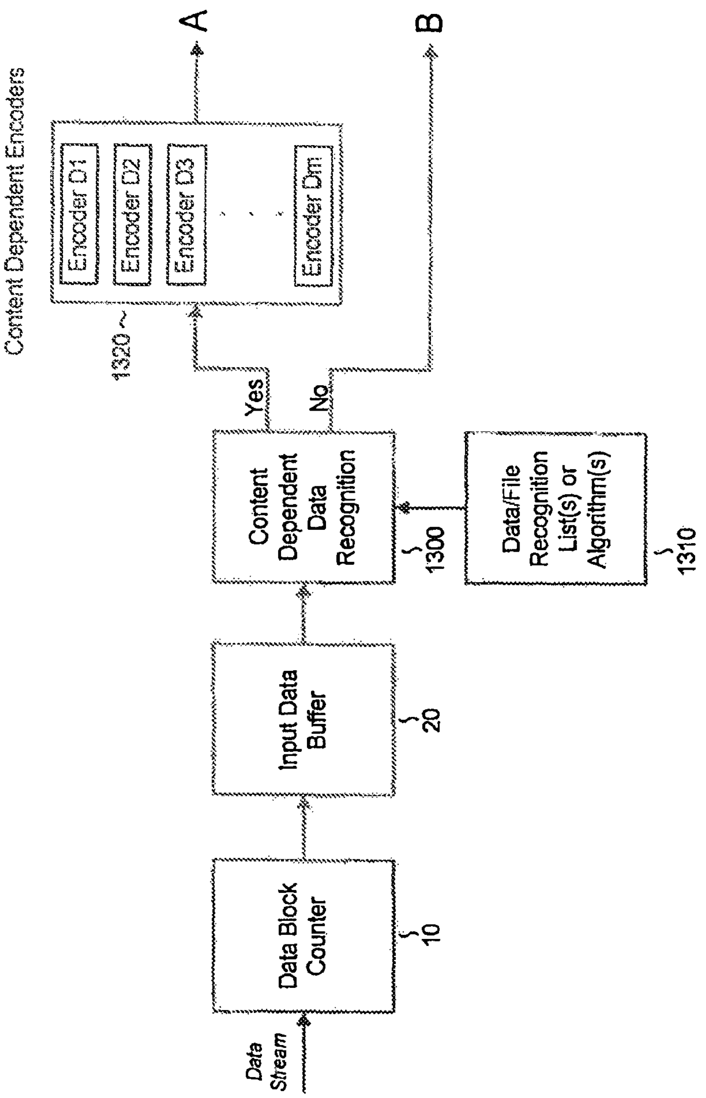
Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
. . .
Encoder Dm
A
B

FIGURE 15A

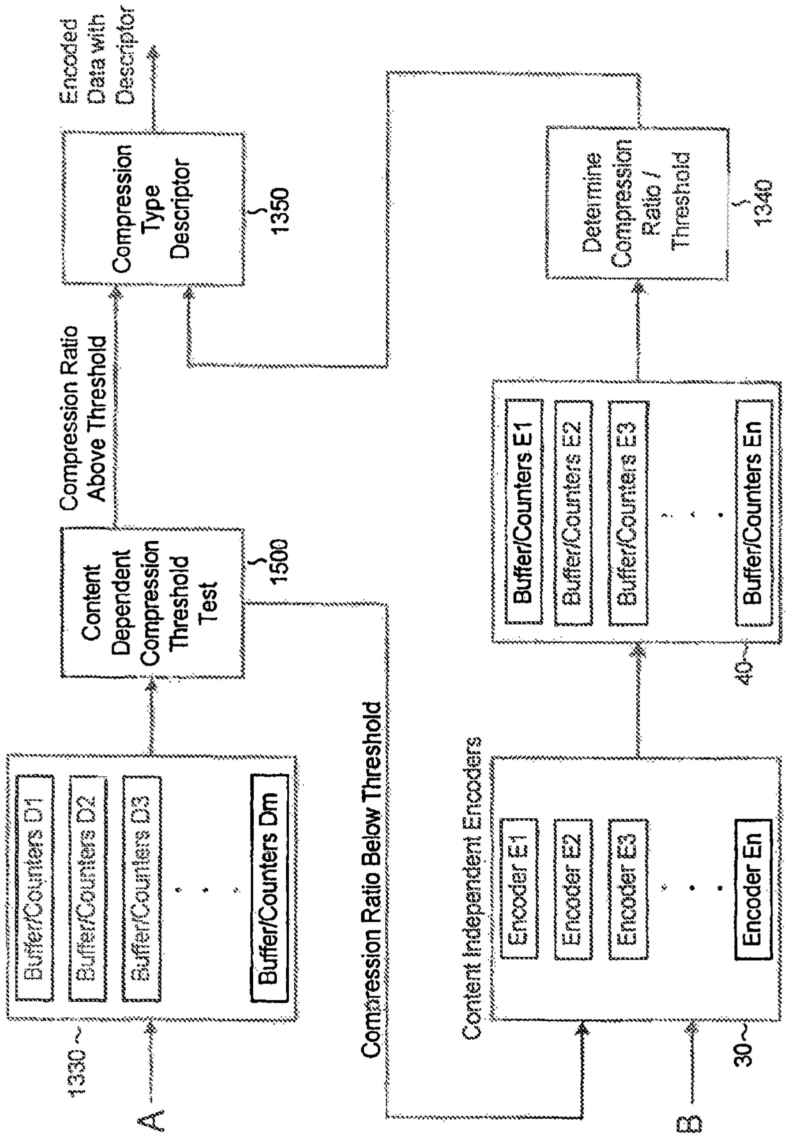
A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
Content Dependent Compression Threshold Test
1500
Compression Ratio Above Threshold
Compression Type Descriptor
1350
Encoded Data with Descriptor
Compression Ratio Below Threshold
Content Independent Encoders
Encoder E1
Encoder E2
Encoder E3
Encoder En
30
B
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio / Threshold
1340

FIGURE 15B

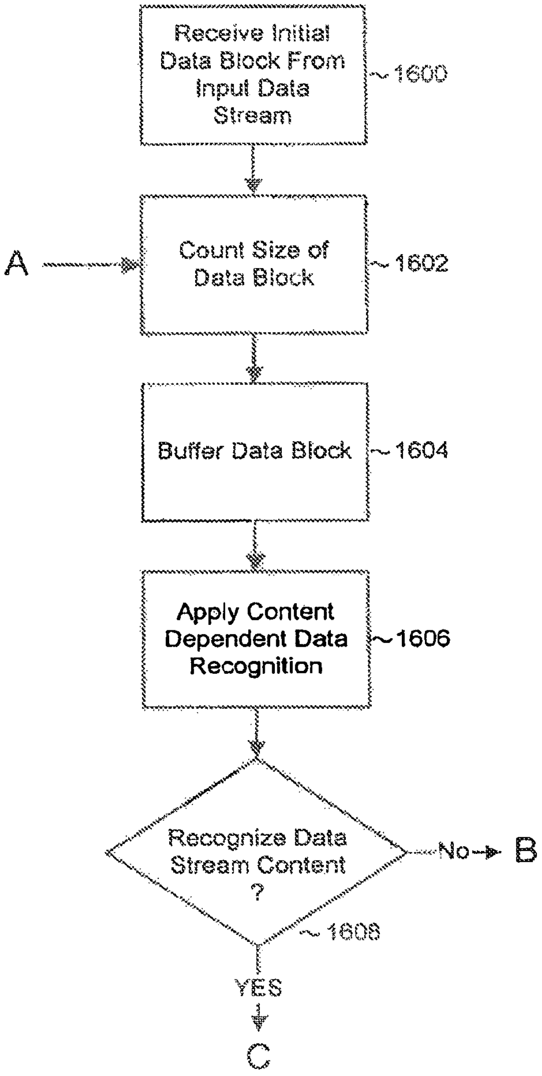
Receive Initial Data Block From Input Data Stream
1600
A
Count Size of Data Block
1602
Buffer Data Block
1604
Apply Content Dependent Data Recognition
1606
Recognize Data Stream Content ?
No
B
1608
YES
C

FIGURE 16A

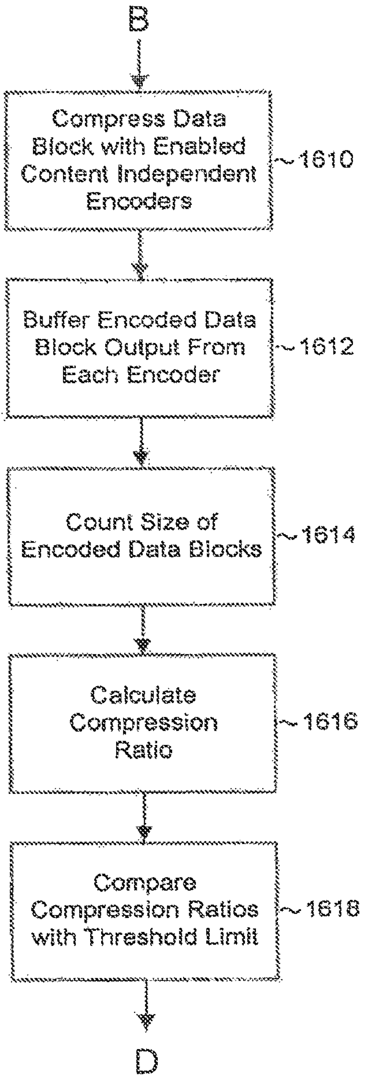
B
Compress Data Block with Enabled Content Independent Encoders
1610
Buffer Encoded Data Block Output From Each Encoder
1612
Count Size of Encoded Data Blocks
1614
Calculate Compression Ratio
1616
Compare Compression Ratios with Threshold Limit
1618
D

FIGURE 16B

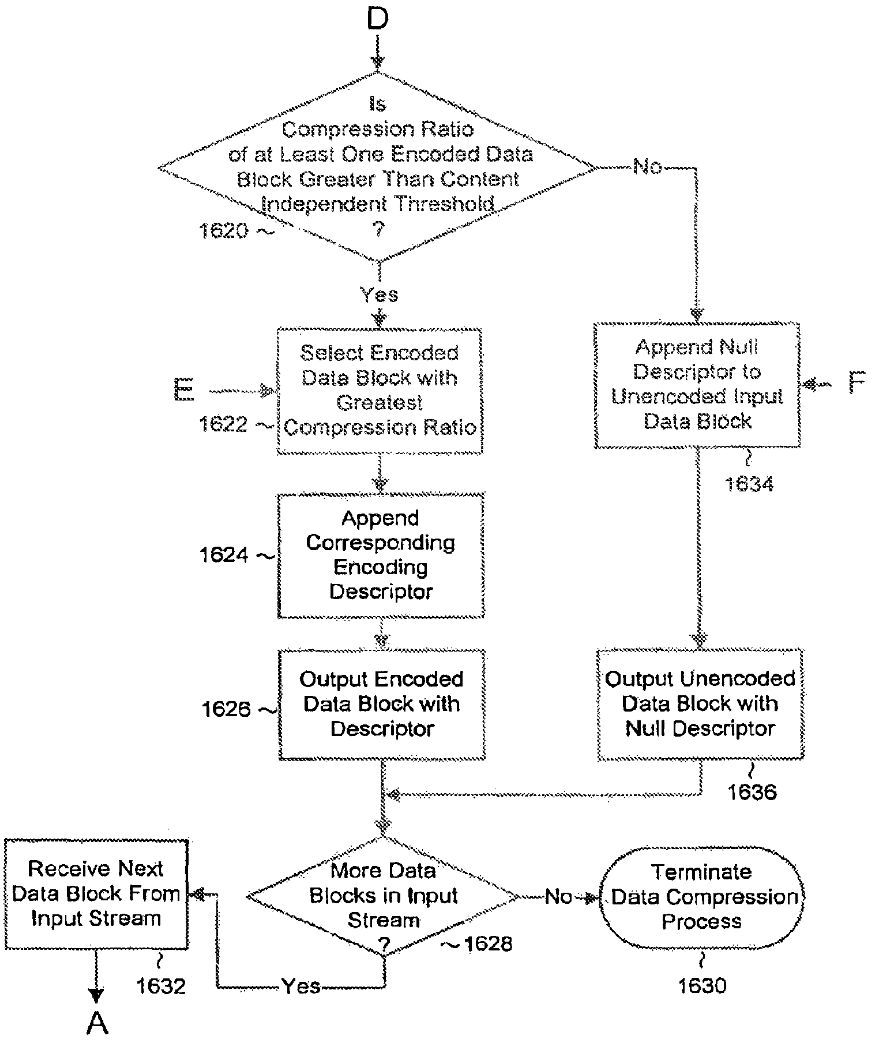
D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1620
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1622
Append Null Descriptor to Unencoded Input Data Block
F
1634
Append Corresponding Encoding Descriptor
1624
Output Encoded Data Block with Descriptor
1626
Output Unencoded Data Block with Null Descriptor
1636
Receive Next Data Block From Input Stream
1632
A
More Data Blocks in Input Stream ?
1628
Yes
No
Terminate Data Compression Process
1630

FIGURE 16C

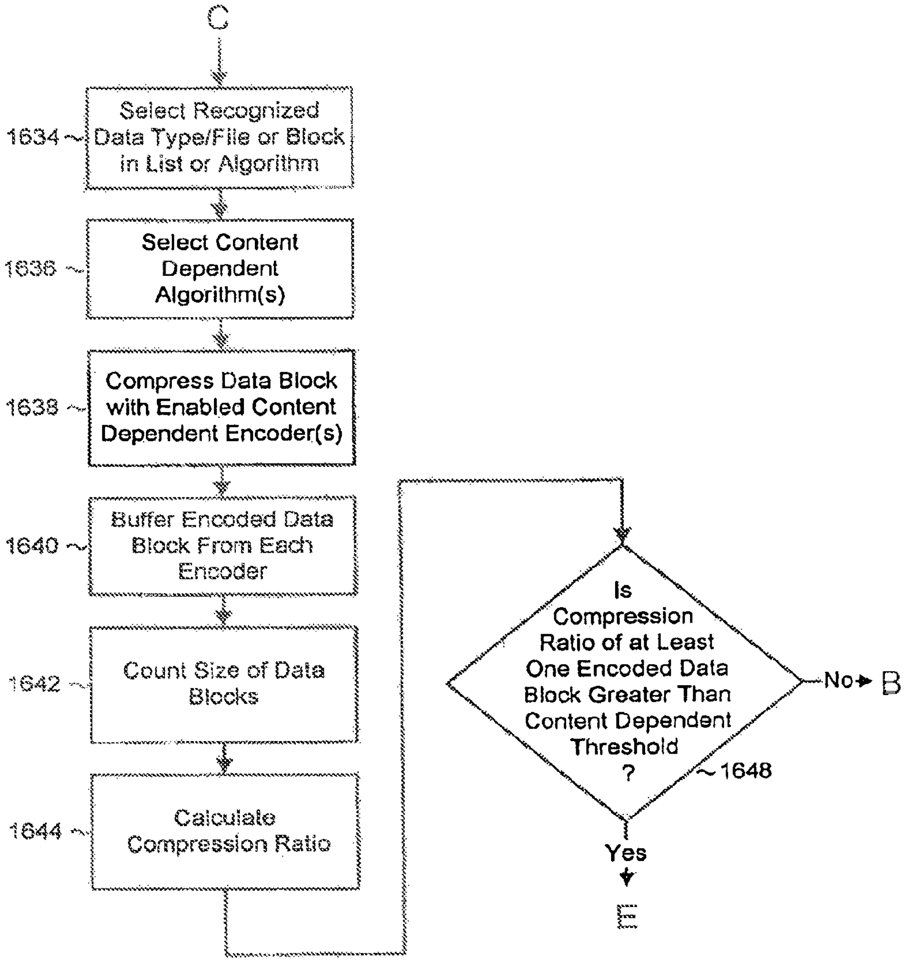
C
1634
Select Recognized Data Type/File or Block in List or Algorithm
1636
Select Content Dependent Algorithm(s)
1638
Compress Data Block with Enabled Content Dependent Encoder(s)
1640
Buffer Encoded Data Block From Each Encoder
1642
Count Size of Data Blocks
1644
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1648
No
B
Yes
E

FIGURE 16D

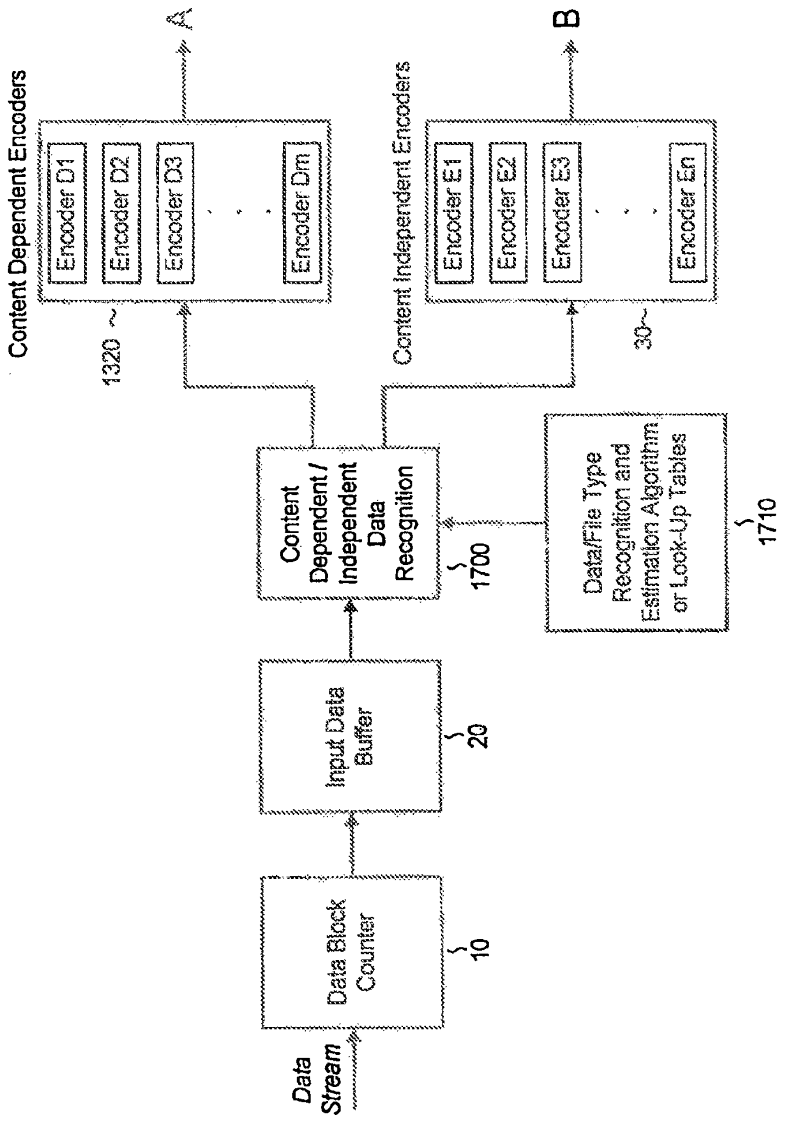
Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent / Independent Data Recognition
1700
Data/File Type Recognition and Estimation Algorithm or Look-Up Tables
1710
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
. . .
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
. . .
Encoder En
B

FIGURE 17A

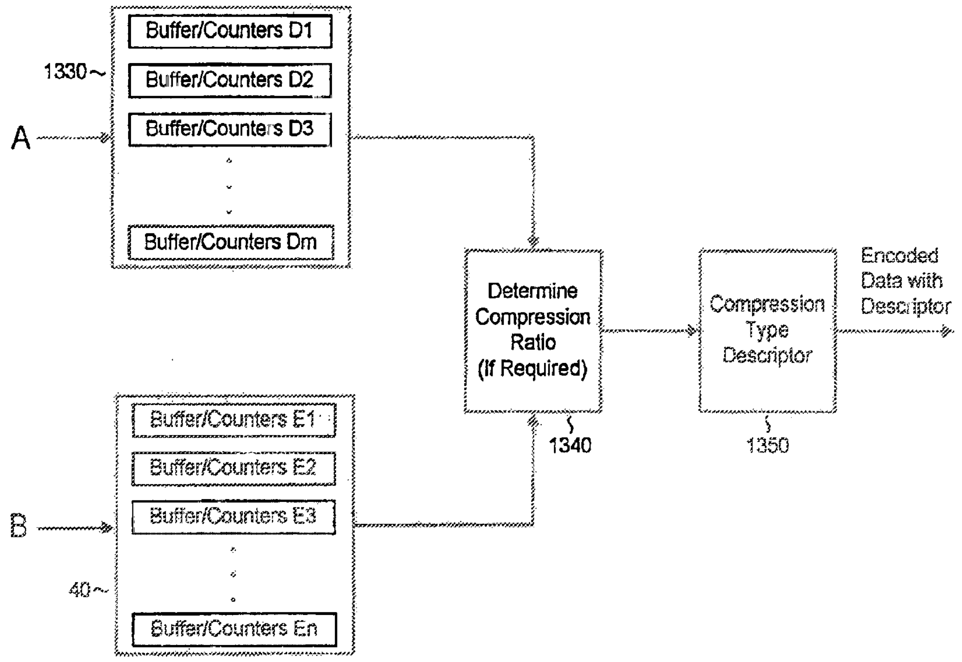
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
1330
A
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
40
B
Determine Compression Ratio (If Required)
1340
Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 17B

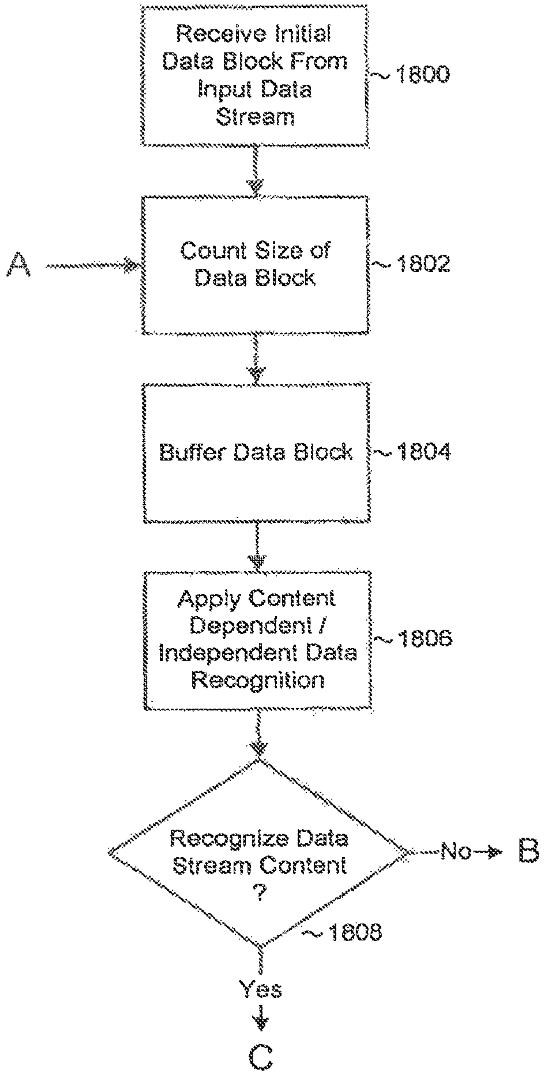
Receive Initial Data Block From Input Data Stream
1800
A
Count Size of Data Block
1802
Buffer Data Block
1804
Apply Content Dependent / Independent Data Recognition
1806
Recognize Data Stream Content ?
No
B
1808
Yes
C

FIGURE 18A

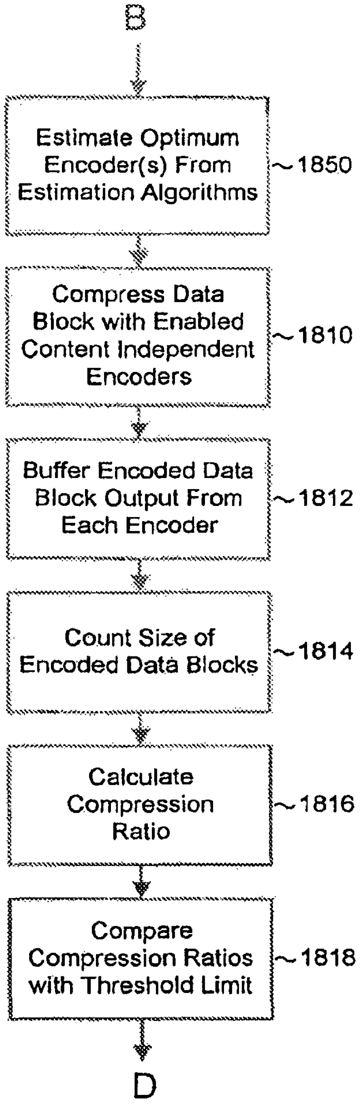
B
Estimate Optimum Encoder(s) From Estimation Algorithms
1850
Compress Data Block with Enabled Content Independent Encoders
1810
Buffer Encoded Data Block Output From Each Encoder
1812
Count Size of Encoded Data Blocks
1814
Calculate Compression Ratio
1816
Compare Compression Ratios with Threshold Limit
1818
D

FIGURE 18B

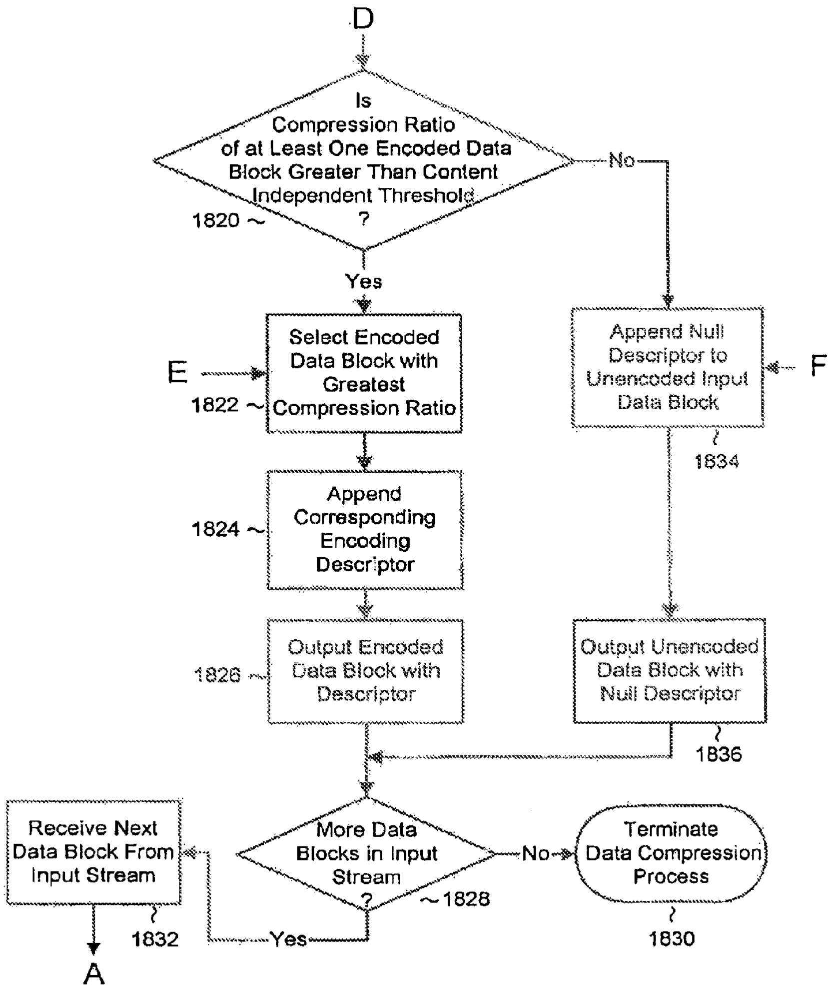
D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1820
No
Yes
E
Select Encoded Data Block with Greatest Compression Ratio
1822
Append Null Descriptor to Unencoded Input Data Block
F
1834
Append Corresponding Encoding Descriptor
1824
Output Encoded Data Block with Descriptor
1826
Output Unencoded Data Block with Null Descriptor
1836
Receive Next Data Block From Input Stream
More Data Blocks in Input Stream ?
1828
No
Terminate Data Compression Process
1832
Yes
1830
A

FIGURE 18C

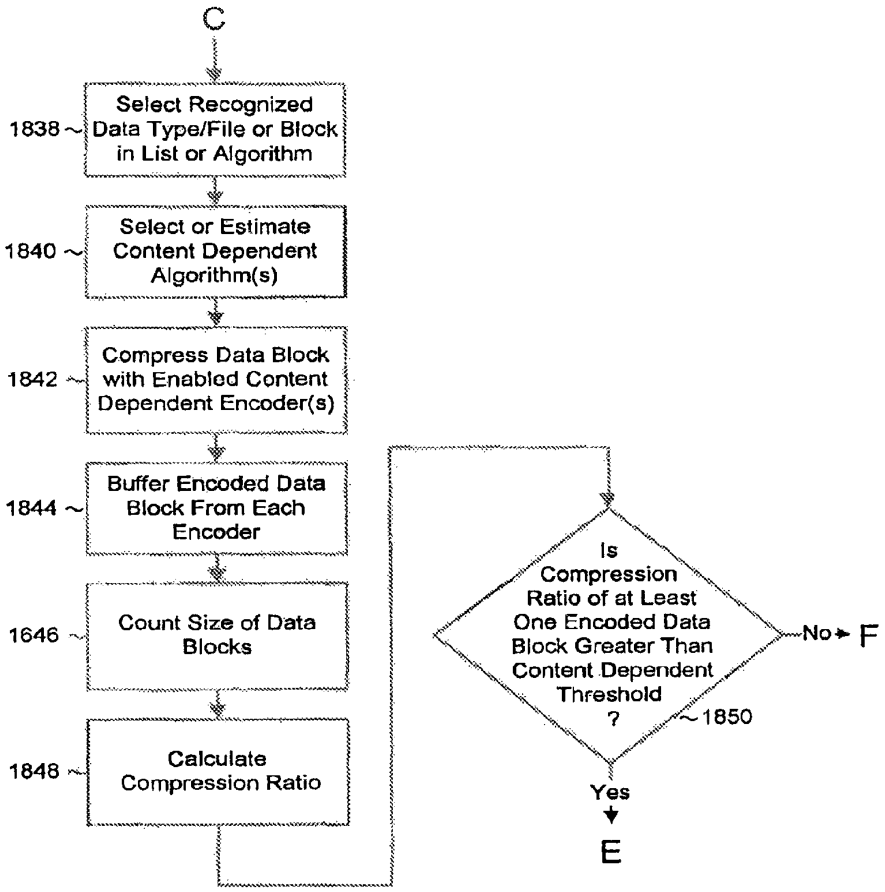
C
1838
Select Recognized Data Type/File or Block in List or Algorithm
1840
Select or Estimate Content Dependent Algorithm(s)
1842
Compress Data Block with Enabled Content Dependent Encoder(s)
1844
Buffer Encoded Data Block From Each Encoder
1646
Count Size of Data Blocks
1848
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1850
No
F
Yes
E

FIGURE 18D

DATA COMPRESSION SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 14/035,561, filed Sep. 24, 2013, which is a Continuation of U.S. patent application Ser. No. 13/154,211, filed Jun. 6, 2011, which is a Continuation of U.S. patent application Ser. No. 12/703,042, filed Feb. 9, 2010, now U.S. Pat. No. 8,502,707, which is a Continuation of both U.S. patent application Ser. No. 11/651,366, filed Jan. 8, 2007, now abandoned, and U.S. patent application Ser. No. 11/651,365, filed Jan. 8, 2007, now U.S. Pat. No. 7,714,747. Each of application Ser. No. 11/651,366 and application Ser. No. 11/651,365 is a Continuation of U.S. patent application Ser. No. 10/668,768, filed Sep. 22, 2003, now U.S. Pat. No. 7,161,506, which is a Continuation of U.S. patent application Ser. No. 10/016,355, filed Oct. 29, 2001, now U.S. Pat. No. 6,624,761, which is a Continuation-In-Part of U.S. patent application Ser. No. 09/705,446, filed Nov. 3, 2000, now U.S. Pat. No. 6,309,424, which is a Continuation of U.S. patent application Ser. No. 09/210,491, filed Dec. 11, 1998, which is now U.S. Pat. No. 6,195,024. Each of the listed applications are incorporated herein by reference in their entireties.

BACKGROUND

1. Technical Field

The present invention relates generally to a data compression and decompression and, more particularly, to systems and methods for data compression using content independent and content dependent data compression and decompression.

2. Description of Related Art

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video, frequently exists in the natural world as analog information. As is well known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossless and lossy data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Entropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than the entropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the entropy of a given data set.

There are various problems associated with the use of lossless compression techniques. One fundamental problem encountered with most lossless data compression techniques are their content sensitive behavior. This is often referred to as data dependency. Data dependency implies that the compression ratio achieved is highly contingent upon the content of the data being compressed. For example, database files often have large unused fields and high data redundancies, offering the opportunity to losslessly compress data at ratios of 5 to 1 or more. In contrast, concise software programs have little to no data redundancy and, typically, will not losslessly compress better than 2 to 1.

Another problem with lossless compression is that there are significant variations in the compression ratio obtained when using a single lossless data compression technique for data streams having different data content and data size. This process is known as natural variation.

A further problem is that negative compression may occur when certain data compression techniques act upon many types of highly compressed data. Highly compressed data appears random and many data compression techniques will substantially expand, not compress this type of data.

For a given application, there are many factors that govern the applicability of various data compression techniques. These factors include compression ratio, encoding and decoding processing requirements, encoding and decoding time delays, compatibility with existing standards, and implementation complexity and cost, along with the is adaptability and robustness to variations in input data. A direct relationship exists in the current art between compression ratio and the amount and complexity of processing required. One of the limiting factors in most existing prior art lossless data compression techniques is the rate at which the encoding and decoding processes are performed. Hardware and software implementation tradeoffs are often dictated by encoder and decoder complexity along with cost.

Another problem associated with lossless compression methods is determining the optimal compression technique for a given set of input data and intended application. To combat this problem, there are many conventional content dependent techniques that may be utilized. For instance, file type descriptors are typically appended to file names to describe the application programs that normally act upon the data contained within the file. In this manner data types, data structures, and formats within a given file may be ascertained. Fundamental limitations with this content dependent technique include:

(1) the extremely large number of application programs, some of which do not possess published or documented file formats, data structures, or data type descriptors;

(2) the ability for any data compression supplier or consortium to acquire, store, and access the vast amounts of data required to identify known file descriptors and associated data types, data structures, and formats; and

(3) the rate at which new application programs are developed and the need to update file format data descriptions accordingly.

An alternative technique that approaches the problem of selecting an appropriate lossless data compression technique is disclosed, for example, in U.S. Pat. No. 5,467,087 to Chu entitled "High Speed Lossless Data Compression System" ("Chu"). FIG. **1** illustrates an embodiment of this data compression and decompression technique. Data compression **1** comprises two phases, a data pre-compression phase **2** and a data compression phase **3**. Data decompression **4** of a compressed input data stream is also comprised of two phases, a data type retrieval phase **5** and a data decompression phase **6**. During the data compression process **1**, the data pre-compressor **2** accepts an uncompressed data stream, identifies the data type of the input stream, and generates a data type identification signal. The data compressor **3** selects a data compression method from a preselected set of methods to compress the input data stream, with the intention of producing the best available compression ratio for that particular data type.

There are several limitations associated with the Chu method. One such limitation is the need to unambiguously identify various data types. While these might include such common data types as ASCII, binary, or unicode, there, in fact, exists a broad universe of data types that fall outside the three most common data types. Examples of these alternate data types include: signed and unsigned integers of various lengths, differing types and precision of floating point numbers, pointers, other forms of character text, and a multitude of user defined data types. Additionally, data types may be interspersed or partially compressed, making data type recognition difficult and/or impractical. Another limitation is that given a known data type, or mix of data types within a specific set or subset of input data, it may be difficult and/or impractical to predict which data encoding technique yields the highest compression ratio.

Accordingly, there is a need for a data compression system and method that would address limitations in conventional data compression techniques as described above.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing fast and efficient data compression using a combination of content independent data compression and content dependent data compression. In one aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

performing content independent data compression on the data block, if the data type of the data block is not identified.

In another aspect, the step of performing content independent data compression comprises: encoding the data block with a plurality of encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the encoders; comparing each of the determined compression ratios with a first compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression ratios do not meet the first compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the first compression threshold.

In another aspect, the step of performing content dependent compression comprises the steps of: selecting one or more encoders associated with the identified data type and encoding the data block with the selected encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the selected encoders; comparing each of the determined compression ratios with a second compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression do not meet the second compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the second compression threshold.

In yet another aspect, the step of performing content independent data compression on the data block, if the data type of the data block is not identified, comprises the steps of: estimating a desirability of using of one or more encoder types based one characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of performing content dependent data compression on the data block, if the data type of the data block is identified, comprises the steps of: estimating a desirability of using of one or more encoder types based on characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of analyzing the data block comprises analyzing the data block to recognize one of a data type, data structure, data block format, file substructure, and/or file types. A further step comprises maintaining an association between encoder types and data types, data structures, data block formats, file substructure, and/or file types.

In yet another aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

determining a compression ratio of the compressed data block obtained using the content dependent compression and comparing the compression ratio with a first compression threshold; and

performing content independent data compression on the data block, if the data type of the data block is not identified or if the compression ratio of the compressed data block obtained using the content dependent compression does not meet the first compression threshold.

Advantageously, the present invention employs a plurality of encoders applying a plurality of compression techniques on an input data stream so as to achieve maximum compression in accordance with the real-time or pseudo real-time data rate constraint. Thus, the output bit rate is not fixed and the amount, if any, of permissible data quality degradation is user or data specified.

These and other aspects, features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments, which is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block/flow diagram of a content dependent high-speed lossless data compression and decompression system/method according to the prior art;

FIG. **2** is a block diagram of a content independent data compression system according to one embodiment of the present invention;

FIGS. **3***a* and **3***b* comprise a flow diagram of a data compression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **2**;

FIG. **4** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an enhanced metric for selecting an optimal encoding technique;

FIGS. **5***a* and **5***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **4**;

FIG. **6** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an a priori specified timer that provides real-time or pseudo real-time of output data;

FIGS. **7***a* and **7***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **6**;

FIG. **8** is a block diagram of a content independent data compression system according to another embodiment having an a priori specified timer that provides real-time or pseudo real-time of output data and an enhanced metric for selecting an optimal encoding technique;

FIG. **9** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an encoding architecture comprising a plurality of sets of serially cascaded encoders;

FIGS. **10***a* and **10***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **9**;

FIG. **11** is block diagram of a content independent data decompression system according to one embodiment of the present invention;

FIG. **12** is a flow diagram of a data decompression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **11**;

FIGS. **13***a* and **13***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to an embodiment of the present invention;

FIGS. **14***a*-**14***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to one aspect of the present invention;

FIGS. **15***a* and **15***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention;

FIGS. **16***a*-**16***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention;

FIGS. **17***a* and **17***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention; and

FIGS. **18***a*-**18***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention.

DETAILED DESCRIPTION OF TILE INVENTION

The present invention is directed to systems and methods for providing data compression and decompression using content independent and content dependent data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. In particular, the system modules described herein are preferably implemented in software as an application program that is executable by, e.g., a general purpose computer or any machine or device having any suitable and preferred microprocessor architecture. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform also includes an operating system and microinstruction code. The various processes and functions described herein may be either part of the microinstruction code or application programs which are executed via the operating system. In addition, various other peripheral devices may be connected to the computer platform such as an additional data storage device and a printing device.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in which the systems are programmed. It is to be appreciated that special purpose microprocessors may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **2** a block diagram illustrates a content independent data compression system according to one embodiment of the present invention. The data compression system includes a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

An encoder module **30** is operatively connected to the buffer **20** and comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as ran length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **30** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **10**). Data compression is performed by the encoder module **30** wherein each of the encoders E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the is encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **40** is operatively connected to the encoding module **30** for buffering and counting the size of each of the encoded data blocks output from encoder module **30**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **50**, operatively connected to the output buffer/counter **40**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **50** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **60**, operatively coupled to the compression ratio module **50**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

The operation of the data compression system of FIG. **2** will now be discussed in is further detail with reference to the flow diagram of FIGS. **3***a* and **3***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **300**). As stated above, data compression is performed on a per data block basis. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **302**). The data block is then stored in the buffer **20** (step **304**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **306**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **308**), and the encoded data block size is counted (step **310**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of each encoded data block output from the enabled encoders (step **312**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **314**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art.

After the compression ratios are compared with the threshold, a determination is s made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **316**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **316**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **318**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **320**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **316**), then the encoded data block having the greatest compression ratio is selected (step **322**). An appropriate data compression type descriptor is then appended (step **324**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **326**).

After the encoded data block or the unencoded data input data block is output (steps **326** and **320**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **328**). If the input data stream includes additional data blocks (affirmative result in step **328**), the next successive data block is received (step **330**), its block size is counted (return to step **302**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **328**), data compression of the input data stream is finished (step **322**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

Referring now to FIG. **4**, a block diagram illustrates a content independent data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **4** is similar to the data compression system of FIG. **2** except that the embodiment of FIG. **4** includes an enhanced metric functionality for selecting an optimal encoding technique. In particular, each of the encoders E**1** . . . En in the encoder module **30** is tagged with a corresponding one of user-selected encoder desirability factors **70**. Encoder desirability is defined as an a priori user specified factor that takes into account any number of user considerations including, but not limited to, compatibility of the encoded data with existing standards, data error robustness, or any other aggregation of factors that the user wishes to consider for a particular application. Each encoded data block output from the encoder module **30** has a corresponding desirability factor appended thereto. A figure of merit module **80**, operatively coupled to the compression ratio module **50** and the descriptor module **60**, is provided for calculating a figure of merit for each of the encoded data blocks which possess a compression ratio greater than the compression ratio threshold limit. The figure of merit for each encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor. As discussed below in further detail with reference to FIGS. **5***a* and **5***b*, the figure of merit substitutes the a priori user compression threshold limit for selecting and outputting encoded data blocks.

The operation of the data compression system of FIG. **4** will now be discussed in further detail with reference to the flow diagram of FIGS. **5***a* and **5***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **500**). The size of the first data block is then determined by the counter module **10** (step **502**). The data block is then stored in the buffer **20** (step **504**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder in the encoder set E**1** . . . En (step **506**). Each encoded data block processed in the encoder module **30** is tagged with an encoder desirability factor that corresponds the particular encoding technique applied to the encoded data block (step **508**). Upon completion of the encoding of the input data block, an encoded data block with its corresponding desirability factor is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **510**), and the encoded data block size is counted (step **512**).

Next, a compression ratio obtained by each enabled encoder is calculated by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **514**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **516**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **518**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **518**), then the original unencoded input data block is selected for output and a null data compression type descriptor (as discussed above) is appended thereto (step **520**). Accordingly, the original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **522**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **518**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **524**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected for output (step **526**). An appropriate data compression type descriptor is then appended (step **528**) to indicate the data encoding technique applied to the encoded data block. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **530**).

After the encoded data block or the unencoded input data block is output (steps **530** and **522**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **532**). If the input data stream includes additional data blocks (affirmative result in step **532**), then the next successive data block is received (step **534**), its block size is counted (return to step **502**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **532**), data compression of the input data stream is finished (step **536**).

Referring now to FIG. **6**, a block diagram illustrates a data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **6** is similar to the data compression system discussed in detail above with reference to FIG. **2** except that the embodiment of FIG. **6** includes an a priori specified timer that provides real-time or pseudo real-time output data. In particular, an interval timer **90**, operatively coupled to the encoder module **30**, is preloaded with a user specified time value. The role of the interval timer (as will be explained in greater detail below with reference to FIGS. **7***a* and **7***b*) is to limit the processing time for each input data block processed by the encoder module **30** so as to ensure that the real-time, pseudo real-time, or other time critical nature of the data compression processes is preserved.

The operation of the data compression system of FIG. **6** will now be discussed in further detail with reference to the flow diagram of FIGS. **7***a* and **7***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **700**), and its size is determined by the counter module **10** (step **702**). The data block is then stored in buffer **20** (step **704**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **706**) and starts counting towards a user-specified time limit. The input data block is then sent to the encoder module **30** wherein data compression of the data block by each (enabled) encoder E**1** . . . En commences (step **708**). Next, a determination is made as to whether the user specified time expires before the completion of the encoding process (steps **710** and **712**). If the encoding process is completed before or at the expiration of the timer, i.e., each encoder (E**1** through En) completes its respective encoding process (negative result in step **710** and affirmative result in step **712**), then an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **714**).

On the other hand, if the timer expires (affirmative result in **710**), the encoding process is halted (step **716**). Then, encoded data blocks from only those enabled encoders E**1** . . . En that have completed the encoding process are selected and maintained in buffers (step **718**). It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency and natural variation, it is possible that certain encoders may not operate quickly enough and, therefore, do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are buffered (step **714** or **718**), the size of each encoded data block is counted (step **720**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **722**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **724**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **726**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **726**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **728**). The original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **730**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **726**), then the encoded data block having the greatest compression ratio is selected (step **732**). An appropriate data compression type descriptor is then appended (step **734**). The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **736**).

After the encoded data block or the unencoded input data block is output (steps **730** or **736**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **738**). If the input data stream includes additional data blocks (affirmative result in step **738**), the next successive data block is received (step **740**), its block size is counted (return to step **702**) and the data compression process in repeated. This process is iterated for each data block in the input data stream, with each data block being processed within the user-specified time limit as discussed above. Once the final input data block is processed (negative result in step **738**), data compression of the input data stream is complete (step **742**).

Referring now to FIG. **8**, a block diagram illustrates a content independent data compression system according to another embodiment of the present system. The data compression system of FIG. **8** incorporates all of the features discussed above in connection with the system embodiments of FIGS. **2**, **4**, and **6**. For example, the system of FIG. **8** incorporates both the a priori specified timer for providing real-time or pseudo real-time of output data, as well as the enhanced metric for selecting an optimal encoding technique. Based on the foregoing discussion, the operation of the system of FIG. **8** is understood by those skilled in the art.

Referring now to FIG. **9**, a block diagram illustrates a data compression system according to a preferred embodiment of the present invention. The system of FIG. **9** contains many of the features of the previous embodiments discussed above. However, this embodiment advantageously includes a cascaded encoder module **30***c* having an encoding architecture comprising a plurality of sets of serially cascaded encoders Em,n, where "m" refers to the encoding path (i.e., the encoder set) and where "n" refers to the number of encoders in the respective path. It is to be understood that each set of serially cascaded encoders can include any number of disparate and/or similar encoders (i.e., n can be any value for a given path m).

The system of FIG. **9** also includes a output buffer module **40***c* which comprises a plurality of buffer/counters B/Cm,n, each associated with a corresponding one of the encoders Em,n. In this embodiment, an input data block is sequentially applied to successive encoders (encoder stages) in the encoder path so as to increase the data compression ratio. For example, the output data block from a first encoder E**1**,**1**, is buffered and counted in B/C**1**,**1**, for subsequent processing by a second encoder E**1**,**2**. Advantageously, these parallel sets of sequential encoders are applied to the input data stream to effect content free lossless data compression. This embodiment provides for multi-stage sequential encoding of data with the maximum number of encoding steps subject to the available real-time, pseudo real-time, or other timing constraints.

As with each previously discussed embodiment, the encoders Em,n may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Encoding techniques are selected based upon their ability to effectively encode different types of input data. A full complement of encoders provides for broad coverage of existing and future data types. The input data blocks may be applied simultaneously to the encoder paths (i.e., the encoder paths may operate in parallel, utilizing task multiplexing on a single central processor, or via dedicated hardware, or by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, an input data block may be sequentially applied to the encoder paths. Moreover, each serially cascaded encoder path may comprise a fixed (predetermined) sequence of encoders or a random sequence of encoders. Advantageously, by simultaneously or sequentially processing input data blocks via a plurality of sets of serially cascaded encoders, content free data compression is achieved.

The operation of the data compression system of FIG. **9** will now be discussed in further detail with reference to the flow diagram of FIGS. **10***a* and **10***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **100**), and its size is determined by the counter module **10** (step **102**). The data block is then stored in buffer **20** (step **104**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **106**) and starts counting towards a user-specified time limit. The input data block is then sent to the cascade encoder module **30**C wherein the input data block is applied to the first encoder (i.e., first encoding stage) in each of the cascaded encoder paths E**1**,**1** . . . Em,**1** (step **108**). Next, a determination is made as to whether the user specified time expires before the completion of the first stage encoding process (steps **110** and **112**). If the first stage encoding process is completed before the expiration of the timer, i.e., each encoder (E**1**,**1** . . . Em,**1**) completes its respective encoding process (negative result in step **110** and affirmative result in step **112**), then an encoded data block is output from each encoder E**1**,**1** . . . Em,**1** and maintained in a corresponding buffer (step **114**). Then for each cascade encoder path, the output of the completed encoding stage is applied to the next successive encoding stage in the cascade path (step **116**). This process (steps **110**, **112**, **114**, and **116**) is repeated until the earlier of the timer expiration (affirmative result in step **110**) or the completion of encoding by each encoder stage in the serially cascaded paths, at which time the encoding process is halted (step **118**).

Then, for each cascade encoder path, the buffered encoded data block output by the last encoder stage that completes the encoding process before the expiration of the timer is selected for further processing (step **120**). Advantageously, the interim stages of the multi-stage data encoding process are preserved. For example, the results of encoder E**1**,**1** are preserved even after encoder E**1**,**2** begins encoding the output of encoder E**1**,**1**. If the interval timer expires after encoder E**1**,**1** completes its respective encoding process but before encoder E**1**,**2** completes its respective encoding process, the encoded data block from encoder E**1**,**1** is complete and is utilized for calculating the compression ratio for the corresponding encoder path. The incomplete encoded data block from encoder E**1**,**2** is either discarded or ignored.

It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders in the cascade encoder paths complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency, natural variation and the sequential application of the cascaded encoders, it is possible that certain encoders may not operate quickly enough and therefore do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are selected (step **120**), the size of each encoded data block is counted (step **122**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each encoder (step **124**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **126**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **128**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **128**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **130**). The original unencoded data block and its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **132**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **128**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **134**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected (step **136**). An appropriate data compression type descriptor is then appended (step **138**) to indicate the data encoding technique applied to the encoded data block. For instance, the data type compression descriptor can indicate that the encoded data block was processed by either a single encoding type, a plurality of sequential encoding types, and a plurality of random encoding types. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **140**).

After the unencoded data block or the encoded data input data block is output (steps **132** and **140**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **142**). If the input data stream includes additional data blocks (affirmative result in step **142**), then the next successive data block is received (step **144**), its block size is counted (return to step **102**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **142**), data compression of the input data stream is finished (step **146**).

Referring now to FIG. **11**, a block diagram illustrates a data decompression system according to one embodiment of the present invention. The data decompression system preferably includes an input buffer **1100** that receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **1100** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **1102** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **1104** includes a plurality of decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source. As with the data compression systems discussed above, the decoder module **1104** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time.

The data decompression system also includes an output data buffer **1106** for buffering the decoded data block output from the decoder module **1104**.

The operation of the data decompression system of FIG. **11** will be discussed in further detail with reference to the flow diagram of FIG. **12**. A data stream comprising one or more data blocks of compressed or uncompressed data is input into the data decompression system and the first data block in the stream is received (step **1200**) and maintained in the buffer (step **1202**). As with the data compression systems discussed above, data decompression is performed on a per data block basis. The data compression type descriptor is then extracted from the input data block (step **1204**). A determination is then made as to whether the data compression type descriptor is null (step **1206**). If the data compression type descriptor is determined to be null (affirmative result in step **1206**), then no decoding is applied to the input data block and the original undecoded data block is output (or maintained in the output buffer) (step **1208**).

On the other hand, if the data compression type descriptor is determined to be any value other than null (negative result in step **1206**), the corresponding decoder or decoders are then selected (step **1210**) from the available set of decoders D**1** . . . Dn in the decoding module **1104**. It is to be understood that the data compression type descriptor may mandate the application of: a single specific decoder, an ordered sequence of specific decoders, a random order of specific decoders, a class or family of decoders, a mandatory or optional application of parallel decoders, or any combination or permutation thereof. The input data block is then decoded using the selected decoders (step **1212**), and output (or maintained in the output buffer **1106**) for subsequent data processing, storage, or transmittal (step **1214**). A determination is then made as to whether the input data stream contains additional data blocks to be processed (step **1216**). If the input data stream includes additional data blocks (affirmative result in step **1216**), the next successive data block is received (step **1220**), and buffered (return to step **1202**). Thereafter, the data decompression process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1216**), data decompression of the input data stream is finished (step **1218**).

In other embodiments of the present invention described below, data compression is achieved using a combination of content dependent data compression and content independent data compression. For example, FIGS. **13***a* and **13***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to one embodiment of the present invention, wherein content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The data compression system comprises a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds a priori specified content independent or content dependent minimum compression ratio thresholds. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

A content dependent data recognition module **1300** analyzes the incoming data stream to recognize data types, data structures, data block formats, file substructures, file types, and/or any other parameters that may be indicative of either the data type/content of a given data block or the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1310** module may be employed to hold and/or determine associations between recognized data parameters and appropriate algorithms. Each data block that is recognized by the content data compression module **1300** is routed to a content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**.

A content dependent encoder module **1320** is operatively connected to the content dependent data recognition module **1300** and comprises a set of encoders D**1**, D**2**, D**3** . . . Dm. The encoder set D**1**, D**2**, D**3** . . . Dm may include any number "n" of those lossless or lossy encoding techniques currently well known within the art such MPEG4, various voice codecs, MPEG3, AC3, AAC, as well as lossless algorithms such as run length, Huffinan, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders and or codecs are preferably selected to provide a broad coverage of existing and future data types.

The content independent encoder module **30**, which is operatively connected to the content dependent data recognition module **1300**, comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Again, it is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder modules (content dependent **1320** and content independent **30**) selectively receive the buffered input data blocks (or unbuffered input data blocks from the counter module **10**) from module **1300** based on the results of recognition. Data compression is performed by the respective encoder modules wherein some or all of the encoders D**1** . . . Dm or E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders D**1** . . . Dm and E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoder set D**1** through Dm of encoder module **1320** and/or the encoder set E**1** through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders D**1** through Dm and E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block. It should be further noted that one or more algorithms may be implemented in dedicated hardware such as an MPEG4 or MP3 encoding integrated circuit.

Buffer/counter modules **1330** and **40** are operatively connected to their respective encoding modules **1320** and **30**, for buffering and counting the size of each of the encoded data blocks output from the respective encoder modules. Specifically, the content dependent buffer/counter **1330** comprises a plurality of buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm, each operatively associated with a corresponding one of the encoders D**1** . . . Dm. Similarly the content independent buffer/counters BCE**1**, BCE**2**, BCE**3** . . . BCEn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **1340**, operatively connected to the content dependent output buffer/counters **1330** and content independent buffer/counters **40** determines the compression ratio obtained for each of the enabled encoders D**1** . . . Dm and or E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn. In addition, the compression ratio module **1340** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn achieves a compression that meets an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit maybe specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It should be noted that different threshold values may be applied to content dependent and content independent encoded data. Further these thresholds may be adaptively modified based upon enabled encoders in either or both the content dependent or content independent encoder sets, along with any associated parameters. A compression type description module **1350**, operatively coupled to the compression ratio module **1340**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

A mode of operation of the data compression system of FIGS. **13***a* and **13***b* will now be discussed with reference to the flow diagrams of FIGS. **14***a*-**14***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. In general, content independent data compression is applied to a given data block when the content of a data block cannot be identified or is not associated with a specific data compression algorithm. More specifically, referring to FIG. **14***a*, a data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1400**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1402**). The data block is then stored in the buffer **20** (step **1404**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1408**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1410**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1412**), and the encoded data block size is counted (step **1414**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1416**). Each compression ratio is then compared with an apriori-specified compression ratio threshold (step **1418**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

As previously stated the data block stored in the buffer **20** (step **1404**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1434**) the appropriate content dependent algorithms are enabled and initialized (step **1436**), and the data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1438**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1440**), and the encoded data block size is counted (step **1442**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1444**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1448**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

After the encoded data block or the unencoded data input data block is output (steps **1426** and **1436**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1428**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1432**), its block size is counted (return to step **1402**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1428**), data compression of the input data stream is finished (step **1430**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. Further the encoding may be lossy or lossless dependent upon the input data types. Further if the data type is not recognized the default content independent lossless compression is applied. It is not a requirement that this process be deterministic—in fact a certain probability may be applied if occasional data loss is permitted. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

FIGS. **15***a* and **15***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **15***a* and **15***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **15***a* and **15***b* additionally performs content independent data compression on a data block when the compression ratio obtained for the data block using the content dependent data compression does not meet a specified threshold.

A mode of operation of the data compression system of FIGS. **15***a* and **15***b* will now be discussed with reference to the flow diagram of FIGS. **16***a*-**16***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression, A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1600**), As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1602**). The data block is then stored in the buffer **20** (step **1604**). The data block is then analyzed on a per block or multi-Hock basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1608**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1610**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1612**), and the encoded data block size is counted (step **1614**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1616**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1618**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1620**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1634**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1636**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1620**), then the encoded data block having the greatest compression ratio is selected (step **1622**). An appropriate data compression type descriptor is then appended (step **1624**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1626**).

As previously stated the data block stored in the buffer **20** (step **1604**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1634**) the appropriate content dependent algorithms are enabled and initialized (step **1636**) and the data is routed to the content dependent encoder module **1620** and compressed by each (enabled) encoder D**1** . . . Dm (step **1638**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1640**), and the encoded data block size is counted (step **1642**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1644**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1648**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1648**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is routed to the content independent encoder module **30** and the process resumes with compression utilizing content independent encoders (step **1610**).

After the encoded data block or the unencoded data input data block is output (steps **1626** and **1636**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1628**). If the input data stream includes additional data blocks (affirmative result in step **1628**), the next successive data block is received (step **1632**), its block size is counted (return to step **1602**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1628**), data compression of the input data stream is finished (step **1630**).

FIGS. **17***a* and **17***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **17***a* and **17***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **17***a* and **17***b* additionally uses a priori estimation algorithms or look-up tables to estimate the desirability of using content independent data compression encoders and/or content dependent data compression encoders and selecting appropriate algorithms or subsets thereof based on such estimation.

More specifically, a content dependent data recognition and or estimation module **1700** is utilized to analyze the incoming data stream for recognition of data types, data strictures, data block formats, file substructures, file types, or any other parameters that may be indicative of the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1710** module may be employed to hold associations between recognized data parameters and appropriate algorithms. If the content data compression module recognizes a portion of the data, that portion is routed to the content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**. It is to be appreciated that process of recognition (modules **1700** and **1710**) is not limited to a deterministic recognition, but may farther comprise a probabilistic estimation of which encoders to select for compression from the set of encoders of the content dependent module **1320** or the content independent module **30**. For example, a method may be employed to compute statistics of a data block whereby a determination that the locality of repetition of characters in a data stream is determined is high can suggest a text document, which may be beneficially compressed with a lossless dictionary type algorithm. Further the statistics of repeated characters and relative frequencies may suggest a specific type of dictionary algorithm. Long strings will require a wide dictionary file while a wide diversity of strings may suggest a deep dictionary. Statistics may also be utilized in algorithms such as Huffman where various character statistics will dictate the choice of different Huffinan compression tables. This technique is not limited to lossless algorithms but may be widely employed with lossy algorithms. Header information in frames for video files can imply a specific data resolution. The estimator then may select the appropriate lossy compression algorithm and compression parameters (amount of resolution desired). As shown in previous embodiments of the present invention, desirability of various algorithms and now associated resolutions with lossy type algorithms may also be applied in the estimation selection process.

A mode of operation of the data compression system of FIGS. **17***a* and **17***b* will now be discussed with reference to the flow diagrams of FIGS. **18***a*-**18***d*. The method of FIGS. **18***a*-**18***d* use a priori estimation algorithms or look-up tables to estimate the desirability or probability of using content independent data compression encoders or content dependent data compression encoders, and select appropriate or desirable algorithms or subsets thereof based on such estimates. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1800**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1802**). The data block is then stored in the buffer **20** (step **1804**). The data block is then analyzed on a per block or multi-block basis by the content dependent/content independent data recognition module **1700** (step **1806**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1710** (step **1808**) the data is to the content independent encoder module **30**. An estimate of the best content independent encoders is performed (step **1850**) and the appropriate encoders are enabled and initialized as applicable. The data is then compressed by each (enabled) encoder E**1** . . . En (step **1810**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1812**), and the encoded data block size is counted (step **1814**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1816**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1818**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

As previously stated the data block stored in the buffer **20** (step **1804**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1806**). If the data stream content is recognized or estimated utilizing the recognition list(s) or algorithms(s) module **1710** (affirmative result in step **1808**) the recognized data type/file or block is selected based on a list or algorithm (step **1838**) and an estimate of the desirability of using the associated content dependent algorithms can be determined (step **1840**). For instance, even though a recognized data type may be associated with three different encoders, an estimation of the desirability of using each encoder may result in only one or two of the encoders being actually selected for use. The data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1842**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1844**), and the encoded data block size is counted (step **1846**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1848**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1850**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

After the encoded data block or the unencoded data input data block is output (steps **1826** and **1836**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1828**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1832**), its block size is counted (return to step **1802**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1828**), data compression of the input data stream is finished (step **1830**).

It is to be appreciated that in the embodiments described above with reference to FIGS. **13-18**, an a priori specified time limit or any other real-time requirement may be employed to achieve practical and efficient real-time operation.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A method comprising:

determining whether or not a parameter or attribute of data within a data block is identified for the data block wherein the determining is not based solely on a descriptor that is indicative of the parameter or attribute of the data within the data block;

compressing, if the parameter or attribute of the data within the data block is identified, the data block with at least one encoder associated with the parameter or attribute of the data within the data block to provide a compressed data block; and

compressing, if the parameter or attribute of the data within the data block is not identified, the data block with at least one encoder associated with a non-identifiable parameter or attribute of the data within the data block to provide the compressed data block.

2. The method of claim **1**, further comprising receiving and buffering the data block, wherein the buffering is performed after the receiving of the data block and before compressing of the data block.

3. The method of claim **1**, further comprising transmitting a data token indicative of the compression utilized to provide the compressed data block.

4. The method of claim **3**, further comprising receiving the compressed data block and the data token indicative of the compression utilized to provide the compressed data block.

5. The method of claim **4**, further comprising decompressing the compressed data block based on the token indicative of the compression utilized to provide the compressed data block.

6. The method of claim **1**, wherein the compressing, if a parameter or attribute of the data within the data block is identified, occurs in real-time.

7. The method of claim **1**, wherein the compressing, if a parameter or attribute of the data within the data block is not identified, occurs in real-time.

8. The method of claim **1**, wherein the size of the data block is fixed.

9. The method of claim **1**, wherein the size of the data block is variable.

10. The method of claim **1** further comprising storing the compressed data block.

11. The method of claim **10** further comprising retrieving the stored compressed data block and decompressing the stored compressed data block at a rate that provides the decompressed data block faster than if the data block were retrieved uncompressed.

12. The method of claim **1**, wherein the at least one encoder associated with the parameter or attribute of the data within the data block is lossless.

13. The method of claim **1**, wherein the at least one encoder associated with the non-identifiable parameter or attribute of the data within the data block is lossless.

14. The method of claim **1**, wherein the at least one encoder associated with the parameter or attribute of the data is a Lempel-Ziv encoder.

15. The method of claim **1**, wherein the at least one encoder associated with the non-identifiable parameter or attribute of the data is a Lempel-Ziv encoder.

16. The method of claim **1**, wherein the at least one encoder associated with the parameter or attribute of the data within the data block is provided as a software module.

17. The method of claim **1**, wherein at least one of the least one encoder associated with the parameter or attribute of the data within the data block is operable to be user-disabled.

18. A method comprising:

associating at least one encoder to each one of a plurality of parameters or attributes of data;

analyzing data within a data block to determine whether a parameter or attribute of the data within the data block is identified for the data block;

wherein the analyzing of the data within the data block to identify a parameter or attribute of the data excludes analyzing based only on a descriptor that is indicative of the parameter or attribute of the data within the data block;

identifying a first parameter or attribute of the data of the data block;

compressing, if the first parameter or attribute of the data is the same as one of the plurality of parameter or attributes of the data, the data block with the at least one encoder associated with the one of the plurality of parameters or attributes of the data that is the same as the first parameter or attribute of the data to provide a compressed data block; and

compressing, if the first parameter or attribute of the data is not the same as one of the plurality of parameters or attributes of the data, the data block with a default encoder to provide the compressed data block.

19. The method of claim **18** wherein the data block is first received.

20. The method of claim **18**, wherein the compressing occurs in real-time.

21. The method of claim **18**, further comprising transmitting a token indicative of the compression utilized to provide the compressed data block, with the compressed data block.

22. The method of claim **21** further comprising receiving the transmitted compressed data block and the token and decompressing the compressed data block based on the token.

23. A method comprising:

associating at least one of a plurality of first encoders to each one of a plurality of attributes or parameters of data;

associating at least one second encoder to a non-identifiable parameter or attribute of data;

determining whether a parameter or attribute of data is identified for a data within the data block wherein the determining excludes determining based upon a descriptor indicative of a parameter or attribute of the data;

compressing, if a parameter or attribute of the data is identified as being associated with the at least one of the plurality of first encoders, the data block with the at least one of the plurality of first encoders associated with the parameter or attribute to provide a compressed data block;

compressing, if a parameter or attribute of the data is not identified, the data block with the at least one second encoder to provide the compressed data block; and

transmitting the compressed data block with a token indicative of the compression utilized to provide the compressed data block.

24. The method of claim **23**, further comprising receiving and buffering the data block wherein the buffering is after the receiving of the data block and before the compressing of the data block.

25. The method of claim **23**, wherein the compressing, if a parameter or attribute of the data is identified as being associated with the at least one of the plurality of first encoders, and compressing, if a parameter or attribute of the data is not identified, occurs in real-time.

26. The method of claim **23**, wherein the at least one of the plurality of first encoders is operable to be user-disabled.

27. The method of claim **23** further comprising receiving the transmitted compressed data block and decompressing the compressed data block at a rate that provides the decompressed data block faster than if the data block were transmitted and received in uncompressed form, inclusive of the time to compress.

28. A method comprising:

providing a plurality of compression techniques;

determining whether or not to compress a data block and, if the data block is to be compressed, determining which one of the plurality of compression techniques to utilize to compress the data block and compressing the data block with the determined one of the plurality of compression techniques to provide a compressed data block;

wherein the determining excludes determining based upon a descriptor that is indicative of a parameter or attribute of the data within the data block; and

providing a token associated with the compressed data block, wherein the token is either indicative of the determination not to compress or the determined one of the plurality of compression techniques.

29. The method of claim **28**, wherein the compressing occurs in real-time.

30. The method of claim **28** further comprising transmitting the compressed data block with the token indicative of whether the data block is compressed and if it is compressed, the compression utilized to provide the compressed data block.

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US009667751B2

(12) **United States Patent**
Fallon et al.

(10) **Patent No.: US 9,667,751 B2**
(45) **Date of Patent: *May 30, 2017**

(54) **DATA FEED ACCELERATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/853,581**

(22) Filed: **Sep. 14, 2015**

(65) **Prior Publication Data**

US 2016/0127513 A1 May 5, 2016

Related U.S. Application Data

(63) Continuation of application No. 13/403,785, filed on Feb. 23, 2012, now Pat. No. 9,141,992, which is a

(Continued)

(51) **Int. Cl.**

H03M 7/34	(2006.01)
H04L 29/06	(2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ***H04L 69/04*** (2013.01); ***G06Q 40/04*** (2013.01); ***H03M 7/30*** (2013.01); ***H03M 7/3059*** (2013.01);

(Continued)

(58) **Field of Classification Search**
CPC G06Q 40/04; H03M 7/30; H03M 7/3059; H04L 29/06176; H04L 69/04;

(Continued)

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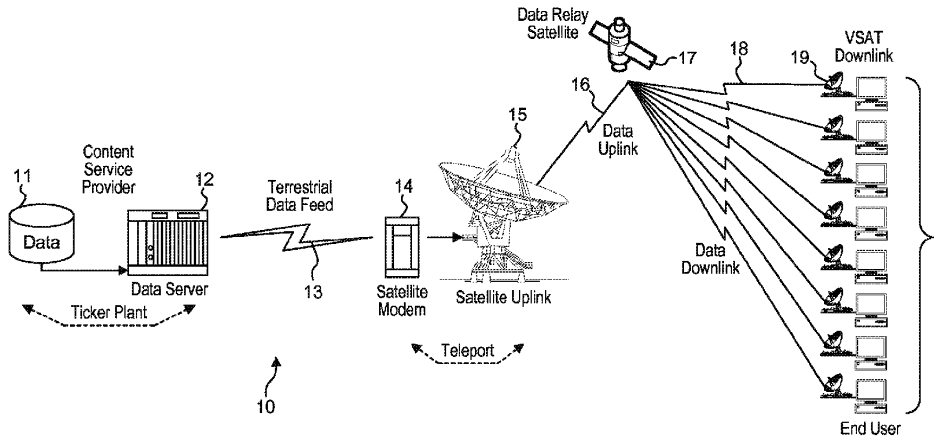
(57) **ABSTRACT**

The transmission of broadcast data, such as financial data and news feeds, is accelerated over a communication channel using data compression and decompression to provide secure transmission and transparent multiplication of communication bandwidth, as well as reduce the latency. Broadcast data may include packets having fields. Encoders associated with particular fields may be selected to compress those particular fields.

48 Claims, 6 Drawing Sheets



Related U.S. Application Data

continuation of application No. 12/857,238, filed on Aug. 16, 2010, now Pat. No. 8,692,695, which is a continuation of application No. 12/131,631, filed on Jun. 2, 2008, now Pat. No. 7,777,651, which is a continuation of application No. 10/434,305, filed on May 7, 2003, now Pat. No. 7,417,568, which is a continuation-in-part of application No. 09/969,987, filed on Oct. 3, 2001, now Pat. No. 9,143,546.

(60) Provisional application No. 60/237,571, filed on Oct. 3, 2000, provisional application No. 60/378,517, filed on May 7, 2002.

(51) **Int. Cl.**

H04L 12/18	(2006.01)
H04L 29/08	(2006.01)
G06Q 40/04	(2012.01)
H03M 7/30	(2006.01)
H01L 51/52	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 12/1895*** (2013.01); ***H04L 29/06027*** (2013.01); ***H04L 29/06176*** (2013.01); ***H04L 65/4076*** (2013.01); ***H04L 65/607*** (2013.01); ***H04L 65/80*** (2013.01); ***H04L 67/26*** (2013.01); *H01L 51/52* (2013.01)

(58) **Field of Classification Search**

CPC H04L 67/26; H04L 65/80; H04L 65/607; H04L 12/1895; H04L 29/06027; H04L 65/4076; H01L 51/52

USPC 341/50, 51

See application file for complete search history.

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Exhibit 16, Prior Art Chart for U.S. Patent No. 7,777,651, 248 pages, *Realtime Data, LLC D/B/A IXO* v. *Morgan Stanley, et al.*, 6:09-cv-326-LED-JDL, 6:10-cv-248-LED-JDL, 6:10-cv-426-LED-JDL, *Realtime Data, LLC D/B/A IXO* v. *CME Group Inc., et al.*, 6:09-cv-327-LED-JDL, 6:10-cv-246-LED-JDL, 6:10-cv-424-LED-JDL, *Realtime Data, LLC D/B/A IXO* v. *Thomson Reuters Corp., et al.*, 6:09-cv-333-LED-JDL, 6:10-cv-247-LED-JDL, 6:10-cv-425-LED-JDL, United States District Court for the Eastern District of Texas Tyler Division, Feb. 4, 2011, citing Dye et al., U.S. Patent No. 7,190,284 and International Publication No. WO 00/45516.

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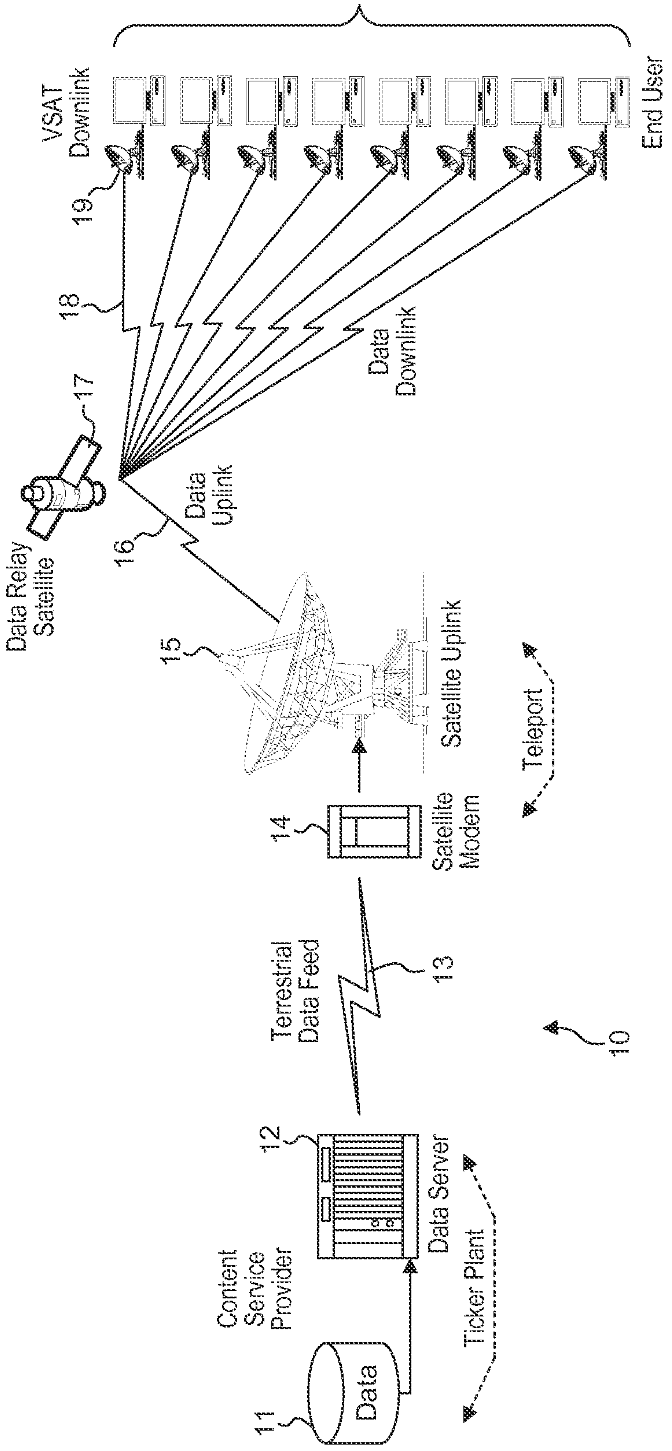
End User
VSAT Downlink
19
18
Data Downlink
17
Data Relay Satellite
16
Data Uplink
15
Satellite Uplink
Teleport
14
Satellite Modem
Terrestrial Data Feed
13
10
12
Data Server
Content Service Provider
Ticker Plant
11
Data

FIG. 1

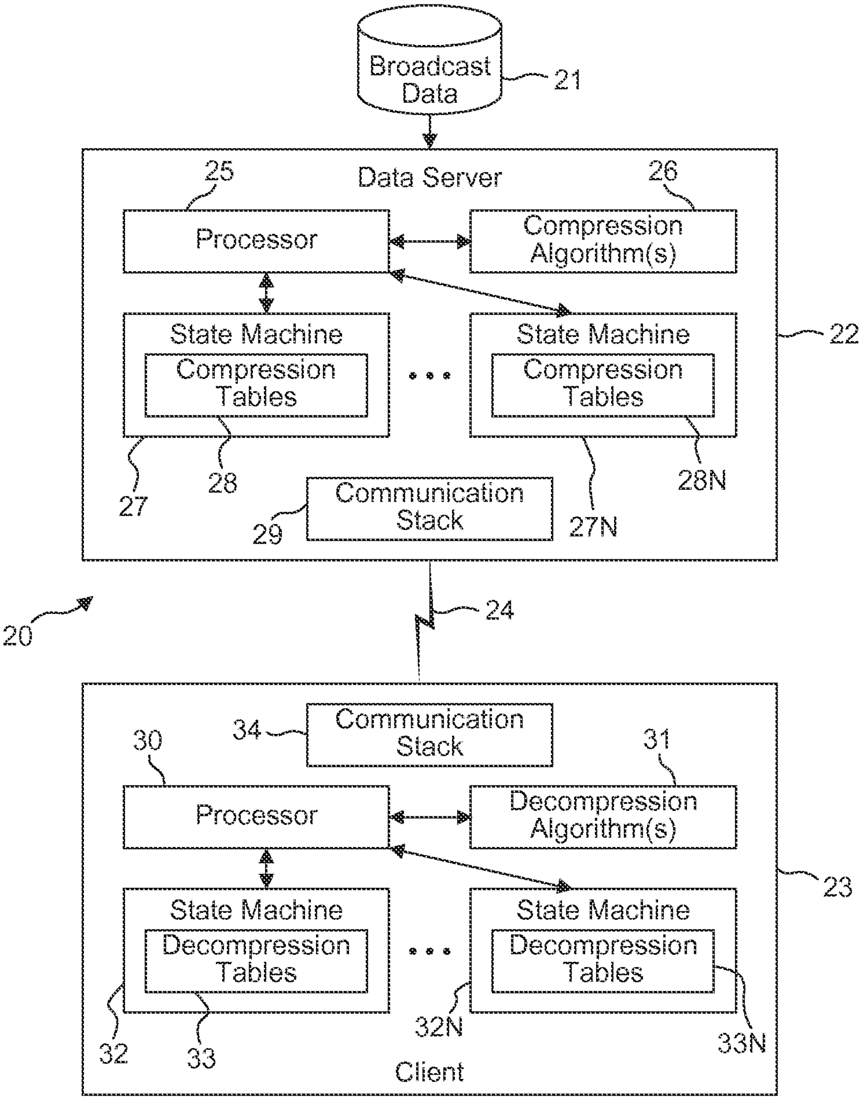
Broadcast Data
21
Data Server
25
Processor
26
Compression Algorithm(s)
State Machine
Compression Tables
State Machine
Compression Tables
22
27
28
28N
Communication Stack
29
27N
24
20
Communication Stack
34
30
31
Processor
Decompression Algorithm(s)
23
State Machine
Decompression Tables
State Machine
Decompression Tables
32
33
32N
33N
Client

FIG. 2

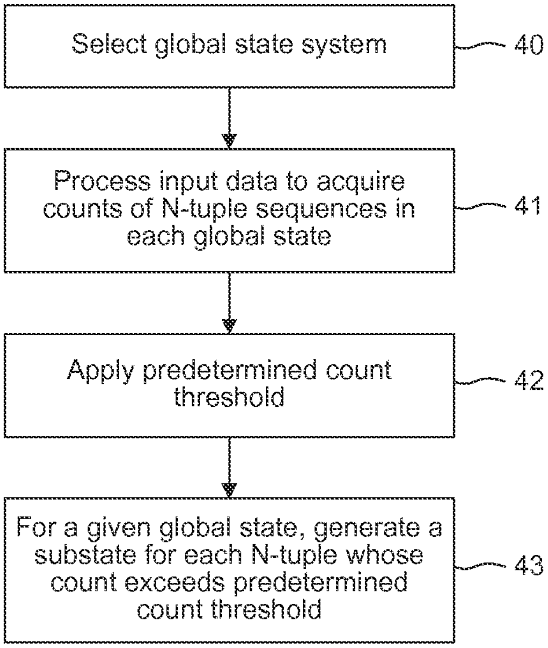
Select global state system
40
Process input data to acquire counts of N-tuple sequences in each global state
41
Apply predetermined count threshold
42
For a given global state, generate a substate for each N-tuple whose count exceeds predetermined count threshold
43

FIG. 3

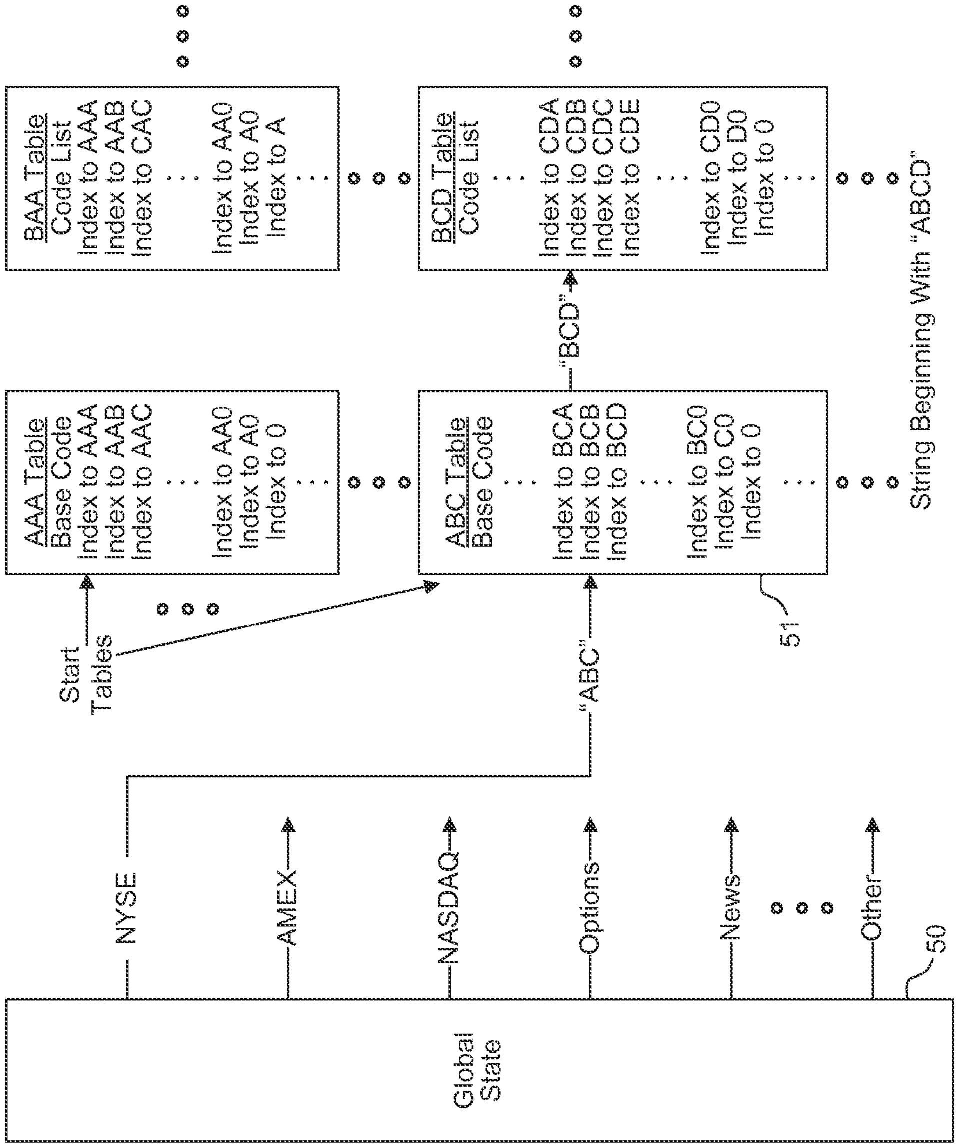
Global State
50
NYSE
AMEX
NASDAQ
Options
News
Other
"ABC"
Start Tables
51
AAA Table
Base Code
Index to AAA
Index to AAB
Index to AAC
Index to AA0
Index to A0
Index to 0
ABC Table
Base Code
Index to BCA
Index to BCB
Index to BCD
Index to BC0
Index to C0
Index to 0
"BCD"
BAA Table
Code List
Index to AAA
Index to AAB
Index to CAC
Index to AA0
Index to A0
Index to A
BCD Table
Code List
Index to CDA
Index to CDB
Index to CDC
Index to CDE
Index to CD0
Index to D0
Index to 0
String Beginning With "ABCD"

FIG. 4

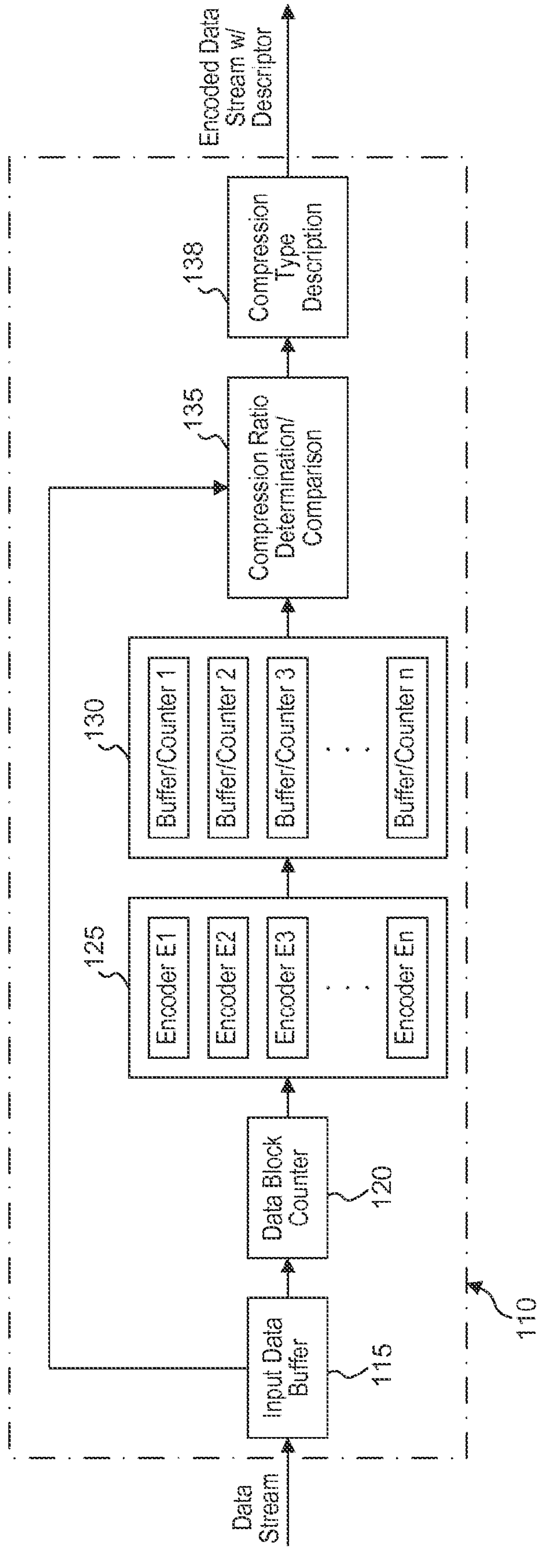
Data Stream
110
Input Data Buffer
115
Data Block Counter
120
125
Encoder E1
Encoder E2
Encoder E3
. . .
Encoder En
130
Buffer/Counter 1
Buffer/Counter 2
Buffer/Counter 3
. . .
Buffer/Counter n
135
Compression Ratio Determination/ Comparison
138
Compression Type Description
Encoded Data Stream w/ Descriptor

FIG. 5

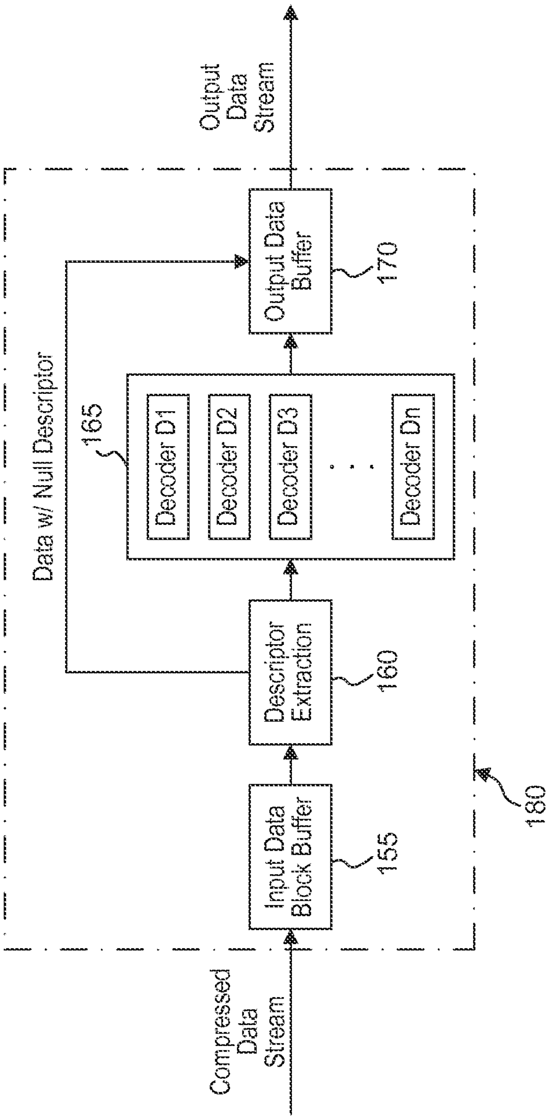
Compressed Data Stream
Input Data Block Buffer
155
Descriptor Extraction
160
Data w/ Null Descriptor
165
Decoder D1
Decoder D2
Decoder D3
. . .
Decoder Dn
Output Data Buffer
170
Output Data Stream
180

FIG. 6

DATA FEED ACCELERATION

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation of U.S. patent application Ser. No. 13/403,785, filed Feb. 23, 2012, which is a continuation of U.S. patent application Ser. No. 12/857,238, filed Aug. 16, 2010, now U.S. Pat. No. 8,692,695, which is a continuation of U.S. patent application Ser. No. 12/131,631, filed Jun. 2, 2008, now U.S. Pat. No. 7,777,651, which is a continuation of U.S. patent application Ser. No. 10/434,305, filed May 7, 2003, now U.S. Pat. No. 7,417,568, which is a continuation-in-part of U.S. patent application Ser. No. 09/969,987, filed Oct. 3, 2001, which claims the benefit of U.S. Provisional Patent Application No. 60/237,571, filed on Oct. 3, 2000, each of which are fully incorporated herein by reference. In addition, U.S. patent application Ser. No. 10/434,305 claims the benefit of U.S. Provisional Patent Application No. 60/378,517, filed May 7, 2002, which is fully incorporated herein by reference.

TECHNICAL FIELD

The present invention relates generally to systems and method for providing data transmission, and in particular, to systems and method for providing accelerated transmission of data, such as financial trading data, financial services data, financial analytical data, company background data and news feeds, advertisements, and all other forms or information over a communication channel using data compression and decompression to provide data broadcast feeds, bi-directional data transfers, and all other forms of communication with or without security and effectively increase the bandwidth of the communication channel and/or reduce the latency of data transmission.

BACKGROUND

The financial markets and financial information services industry encompass a broad range of financial information ranging from basic stock quotations, bids, order, fulfillment, financial and quotations to analyst reports to detailed pricing of Treasury Bills and Callable bonds. Users of financial information can now generally be divided into three segments—Traders, Information Users and Analytics Users, although some users constitute components from one or more of these categories.

Traders utilize data from financial markets such as NASDAQ, the American Stock Exchange, the New York Stock Exchange, the Tokyo Exchange, the London Exchange, the Chicago Options Board, and similar institutions that offer the ability to buy and sell stocks, options, futures, bonds, derivatives, and other financial instruments. The need for vast quantities of information is vital for making informed decisions and executing optimal transactions

Thus given the importance of receiving this information over computer networks, an improved system and method for providing secure point-to-point solution for transparent multiplication of bandwidth over conventional communication channels is highly desirable.

For example, with the introduction of Nasdaq's next generation trading system SuperMontage, Nasdaq will offer market data users an unparalleled view into the activity, liquidity, and transparency of the Nasdaq market.

For example, currently Nasdaq provides each market participant's best-attributed quotation in each stock in which

it makes a market. This system known as SuperMontage allows Nasdaq to accept multiple orders from each market participate in each stock for execution within SuperMontage. Nasdaq offers that data, with multiple levels of interest from individual market participants, through new data services.

Nasdaq provides this data on both an aggregated and a detailed basis for the top five price levels in SuperMontage. This data is currently offered through market data vendors and broker/dealer distributors via the following four entitlement packages:

QuoteView^{SM} Each SuperMontage participant's best bid and offer, as well as the best bid and offer available on SuperMontage.

DepthView^{SM} The aggregate size, by price level, of all Nasdaq market participants' attributed and unattributed quotations/orders that are in the top five price levels in SuperMontage.

PowerView^{SM} Bundled QuoteView and DepthView.

TotalView^{SM} PowerView plus all Nasdaq market participants' attributed quotations/orders that are in the top five price levels in SuperMontage, in addition to the aggregate size of all unattributed quotes/orders at each of the top five price levels.

The NASDAQ SuperMontage trading system has been cited to be representative of trend for explosive growth in the quantity of information for all emergent and future trading and financial information distribution systems. Increases in processing power at the end user sites will allow traders, analysts, and all other interested parties to process substantially larger quantities of data in far shorter periods of time, increasing the demand substantially.

The ever increasing need for liquidity in the financials markets, coupled with the competitive pressures on reducing bid/ask spreads and instantaneous order matching/fulfillment, along the need for synchronized low latency data dissemination makes the need for the present invention ever more important. Depth of market information, required to achieve many of these goals requires orders of magnitude increases in Realtime trade information and bid/ask pricing (Best, 2nd best, . . .).

A fundamental problem within the current art is the high cost of implementing, disseminating, and operating trading systems such as SuperMontage within the financial services industry. This is in large part due to the high bandwidth required to transfer the large quantities of data inherent in the operation of these systems. In addition the processing power required to store, transmit, route, and display the information further compounds cost and complexity.

This fundamental problem is in large part the result of utilizing multiple simultaneous T1 lines to transmit data. The data must be multiplexed into separate data streams, transmitted on separate data lines, and de-multiplexed and checked. Software solutions have high latency and cost while hardware solutions have even higher cost and complexity with somewhat lower latency. In addition the synchronization and data integrity checking require substantial cost, complexity, inherent unreliability, and latency. These and other limitations are solved by the present invention.

Further compounding this issue is a globalization and consolidation taking place amongst the various financial exchanges. The emergence of localized exchanges (ECNS-Electronic Computer Networks) coupled with the goal of 24 hour/7 day global trading will, in and of itself, drive another exponential increase in long haul international bandwidth requirements, while ECNs and other localized trading networks will similarly drive domestic bandwidth requirements. Clearly long haul links are orders of magnitude more expensive than domestic links and the value and significance of the present invention is at least proportionately more important.

Information users range from non-finance business professionals to curious stock market investors and tend to seek basic financial information and data. Analytical users on the other hand, tend to be finance professionals who require more arcane financial information and utilize sophisticated analytical tools to manipulate and analyze data (e.g. for writing option contracts).

Historically, proprietary systems, such as Thomson, Bloomberg, Reuters and Bridge Information, have been the primary electronic source for financial information to both the informational and analytical users. These closed systems required dedicated telecommunications lines and often product-specific hardware and software. The most typical installations are land-based networking solutions such as T1, or ISDN, and satellite-based "wireless" solutions at speeds of 384 kbps.

Latency of financial data is critical to the execution of financial transactions. Indeed the more timely receipt of financial data from various sources including the New York Stock Exchange, American Stock Exchange, National Association of Securities Dealers (NASDAQ), Options Exchange, Commodities Exchanges, and Futures presents a fundamental advantage to those who trade. Latency is induced by the long time taken transmit and receive uncompressed data or to compress and encrypt data prior to transmission, along with the associated time to decrypt and decompress. Often current methods of encryption and compression take as much or substantially more time than the actual time to transmit the uncompressed, unencrypted data. Thus another problem within the current art is the latency induced by the act of encryption, compression, decryption, and decompression. The present invention overcomes this limitation within the current art.

Modern data compression algorithms suffer from poor compression, high latency, or both. Within the present art algorithms such as Lempel-Ziv, modified/embellished Lempel-Ziv, Binary Arithmetic, and Huffman coding are essentially generic algorithm having a varied effectiveness on different data types. Also small increases in compression to the negentropy limit of the data generally require exponentially greater periods of time and substantially higher latency. Negentropy is herein defined as the information content within a given piece of data. Generic algorithms are currently utilized as data types and content format is constantly changed within the financial industry. Many changes are gradual however there are also abrupt changes, such as the recent switch to decimalization to reduce granularity that has imposed substantial requirements on data transmission bandwidth infrastructure within the financial industry. Thus another problem within the current art is the high latency and poor compression due to the use of generic data compression algorithms on financial data and news feeds. This limitation is also overcome by the present invention.

Within the financial and news feeds, data is often segregated into packets for transmission. Further, in inquiry-response type systems, as found in many financial research systems, the size of request packets and also response packets is quite small. As such, response servers often wait for long periods of time (for example 500 msec) to aggregate data packets prior to transmission back to the inquirer. By aggregating the data, and then applying compression, somewhat higher compression ratios are often achieved. This then translates to lower data communications costs or more customers served for a given amount of available communications bandwidth. Thus another problem within the current art is the substantial latency caused by aggregating data packets due to poor data compression efficiency and packet overhead. This limitation is also solved by the present invention.

Another problem within the current art is the need for data redundancy. Currently many trading systems utilize two independent links to compare data to verify integrity. Second, the bandwidth of discrete last mile links, typically T1s, is limited to 1.5 Megabits/second.

Increases in bandwidth beyond this point require complex protocols to fuse data from multiple links, adding cost and complexity, while also increasing latency and inherent data error rates. This limitation is also solved by the present invention.

Another limitation within the current art is that nearly all financial institutions use one or more T1 lines to transfer information to and from their customers. While the costs of bandwidth have moderately decreased over recent years this trend is slowing and the need forever increased bandwidth will substantively overshadow any future reductions. Indeed with the recent fall-out of the telecommunications companies the data communications price wars will end and we could easily see an increase in the cost of bandwidth. US Domestic T1 lines currently range from several hundred dollars to upwards of a thousand dollars per link, dependent upon quantity of T1 lines purchased, geographic location, length of connection, and quality/conditioning of line. Fractional T1 lines may also be purchased in 64 Kilobit/second increments with some cost savings.

A standard T1 line transmits data at a rate of 1.544 megabits per second. Accounting for framing and data transmission overhead this means that a T1 line is capable of transmitting a 150 Kilobytes per second. While 30× faster than a modem line (which provides only 5 kilobytes per second), both are relatively slow in relation to any reasonable level of information flow. For example, transferring the contents of data on a single CDROM would take well over an hour!

Thus it is likely that the capacity of many existing T1 lines will be exceeded in the near future. For our current example let's assume that we need to double the capacity of a T1 line. Normally this is done by adding a second T1 line and combining the contents of both with Multi-Link Point to Point Protocol (MLPP) or another relatively complex protocol. Within the current art this is neither necessary nor desirable. In fact any increase over the current limitation of a T1 line results in the addition of a second line. This limitation is overcome by the present invention.

Another limitation with the current art is the extraordinary bandwidth required for real-time (hot) co-location processing which has been dramatically increased as a result of the acts of terror committed against the United States of America on Sep. 11, 2001. In order for the redundancy of any co-location to be effective, it must be resident in a geographically disparate location; this could be a different state, a different coast, or even a different country. The trend towards globalization will further compound the need for the ability to simultaneously process transactions at geographically diverse co-locations.

It is a widely known fact within the financial industry that the overall throughput of transactions is governed by the bandwidth and latency of the co-location data link, along with delays associated with synchronization, i.e. the transaction must be complete at both locations and each location must know that the other location is complete before the transaction is finalized.

High bandwidth links such as T3's are often utilized as part of this backbone structure. A single T3 line has the bandwidth of Twenty-Eight T1 lines (28×1.544=43.232 megabits/second). Thus, in the best case, a T3 line is capable of transmitting 5.4 megabytes/second. By way of comparison, the contents of a single CDROM may be transferred in approximately two minutes with a T3 link. As stated earlier, a single T1 line would take over an hour to transmit the same quantity of data.

The volume of real-time data that is required to operate any major financial institution is staggering by comparison. To deal with this issue only critical account and transaction information is currently processed by co-locations in real-time. In fact, many institutions use batch mode processing where the transactions are only repeated "backed up" at the co-locations some time period later, up to 15 minutes or longer. The limitation of highly significant bandwidth and/or long delays with co-location processing and long latency times is solved by the present invention.

Thus given the importance of receiving financial information over computer networks, an improved system and method for providing secure point-to-point solution for transparent multiplication of bandwidth over conventional communication channels is highly desirable.

As previously stated, these and other limitations within the current art are solved by the present invention.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing accelerated data transmission, and in particular to systems and methods of providing accelerated transmission of data, such as financial trading data, financial services data, financial analytical data, company background data, news, advertisements, and all other forms of information over a communications channel utilizing data compression and decompression to provide data transfer (secure or non-secure) and effectively increase the bandwidth of the communication channel and/or reduce the latency of data transmission. The present invention is universally applicable to all forms of data communication including broadcast type systems and bi-directional systems of any manner and any number of users or sites.

These and other aspects, features and advantages, of the present invention will become apparent from the following detailed description of preferred embodiments that is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** is a block diagram of a system in which the present invention may be implemented for transmitting broadcast data;

FIG. **2** is a block diagram of a system and method for providing accelerated transmission of data over a communication channel according to an embodiment of the present invention;

FIG. **3** is a flow diagram illustrating a method for generating compression/decompression state machines according to one aspect of the present invention;

FIG. **4** is a diagram illustrating an exemplary encoding table structure according to the present invention, which may be generated using the process of FIG. **3**.

FIG. **5** is a diagram of a system/method for providing content independent data compression, which may be implemented for providing accelerated data transmission according to the present invention; and

FIG. **6** is a diagram of a system/method for providing content independent data decompression, which may be implemented for providing accelerated data transmission according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed to systems and methods for providing accelerated transmission of broadcast data, such as financial data and news feeds, over a communication channel using data compression and decompression to provide secure transmission and transparent multiplication of communication bandwidth, as well as reduce the latency associated with data transmission of conventional systems.

In this disclosure, the following patents and patent applications, all of which are commonly owned, are fully incorporated herein by reference: U.S. Pat. No. 6,195,024, issued on Feb. 27, 2001, and U.S. Pat. No. 6,309,424, issued on Oct. 30, 2001 and U.S. patent application Ser. No. 10/076,013 filed on Feb. 13, 2002, Ser. No. 10/016,355, filed on Oct. 29, 2001, Ser. No. 09/481,243 filed on Jan. 11, 2000, and Ser. No. 09/266,394 filed on Mar. 11, 1999.

In general, the term "accelerated" data transmission refers to a process of receiving a data stream for transmission over a communication channel, compressing the broadcast data stream in real-time (wherein the term "real time" as used herein collectively refers to substantially real time, or at real time, or greater than real time) at a compression rate that increases the effective bandwidth of the communication channel, and transmitting the compressed broadcast data over the communication channel. The effective increase in bandwidth and reduction of latency of the communication channel is achieved by virtue of the fast than real-time, real-time, near real time, compression of a received data stream prior to transmission.

For instance, assume that the communication channel has a bandwidth of "B" megabytes per second. If a data transmission controller is capable of compressing (in substantially real time, real time, or faster than real time) an input data stream with an average compression rate of 3:1, then data can be transmitted over the communication channel at an effective rate of up to 3*B megabytes per second, thereby effectively increasing the bandwidth of the communication channel by a factor of three.

Further, when the receiver is capable decompressing (in substantially real time, real time, or faster than real time) the compressed data stream at a rate approximately equal to the compression rate, the point-to-point transmission rate between the transmitter and receiver is transparently increased. Advantageously, accelerated data transmission can mitigate the traditional bottleneck associated with, e.g., local and network data transmission.

If the compression and decompression are accomplished in real-time or faster, the compressed, transmitted and decompressed data is available before the receipt of an equivalent uncompressed stream. The "acceleration" of data transmission over the communication channel is achieved when the total time for compression, transmission, and decompression, is less than the total time for transmitting the data in uncompressed form. The fundamental operating principle of data acceleration is governed by the following relationship:

$$[T_{Compress}+T_{Transmit\ Accelerated}+T_{Decompress}]<T_{Transmit\ w/o\ Compression} \qquad \text{EQ [1]}$$

Where:

$T_{Compress}$=Time to Compress a Packet of Data

$T_{Transmit\ Accelerated}$=Time to Transmit Compressed Data Packet

$T_{Decompress}$=Time to Decompress the Compresse Data Packet

$T_{Transmit\ w/o\ Compression}$=Time to Transmit the Uncompressed (Original) Data Packet

As stated in Equation [1] above, if the time to compress, transmit, and decompress a data packet is less than the time to transmit the data in original format, then the delivery of the data is said to be accelerated.

In the above relationship, a fundamental premise is that all information is preferably fully preserved. As such, lossless data compression is preferably applied. While this disclosure is directed to transmission of data in financial networks, for example, the concept of "acceleration" may be applied to the storage and retrieval of data to any memory or storage device using the compression methods disclosed in the above-incorporated U.S. Pat. Nos. 6,195,024 and 6,309,424, and U.S. application Ser. No. 10/016,355, and the storage acceleration techniques disclosed in the above-incorporated application Ser. Nos. 09/481,243 and 09/266,394.

Returning to Equation [1], data acceleration depends on several factors including the creation of compression and decompression algorithms that are both effective (achieve good compression ratios) and efficient (operate rapidly with a minimum of computing processor and memory resources).

Rearranging the terms of Equation [1] we can see that the total time to transmit data in an "accelerated" form (transmit compressed data) is the sum of the original time to transmit the data in an uncompressed fashion divided by the actual compression ratio achieved, plus the time to compress and decompress the data.

$$T_{Transmit\ Accelerated}=[T_{Transmit\ w/o\ Compression}/CR]+T_{Compress}+T_{Decompress} \qquad \text{EQ [2]}$$

Where:

CR=Compression Ratio

Thus the latency reduction is the simple arithmetic difference between the time to transmit the original data minus the total time to transmit the accelerated data (per Equation 2 above), resulting in:

$$T_{Latency\ Reduction}=T_{Transmit\ w/o\ Compression}-T_{Transmit\ Accelerated} \qquad \text{EQ [3]}$$

And finally the achieved "Acceleration Ratio" is defined as:

$$\text{Acceleration Ratio}=T_{Transmit\ w/o\ Compression}/T_{Transmit\ Accelerated} \qquad \text{EQ [4]}$$

A number of interesting observations come to light from these relatively simple algebraic relationships and are implemented within the present invention:

Compression Ratio: The present inventions achieve a consistent reduction in latency. The data compression ratio is substantial and repeatable on each data packet.

Compression Rate: The present invention achieves a consistent reduction in latency. Both the time to compress and decompress the data packet must be an absolute minimum, repeatable on each data packet, and always within predefined allowable bounds.

Packet Independence: The present invention has no packet-to-packet data dependency. By way of example, in UDP and Multicast operations there are no guarantees on delivery of data packets, nor on the order of delivered data packets. IP data packets, similarly, have no guarantee on the order of delivery also. Thus algorithms that rely on dictionaries (Zlib, Glib, Lempel Ziv, etc.) are inherently unreliable in any financial real-world financial data applications.

It is to be understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU) or digital signal processors (DSP), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform may also include an operating system, microinstruction code, and dedicated processing hardware utilizing combinatorial logic or finite state machines. The various processes and functions described herein may be either part of the hardware, microinstruction code or application programs that are executed via the operating system, or any combination thereof.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in that the systems are programmed. General purpose computers, servers, workstations, personal digital assistants, special purpose microprocessors, dedicated hardware, or and combination thereof may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

It should be noted that the techniques, methods, and algorithms and teachings of the present invention are representative and the present invention may be applied to any financial network, trading system, data feed or other information system.

FIG. **1** is a diagram illustrating a system in which the present invention may be implemented. The system **10** comprises content **11** and data server **12** associated with a service provider of broadcast data. The content **11** comprises information that is processed by the data server **12** to generate a broadcast, e.g., a news feed or financial data feed. As explained in further detail below, the data server **12** employs data compression to encode/encrypt the broadcast data **11** prior to transmission over various communication channels to one or more client site systems **20** of subscribing users, which comprise the necessary software and hardware to decode/decrypt the compressed broadcast data in real-time. In the exemplary embodiment of FIG. **1**, the communication channels comprise a landline **13** that feeds the compressed broadcast data to a satellite system comprising modem **14** and an uplink system **15**, which provides a data uplink **16** to a relay **17**. The relay **17** provides data downlinks **18** to one or more downlink systems **19**.

Advantageously, the proprietary software used by the data server **12** to compress the data stream in real-time and software used by the workstations **19** to decompress the data stream in real-time effectively provides a seamless and transparent increase in the transmission bandwidth of the various communication channels used, without requiring modification of existing network infrastructure.

Referring now to FIG. **2**, a block diagram illustrates a system/method for providing accelerated transmission of data according to one embodiment of the present invention. More specifically, FIG. **2** illustrates embodiments of a broadcast data server (transmitter) and client system (receiver) for implementing accelerated transmission and real-time processing of broadcast data. Broadcast data **21** (comprising one or more different broadcast types) is processed by data server **22** prior to transmission to client **23** over a communication channel **24**. The data server **22** utilizes a processor **25** (e.g., microprocessor, digital signal processor, etc.) for executing one or more compression algorithms **26** for compressing (in real-time) the broadcast data **21** prior to transmission. In preferred embodiments, compression is achieved using Huffman or Arithmetic encoding, wherein one or more state machines **27**-**27***n* are constructed based on a-priori knowledge of the structure and content of one or more given broadcast and data feeds.

As explained in further detail below, each state machine **27**-**27***n* comprises a set of compression tables that comprise information for encoding the next character (text, integer, etc.) or sequence of characters in the broadcast data feed, as well as pointers which point to the next state (encoding table) based on the character or character sequence. As explained in greater detail below, a skeleton for each state machine **27**-**27***n* (nodes and pointers) is preferably built by finding sequences of characters (n-tuples) that frequently appear in a given data input. Once a skeleton has been determined, a large set of data is processed through the system and counts are kept of character n-tuples for each state. These counts are then used to construct the compression tables associated with the state machine to provide statistical compression. The compressed data is transmitted over the communication channel **24** via a communication stack using any suitable protocol (e.g., RTP (real time protocol) using RTCP (real-time control protocol), TCP/IP, UDP, or any real-time streaming protocol with suitable control mechanism).

Similarly, the client **23** comprises a processor **30** for executing one or more decompression algorithms **31**. Depending one the data feed type, one of a plurality of decompression state machines **32**-**32***n* are used to decompress the compressed data stream received by the client **23** via communication stack **34**. Each state machine **32**-**32***n* comprises a set of decompression tables **33**-**33***n* that comprise information for decode the next encoded character (or symbol) or sequence of symbols in the compressed broadcast data feed, as well as pointers which point to the next state based on the symbol or symbol sequence. For each compression state machine **27**-**27***n* in the data server, a corresponding decompression state machine **32**-**32***n* is needed in the client **23** to decompress the associated data stream.

Advantageously, a compression/decompression scheme according to the present invention using Huffman or Arithmetic encoding provides secure transmission via de facto or virtual "encryption" in a real-time environment. Indeed, virtual encryption is achieved by virtue of the fast, yet complex, data compression using Huffman tree, for example, without necessarily requiring actual encryption of the compressed data and decryption of the compressed data. Because of the time-sensitive nature of the market data, and the ever-changing and data-dependent nature of the arithmetic scheme, decryption is virtually impractical, or so complex and useless as to render the data worthless upon eventual decoding.

However, data compression using Huffman or Arithmetic encoding yields encoded data that is very difficult to decode than current encryption schemes such as plain text or simple bit shuffling codes as currently used by broadcast service providers. An attacker must have the compression model and the tables used to compress the data stream to be able to obtain useful information from it. Thus, at one level of security, the client-side decompression tables are preferably stored in encrypted form and are decrypted on being loaded into the processor **30** (e.g., general purpose processor, DSP, etc.) using an encryption/decryption key that is validated for a subscribing user. In this manner, a client will be unable to use the tables on other processors or sites or after terminating a service contract.

Since Huffman compression uses the same bit code for a character each time it appears in a given context, an attacker with a very large data set of compressed and uncompressed data could possibly reconstruct the tables, assuming the overall model were known. Arithmetic compression, on the other hand, generates different bit patterns for the same character in the same context depending on surrounding characters. Arithmetic encoding provides at least an order of magnitude more difficult to recover the tables from the compressed and uncompressed data streams.

The following is a detailed discussion of a compression scheme using Huffman or Arithmetic encoding for providing accelerated transmission of broadcast data according to one aspect of the present invention. It is to be appreciated that the present invention is applicable with any data stream whose statistical regularity may be captured and represented in a state machine model. For example, the present invention applies to packetized data streams, in which the packets are limited in type format and content.

In one embodiment using Huffman or Arithmetic encoding, each character or character sequence is encoded (converted to a binary code) based on the frequency of character or character sequence in a given "context". For a given context, frequently appearing characters are encoded with few bits while infrequently appearing characters are encoded with more bits. High compression ratios are obtained if the frequency distribution of characters in most contexts is highly skewed with few frequently appearing characters and many characters seldomly (or never) appear.

Referring now to FIG. **3**, a flow diagram illustrates a method for generating compression/decompression state machines according to one aspect of the present invention. The "context" in which a character (or character sequence) is encoded in a given broadcast stream is based on a "global state" that represents packet type and large-scale structure and the previous few characters. The first step in building a compression scheme involves selecting a global state system based on the packet structure of the broadcast model (step **40**). More specifically, a global state system is constructed based on a priori knowledge of the data stream model, e.g., the packet type frequency and structure of the broadcast model. By way of example, one model for financial data may comprise four global states representing: a beginning of packet, an options packet, a NYSE (New York Stock Exchange) packet and some other packet type. Further, additional codes may be added to the encoding tables to indicate global state transitions (e.g., for an end of packet code in the broadcast model). If there is internal structure to packets, such as a header with different statistics than the body, additional global states could be added.

Once a global state system is selected, training samples from an associated data stream are passed through the global model to acquire counts of frequencies of the occurrence of n-tuple character sequences ending in each of the model states (step **41**). In a preferred embodiment, the n-tuples comprise character sequences having 1, 2 and 3 characters. Using the acquired counts, sub-states (or "local states") of the predefined global states are constructed based on previous characters in the data stream. A local state may depend on either none, 1, 2, or 3 (or more) previous characters in the stream. To provide a practical limitation, a predetermined count threshold is preferably applied to the count data (step

42) and only those sequences that occur more often than the count threshold are added as local states (step **43**). For example, if a three-character sequence does not occur sufficiently frequently, the count for the last two characters is tested, etc.

It is to be understood that any character sequence length "n" may be implemented depending on the application. The longer the allowed character sequence, the more memory is needed to store the encoding tables and/or the lower the count threshold should be set.

As samples of the data are passed through the state model, character (and transition code) counts for each context are accumulated. These counts are used to build the Huffman or Arithmetic coding tables. The construction of the global and local models is an iterative process. The count threshold for forming local states can be adjusted depending on the application. For instance, a larger threshold will result in less local states but less compression as well. Further, a comparison of statistics in local or global states may suggest adding or deleting global states.

The construction of the global model requires knowledge of the data stream packet structure. The construction of the local states is automatic (once the threshold is set).

FIG. **4** is a diagram of an exemplary state diagram (or encoding table structure) according to the present invention, which may be generated using the process of FIG. **3**.

As noted above with reference to FIGS. **1** and **2**, a compression scheme according to the present invention may be implemented in any system to provide accelerated data transmission to multiple client site systems. Preferably, the client site systems may connect at any time, so minimal immediate history may be used (since a newly connected site must be able to pick up quickly). A system according to an embodiment of the present invention uses statistical compression (Huffman or Arithmetic coding) using fixed (or adaptive) tables based on the statistics of a data feed sample. As noted above, it has been determined that the statistical compression schemes described herein are well adapted for use with structured data streams having repetitive data content (e.g., stock symbols and quotes, etc.) to provide fast and efficient data compression/decompression.

The following discussion provides further details regarding the preparation of statistical-based encoding tables and their use for compression/decompression according to the present invention. During a data compression process, the selection of which encoding table to use for compression is preferably based on up to n (where n is preferably equal to 3) preceding characters of the message. In an exemplary broadcast model tested by the present inventors, a data stream comprises messages that begin with an ID code in the range 0-31 with the remainder of the message being characters in the range 32-127. It was found that approximately half of the messages in a given sample began with ID code 0x0c and half of the remainder began with ID code 0x0f. Thus, a separate encoding table is preferably used for a message ID code. Further, separate table sets are used for messages beginning with 0x0c and with 0x0f, with the remaining messages lumped together in another table.

Each table has an additional termination code. The termination code in a "start table" indicates the end of a compression block. The termination code in all other tables indicates the end of the message. Thus, the start table comprises 33 entries and all other tables have 97 entries.

Using one table for each 3-character context would require prohibitive amounts of memory. For example, a complete one-character context would require 33+3*97=324 tables. Then, a complete two-character context would require 324*97=31,428 tables. And finally, a complete three-character context would require 324*97*97=3,048,516 tables. Preferably, as described above, the application of a count threshold at each context size reduces the amount of tables. Only when a context occurs at greater than the threshold rate in the sample will a table be created for that context.

Each table entry includes a link to the next table to be used. For instance, in an "abc" context table, the entry for next character "d" would point to the "bcd" table, if such table was created. If such table was not created, the entry for next character "d" would point to the "cd" table, if such table existed. If no "cd" table exists, the "d" table would be used and if that fails, a base table for the message type would be used.

For a client site system to pick up the broadcast feed at any time, clearly identifiable synchronization points are preferably included in the compressed data stream. In a preferred embodiment, data is compressed in blocks with each block comprising some number of complete messages. Preferably, each compressed block ends with at least four bytes with each bit being logic 1 and no interior point in the compressed block will comprise 32 consecutive 1 bits. The compressed block preferably begins with two bytes giving the decompressed size of the block shifted to guarantee that the first byte of the compressed block is not all 1's. Thus, to achieve synchronization, the client site system can scan the input compressed data stream for 4 bytes of 0xff, wherein the next byte not equal to 0xff is deemed the start of a compressed block. In other words, the receiver will accumulate the compressed data until at least a sequence of 4 bytes each having a value of 0xff is detected in the input stream, at which point decompression will commence on the compressed input stream.

In another embodiment of the present invention, if a compressed block is more than 6 bytes longer than the uncompressed data, the data block is transmitted uncompressed preceded by the shifted two-byte count with the high bit set and trailed by 4 bytes of 0xff.

The following is discussion of a method for preparing Huffman Tables according to one aspect of the present invention. The Huffman codes generated by a conventional optimal algorithm have been modified in various ways in accordance with the present invention. First, in order that there not be 32 consecutive one bits in the data stream except at the end of a compression block, a termination code in each table comprises all 1 bits.

Further, to reduce space required for decompression tables, and ensure no sequence of 32 1 bits, each code is preferably decoded as follows:

a) The first 7 bits are used to index into a table. If the character code is no more than 7 bits, it can be read directly;

b) otherwise, some number N of initial bits is discarded and the next 7 bits are used to index a second table to find the character.

Based on these steps, preferably, no character code can use more than 14 bits and all codes of more than 7 bits must fit into the code space of the N initial bits. If N is 3, for instance, then no code can use more than 10 bits.

To achieve this, the code space required for all optimal codes of more than 7 bits is first determined, following by a determining the initial offset N. Every code comprising more than N+7 bits is preferably shortened, and other codes are lengthened to balance the code tree. It is possible that this may cause the code space for codes over 7 bits to increase so that N may need to be decreased. Preferably, this process is performed in a manner that causes minimal reduction in the efficiency of the codes.

The above modifications to convention optimal algorithm yields codes in which no non-termination code ends in more than 7 1 bits, no non-termination code begins with more than 6 1 bits, no termination code is more than 14 1 bits and no non-termination packet start code begins with more than 5 1 bits. Thus, in the middle of a packet, a sequence of no more than 13 bits of logic 1 can occur, while, at the end of a packet, a sequence of no more than 26 bits of logic 1 can occur.

In another embodiment of the present invention, Arithmetic compression can be used instead of Huffman encoding. The tables for Arithmetic encoding are preferably constructed such that a sequence of 32 bits of logic 1 will not occur in the interior of a message (which is important for a random sign-on in the middle of the stream).

Arithmetic compression provides an advantage of about 6% better compression than Huffman and uses half as much memory for tables, which allows the number of tables to be increased). Indeed, the addition of more tables and/or another level of tables yields more efficient compression. Although Arithmetic compression may take about 6 times as long as Huffman, this can certainly be improved by flattening the subroutine call tree (wherein there is a subroutine call for each output bit.)

In summary, a compression scheme according to one aspect of the invention utilizes a state machine, wherein in each state, there is a compression/decompression table comprising information on how to encode/decode the next character, as well as pointers that indicated which state to go to based on that character. A skeleton of the state machine (nodes and pointers) is preferably built by finding sequences of characters that appear often in the input. Once the skeleton has been determined, a large set of data is run through the system and counts are kept of characters seen in each state. These counts are then used to construct the encode/decode tables for the statistical compression.

Other approaches may be used to build the skeleton of the state machine. A very large fraction of the traffic on a certain feed consists of messages in the digital data feed format, which is fairly constrained. It may be possible to build by hand a skeleton that takes into account this format. For instance, capital letters only appear in the symbol name at the beginning. This long-range context information can be represented with our current approach. Once a basic skeleton is in place, the structure could be extended for sequences that occur frequently.

The above-described statistical compression schemes provide content-dependent compression and decompression. In other words, for a given data stream, the above schemes are preferably structured based on the data model associated with the given stream. It is to be appreciated, however, that other compression schemes may be employed for providing accelerated data transmission in accordance with the present invention for providing effectively increased communication bandwidth and/or reduction in latency. For instance, in another embodiment of the present invention, the data compression/decompression techniques disclosed in the above-incorporated U.S. Pat. No. 6,195,024, entitled "Content Independent Data Compression Method and System" may be used in addition to, or in lieu of, the statistical based compression schemes described above.

In general, a content-independent data compression system is a data compression system that provides an optimal compression ratio for an encoded stream regardless of the data content of the input data stream. A content-independent data compression method generally comprises the steps of compressing an input data stream, which comprises a plurality of disparate data types, using a plurality of different encoders. In other words, each encoder compresses the input data stream and outputs blocks of compressed data. An encoded data stream is then generated by selectively combining compressed data blocks output from the encoders based on compression ratios obtained by the encoders. Because a multitude of different data types may be present within a given input data stream, or data block, to it is often difficult and/or impractical to predict the level of compression that will be achieved by any one encoding technique. Indeed, rather than having to first identify the different data types (e.g., ASCII, image data, multimedia data, signed and unsigned integers, pointers, etc.) comprising an input data stream and selecting a data encoding technique that yields the highest compression ratio for each of the identified data types, content-independent data compression advantageously applies the input data stream to each of a plurality of different encoders to, in effect, generate a plurality of encoded data streams. The plurality of encoders are preferably selected based on their ability to effectively encode different types of input data. Ultimately, the final compressed data stream is generated by selectively combining blocks of the compressed streams output from the plurality of encoders. Thus, the resulting compressed output stream will achieve the greatest possible compression, regardless of the data content.

In accordance with another embodiment of the present invention, a compression system may employ both a content-dependent scheme and a content-independent scheme, such as disclosed in the above-incorporated application Ser. No. 10/016,355. In this embodiment, the content-dependent scheme is used as the primary compression/decompression system and the content-independent scheme is used in place of, or in conjunction with, the content dependent scheme, when periodically checked "compression factor" meets a predetermined threshold. For instance, the compression factor may comprise a compression ratio, wherein the compression scheme will be modified when the compression ratio falls below a certain threshold. Further, the "compression factor" may comprise the latency of data transmission, wherein the data compression scheme with be modified when the latency of data transmission exceeds a predetermined threshold.

Indeed, as explained above, the efficiency of the content-dependent compression/decompression schemes described herein is achieved, e.g., by virtue of the fact that the encoding tables are based on, and specifically designed for, the known data model. However, in situations where the data model is may be modified, the efficiency of the content-dependent scheme may be adversely affected, thereby possibly resulting in a reduction in compression efficiency and/or an increase in the overall latency of data transmission. In such a situation, as a backup system, the data compression controller can switch to a content-independent scheme that provides improved compression efficiency and reduction in latency as compared to the primary content-dependent scheme.

In yet another embodiment of the present invention, when the efficiency of a content-dependent scheme falls below a predetermined threshold based on, e.g., a change in the data structure of the data stream, the present invention preferably comprises an automatic mechanism to adaptively modify the encoding tables to generate optimal encoding tables (using the process described above with reference to FIG. **3**).

FIG. **5** is a detailed block diagram illustrates an exemplary content-independent data compression system **110** that may be employed herein. Details of this data compression system are provided in U.S. Pat. No. 6,195,024, which is fully incorporated herein by reference. In this embodiment, the data compression system **110** accepts data blocks from an input data stream and stores the input data block in an input buffer or cache **115**. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. A counter **120** counts or otherwise enumerates the size of input data block in any convenient units including bits, bytes, words, and double words. It should be noted that the input buffer **115** and counter **120** are not required elements of the present invention. The input data buffer **115** may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold.

Data compression is performed by an encoder module **125** that may comprise a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" (where n may=1) of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **125** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **120**). Data compression is performed by the encoder module **125** wherein each of the encoders E1 . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **125** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **130** is operatively connected to the encoder module **125** for buffering and counting the size of each of the encoded data blocks output from encoder module **125**. Specifically, the buffer/counter **130** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **135**, operatively connected to the output buffer/counter **130**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **135** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **138**, operatively coupled to the compression ratio module **135**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block. A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing or transmittal. If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit, then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto. A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing or transmittal.

Again, it is to be understood that the embodiment of the data compression engine of FIG. **5** is exemplary of a preferred compression system which may be implemented in the present invention, and that other compression systems and methods known to those skilled in the art may be employed for providing accelerated data transmission in accordance with the teachings herein. Indeed, in another embodiment of the compression system disclosed in the above-incorporated U.S. Pat. No. 6,195,024, a timer is included to measure the time elapsed during the encoding process against an a priori-specified time limit. When the time limit expires, only the data output from those encoders (in the encoder module **125**) that have completed the present encoding cycle are compared to determine the encoded data with the highest compression ratio. The time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved. In addition, the results from each encoder in the encoder module **125** may be buffered to allow additional encoders to be sequentially applied to the output of the previous encoder, yielding a more optimal lossless data compression ratio. Such techniques are discussed in greater detail in the above-incorporated U.S. Pat. No. 6,195,024.

Referring now to FIG. **6**, a detailed block diagram illustrates an exemplary decompression system that may be employed herein or accelerated data transmission as disclosed in the above-incorporated U.S. Pat. No. 6,195,024. In this embodiment, the data compression engine **180** accepts compressed data blocks received over a communication channel. The decompression system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable.

The data decompression engine **180** comprises an input buffer **155** that receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **55** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **160** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **165** includes one or more decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source.

As with the data compression systems discussed in the above-incorporated U.S. Pat. No. 6,195,024, the decoder module **165** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time. An output data buffer or cache **170** may be included for buffering the decoded data block output from the decoder module **165**. The output buffer **70** then provides data to the output data stream. It is to be appreciated by those skilled in the art that the data compression system **180** may also include an input data counter and output data counter operatively coupled to the input and output, respectively, of the decoder module **165**. In this manner, the compressed and corresponding decompressed data block may be counted to ensure that sufficient decompression is obtained for the input data block.

Again, it is to be understood that the embodiment of the data decompression system **180** of FIG. **6** is exemplary of a preferred decompression system and method which may be implemented in the present invention, and that other data decompression systems and methods known to those skilled in the art may be employed for providing accelerated data transmission in accordance with the teachings herein.

It is to be appreciated that a data transmission acceleration system according to the present invention offers a business model by which market data vendors and users in the financial information services industry can receive various benefits. For example, the present invention affords transparent multiplication of bandwidth with minimal latency. Experiments have shown that increased bandwidth of up to 3 times can be achieved with minimal latency. Furthermore, proprietary hardware, including chip and board designs, as well as custom embedded and application software and algorithms associated with accelerated data transmission provide a cost-effective solution that can be seamlessly integrated with existing products and infrastructure. Moreover, the data acceleration through "real-time" compression and decompression affords a dramatic reduction in ongoing bandwidth costs. Further, the present invention provides mechanism to differentiate data feeds from other vendors via enriched content or quantity of the data feed.

In addition, a data compression scheme according to the present invention provides dramatically more secure and encrypted feed from current levels, thus, providing the ability to employ a secure and accelerated virtual private network over the Internet for authorized subscribers or clients with proprietary hardware and software installed.

Moreover, the present invention offers the ability to reduce a client's ongoing monthly bandwidth costs as an incentive to subscribe to a vendor's data feed service.

The present invention is readily extendable for use on a global computer network such as the Internet. This is significant since it creates a virtual private network and is important for the market data vendors and others due to its reduced cost in closed network/bandwidth solutions. In effect, the data vendors get to "ride for free" over the world's infrastructure, while still providing the same (and enhanced) services to their customers.

In yet another embodiment of the present invention a highly optimized data compression and decompression system is utilized to accelerate data transfers for data transmission feeds. This type of compression achieves very high compression ratios (over 10:1) on financial data feeds such as Nasdaq Quote Dissemination Service Data (NQDS) and SuperMontage Services. The information utilized to develop the methods described herein for Nasdaq has been garnered solely from public knowledge through specifications available from the Nasdaq Trader and Nasdaq websites. The techniques disclosed herein are broadly applicable to all financial data feeds and information or trading services.

Three types of encoding are utilized dependent upon the data fields and packet structure. In the event that a data field is unrecognizable then content independent data compression is preferably used, as previously discussed herein.

Variable Length Encoding

The basic unit of the compression process is the code. Each message field or set of set of fields being compressed together is assigned one or more codes in the range 0 . . . N. The code for a single character field is the ASCII value of the field minus 32 since all characters are in the range 32 to 127.

For various reasons, additional (escape) codes may be added to those for field values. For example, the category field has an escape code to indicate the end of a block and another to allow encoding of messages, which do not match the current format.

A basic technique used is variable rate encoding of symbols. In this approach, different amounts of the output bits are used to transmit the codes within a set. Higher frequency codes use less output bits while lower frequency codes use more output bits. Thus the average number of bits is reduced. Two methods of accomplishing this are used. The faster method uses a variant of Huffman coding while the slower method uses a form of Arithmetic coding.

In Huffman coding, each code is represent by an integral number of bits. The code sizes are computed using the standard algorithm and then (possibly) adjusted to facilitate table driven decoding (for instance, limiting codes to at most 16 bits). In the table driven decoding method used, there is a 256 element base table and two 256 element forwarding table. At each step, the next 8 bits of the input are used to index into the base table. If the code is represented in no more than 8 bits, it will be found directly. Otherwise, there will be a forwarding entry indicating which forwarding table to use and how many input bits to discard before using the next 8 bits as an index. The entry determining the result also indicates how many bits of the input to discard before processing the next field.

In arithmetic coding, the message is essentially represented as the (approximate) product of fractions with base 16384. The numerators of the fractions are proportional to the frequencies with which the codes appear in the training data. The number of output bits used to represent a code is the base 2 logarithm of the fraction. Thus codes which appear in almost all messages may be represented with fractions of a bit.

Single Character Codes

For arithmetic coding, all single character fields are encoded as the ASCII value−32+the number of escape codes. For Huffman coding, certain single character message fields are encoded in the same way. These include:

MM Trade Desk
Quote Condition
Inside Indicator
Quote Type

Other single character fields, which have a single value that occurs most of the time, are encoded as multiple character fields (see next). In Huffman coding the smallest representation for a code is 1 bit. By combining these fields, we may encode the most common combination of values in 1 bit for the whole set. These include:

Message Category+Message Type
Session Identifier+Originator ID
PMM+Bid Price Denominator+Ask Price Denominator (Quotes)
Inside Status+Inside Type
Inside Bid Denominator+Inside Bid MC
Inside Ask Denominator+Inside Ask MC
UPC Indicator+Short Sale Bid Tick
Market of Origin+Reason

Small Set Multiple Character Codes

Multiple character fields with a small number of common values and certain combinations of single character fields are encoded based on the frequency of the combinations. A list of common combinations is used together with an escape code.

The common combinations are encoded using the corresponding code. All other combinations are encoded by the escape code followed by the (7 bit) ASCII values for the characters in the combination. The fields include the field sets above for Huffman coding as well as the following for both approaches:

Retransmission Requester
MM Location
Currency Code

Large Set Multiple Character Codes

Multiple character alphabetic or alphanumeric fields for which a large number of values are possible (Issue Symbol and MMID/MPID) are encoded as follows. Trailing spaces for Issue Symbols are deleted. Then the result is encoded using:

Variable length codes for a list of the most common values together with escapes for the possible lengths of values not in the list.

A table for the first character of the field.

A table for subsequent characters in the field.

If a value is in the list of most common values, it is encoded with the corresponding code. Otherwise, the value is encoded by sending the escape code corresponding to the (truncated) length of the value, followed by the code for the first character, which is then followed by codes for the remaining characters.

Absolute Numeric Values

Numeric fields are transmitted by sending a variable length code for the number of significant bits of the value followed by the bits of the value other than the most significant bit (which is implicitly **1**). For example, 27 (a 5 bit value) would be represented by the code for a 5 bit value followed by the 4 least significant bits (**11**). These fields include:

Short Bid Price
Long Bid Price
Short Bid Size
Long Bid Size
Short Ask Size
Long Ask Size
Short Inside Bid Size
Long Inside Bid Size
Short Inside Ask Size
Long Inside Ask Size

Relative Numeric Values

Numeric fields expected to be close to the value of numeric values occurring earlier in the message are encoded by encoding the difference between the new value and the base value as follows:

If the difference in non-negative and less than ⅛ of the base value, the difference is encoded by sending a variable length code for the number of significant bits of the difference followed by the bits of the difference other than the most significant bit (which is implicitly **1**). Otherwise, the new value is encoded by sending a variable length code for the number of significant bits of the value followed by the bits of the value other than the most significant bit (which is implicitly **1**). The difference significant bit codes and the value significant bit codes are mutually exclusive. The following fields are encoded using the difference compared to the field in parentheses:

Short Ask Price (Bid Price)
Long Ask Price (Bid Price)
Short Inside Bid Price (Bid Price)
Short Inside Ask Price (Inside Bid Price)
Long Inside Bid Price (Bid Price)
Long Inside Ask Price (Inside Bid Price)

Differences

Both time and Message Sequence Number are encoded as the difference between the new value and a previous value within the compression block. This is transmitted using a code giving the sign of the difference and the number of significant bits in the absolute value of the difference followed by the bits of the absolute value other than the first.

Date

Each message within a compression block is expected to have the same date. The base date is transmitted at the beginning of the block as 7 bits of year, 4 bits of month and 5 bits of day of the month. If the date of a message is different than that of the block, a special escape code is used in place of the encoding of the sequence number and time. This is followed by the year, month and day as above followed by the time in seconds (17 bits) and the sequence number (24 bits).

Message Sequence Number and Time

Message time is converted to seconds after midnight. For all retransmitted messages (Retransmission Requester not "0"), the time is transmitted as a 17-bit value followed by the Message Sequence Number transmitted as a 24-bit value. If the date is not the same as the block date, a time value of 0x1ffff is used as an escape code.

For the first original transmission message in a block, the Message Sequence Number and time are transmitted in the same way.

For arithmetic coding of all other original transmission messages in a block, the Message Sequence Number is transmitted as the encoded change from the Message Sequence Number of the preceding original transmission message. Similarly, the time of all other original transmission messages is encoded as the difference from the previous original transmission message. An escape code in the Message Sequence Number Difference Table is used to indicate that the date is not the same as the block date.

Since almost all sequence number changes are 1 and almost all time changes are 0, we can save a bit (while Huffman coding) by encoding time and sequence number together.

This is done as follows: The most common values for both time and sequence number changes are 0 and 1 so there are three possibilities for each: 0, 1 and something else. Together this yields nine possibilities. An escape code is added to indicate a date different from the block date. To transmit the sequence number and time, the code corresponding the correct combination is first sent and then, if the time difference is not 0 or 1, the difference code for time followed by the difference code for sequence number (if required) is sent.

Unexpected Message Types

For administrative messages or non-control messages of unexpected category or type, the body of the message (the part after the header) is encoded as a 10-bit length field followed by the characters of the body encoded as 7-bit ASCII. Any Quotation message with an unexpected Inside Indicator value will have the remainder of the message encoded similarly.

Termination Code and Error Detection

Each compression block is terminated by an escape code of the message header category or category-type table. If this code is not found before the end of the block or if it is found too soon in the block, an error is returned. It is highly unlikely that a transmission error in the compressed packet could result in decoding so as to end at the same place as the original. The exception to this would be errors in transmitting bits values such as date, time or sequence number or the least significant bits of encoded values or changes. For additional error detection, a CRC check for the original could be added to compressed block.

Experimental Results

The aforecited Data Acceleration Methods were successfully applied to data captured on NASDAQ's NQDS feed. The data captured was first analyzed to optimize the Data Acceleration Methods. Essentially two distinct data rates were evaluated; one similar to the upcoming NASDAQ SuperMontage rate of 9.0 Megabits/sec and the second being the maximum data rate of the NQDS feed of 221 Kilobits/sec. In addition, two modes of data acceleration were applied—one utilizing Arithmetic and the other utilizing Huffman techniques.

The Arithmetic routines typically use 40% more CPU time than the Huffman routines and achieve approximately 15% better compression. On average the compression ratio for the SuperMontage data rate (9.0 Megabits/sec) utilizing Arithmetic Mode, yielded a value of 9.528 with a latency under 10.0 ms. This effectively says that the NQDS feed operating at a SuperMontage rate could be transmitted over one T1 line! Further overall latency can be reduced from 500 msec to something approaching 10 milliseconds if routing delays are reduced. Since the amount of data is substantially less, it will be easier and much more cost efficient to reduce routing delays. Further, since the quantity of transmitted bits is substantially smaller, the skew amongst transmitted packets will also be proportionately lower.

The average compression ratio for the standard NQDS data rate (221 Kbits/sec) was 9.3925 for the Arithmetic Mode with a latency under 128 ms. The higher latency is due to the time required to accumulated data for blocking Since the present invention allows for very high compression ratios with small blocks of data, the latency can be reduced substantially from 128 msec without a loss in compression ratio. This effectively says that the existing NQDS feed could be transmitted over one-half of a 56 Kilobit/sec modem line. Other advantages of using data acceleration according to the invention is that such methods inherently provide (i) a high level of encryption associated with the Arithmetic Mode (with no subsequent impact on latency) and (ii) error detection capability of the decompression methods at the end user site. The first benefit produces additional levels of security for the transmitted data and the second benefit guarantees that corrupted data will not be displayed at the end user site. Furthermore, the need to dynamically compare the redundant data feeds at the end user site is eliminated.

In yet another embodiment of the present invention the aforecited algorithms and all other data compression/decompression algorithms may be utilized in a data field specific compiler that is utilized to create new data feed and data stream specific compression algorithms.

A data field description language is utilized to define a list of possible data fields and parameters along with associated data compression encoders and parameter lists. In one embodiment of the invention the data fields are defined utilizing the following convention:

```
<start list>
<list file name (optional)>
<data field a descriptor, optional parameters>
[data field a compression algorithm x, optional parameters]
<data field b descriptor, optional parameters>
[data field b compression algorithm y, optional parameters]
...
<data field m descriptor, optional parameters>
[data field m compression algorithm n, optional parameters]
<end list>
```

Thus start list and end list are reserved identifiers however any suitable nomenclature can be utilized.

In this simple embodiment of the present invention the list is then submitted to a data compression compiler that accepts the data field list and creates two output files. The first is a data compression algorithm set comprised of data field specific encoders and the second output file is a data decompression algorithm set comprised of encoded data field specific decoders. In practice this compiler can be implemented in any high level language, machine code, or any variant in between. In addition the language can be Java, r Visual Basic, or another interpreted language to be dynamically operated over the Internet.

More advanced embodiments of the list can be created where the order of the data fields is important to the selection of encoders. In this case the fields are an ordered vector set and the encoders are also an ordered vector set.

```
<start list>
<list file name (optional)>
<ordered data field list 1, optional parameters>
<data field a, optional parameters; data field b, optional
    parameters; ...; data field n, optional parameters;>
[data field a compression algorithm x, optional parameters;
    data field b compression algorithm y, optional
    parameters; ...;data field m compression algorithm n]
[data field b compression algorithm x, optional parameters;
    data field a compression algorithm y, optional
    parameters; ...;data field m compression algorithm n]
<end list>
```

In this more sophisticated embodiment the encoders are selected based upon the data fields and their specific ordering.

In yet another embodiment of the present invention the sets of ordered data fields can be assigned to sets by set name, giving the ability for nesting of sets to facilitate ease of coding.

In yet another embodiment of the present invention the optional parameters to each encoder are utilized to share parameters amongst the same or different data fields.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A method for compressing data comprising:
- analyzing content of a data block to identify a parameter, attribute, or value of the data block that excludes analyzing based solely on reading a descriptor;
- selecting an encoder associated with the identified parameter, attribute, or value;
- compressing data in the data block with the selected encoder to produce a compressed data block, wherein the compressing includes utilizing a state machine; and
- storing the compressed data block;
- wherein the time of the compressing the data block and the storing the compressed data block is less than the time of storing the data block in uncompressed form.

2. The method of claim **1**, further comprising transmitting the compressed data block in a data packet to a client, the data packet including both control information and compressed data information.

3. The method of claim **2**, wherein the compressed data block is transmitted utilizing Transmission Control Protocol/Internet Protocol (TCP/IP).

4. The method of claim **3**, wherein the compressed data block is one of a plurality of compressed data blocks transmitted in sequence.

5. The method of claim **2**, wherein the compressed data block is one of a plurality of compressed data blocks transmitted in sequence with a plurality of synchronization points.

6. The method of claim **5**, wherein the plurality of compressed data blocks in sequence is transmitted in User Datagram Protocol (UDP) Packets and wherein at least one synchronization point occurs at the beginning of at least one of the UDP Packets.

7. The method of claim **5**, wherein the plurality of compressed data blocks in sequence is transmitted in User Datagram Protocol (UDP) Packets and wherein at least one synchronization point occurs at the end of at least some of the UDP Packets.

8. The method of claim **5**, wherein the plurality of compressed data blocks in sequence is transmitted in User Datagram Protocol (UDP) Packets and wherein at least one synchronization point occurs at the end of at least one of the UDP Packets.

9. The method of claim **5**, wherein the one or more compressed data blocks in sequence have at least one synchronization point per data block.

10. The method of claim **9**, wherein the at least one synchronization point is a predetermined byte sequence.

11. The method of claim **1**, further comprising transmitting the compressed data block in a packetized data stream having data packets that include control information and compressed data information, and wherein the selected encoder is a packet independent encoder.

12. The method of claim **11**, further comprising resetting the state machine for each data packet.

13. The method of claim **1**, further comprising:
- transmitting the compressed data block and a plurality of other compressed data blocks in a stream of Transmission Control Protocol/Internet Protocol (TCP/IP) packets, the TCP/IP data packets including control information and compressed data information, and
- resetting the state machine used in the compressing for each TCP/IP packet.

14. The method of claim **1**, wherein the state machine includes one or more global state machines, and further comprising selectively storing data blocks in at least one of the one or more global state machines based on a priori knowledge of data block structure.

15. The method of claim **14**, further comprising:
- transmitting the compressed data blocks in a packetized data stream of data packets having control and compressed data information, and
- resetting the one or more local state machines at a predetermined point of each data packet in the packetized data stream.

16. The method of claim **1**, wherein the state machine includes one or more local state machines, and further comprising storing the data in the data block in at least one of the one or more local state machines such that the data is available to encode one or more other data blocks.

17. The method of claim **1**, wherein the state machine is a fixed table, and further comprising storing data in the fixed table based on a priori knowledge of data block structure.

18. The method of claim **1**, wherein the state machine is an adaptive table, and further comprising storing data from selected data block in the adaptive table such that the data is available to encode one or more other data blocks.

19. The method of claim **18**, wherein the compressed data block is to be transmitted in a packetized data stream of data packets having control and compressed data information, and further comprising resetting the adaptive table at a point of each data packet in the packetized data stream.

20. The method of claim **1**, wherein the state machine is an adaptive table and the compressed data block is to be transmitted in a packetized data stream of data packets having control and compressed data information, and further comprising resetting the adaptive table at a point of each data packet in the packetized data stream.

21. The method of claim **1**, wherein the selected encoder is lossless.

22. The method of claim **1**, further comprising compressing the data block with a default lossless encoder when the analyzing of the content of the data block is unable to identify a parameter, attribute, or value of the data block.

23. The method of claim **1**, wherein the storing the compressed data block further comprises storing the compressed data block in a buffer.

24. The method of claim **1**, further comprising transmitting the compressed data block, wherein the time of the compressing the data block, storing the compressed data block, and transmitting the compressed data block is less than the time of transmitting the data block in an uncompressed form.

25. A system for compressing data comprising:

a data server implemented on one or more processors and one or more memory systems and configured to:

analyze content of a data block to identify a parameter, attribute, or value of the data block that excludes analysis based solely on reading a descriptor;

select an encoder associated with the identified parameter, attribute, or value;

compress data in the data block with the selected encoder to produce a compressed data block, wherein the compression utilizes a state machine; and

store the compressed data block;

wherein the time of the compressing the data block and the storing the compressed data block is less than the time of storing the data block in uncompressed form.

26. The system of claim **25**, wherein the data server is further configured to output the compressed data block in a data packet for transmission to a client, the data packet including both control information and compressed data information.

27. The system of claim **26**, wherein the compressed data block is to be transmitted in Transmission Control Protocol/Internet Protocol (TCP/IP) Packets and each (TCP/IP) Packet has at least one synchronization point.

28. The system of claim **27**, wherein the compressed data block is one of a plurality of compressed data blocks to be transmitted in sequence.

29. The system of claim **26**, wherein the compressed data block is one of a plurality of compressed data blocks to be transmitted in sequence with a plurality of synchronization points.

30. The system of claim **29**, wherein the plurality of compressed data blocks in sequence is to be transmitted in User Datagram Protocol (UDP) Packets and wherein at least one synchronization point occurs at the beginning of at least one of the UDP Packets.

31. The system of claim **29**, wherein the plurality of compressed data blocks in sequence is to be transmitted in User Datagram Protocol (UDP) Packets and wherein at least one synchronization point occurs at the end of at least some of the UDP Packets.

32. The system of claim **29**, wherein the plurality of compressed data blocks in sequence is to be transmitted in User Datagram Protocol (UDP) Packets and wherein at least one synchronization point occurs at the end of at least one of the UDP Packets.

33. The system of claim **29**, wherein the one or more compressed data blocks in sequence have at least one synchronization point per data block.

34. The system of claim **25**, wherein the data server is further configured to transmit the data compressed data block in a packetized data stream having data packets that include control information and compressed data information, and wherein the selected encoder is a packet independent encoder.

35. The system of claim **33**, wherein the at least one synchronization point is a predetermined byte sequence.

36. The system of claim **34**, wherein the state machine is reset for each data packet.

37. The system of claim **25**, wherein a plurality of the compressed data blocks are to be transmitted in a stream of Transmission Control Protocol/Internet Protocol (TCP/IP) packets, the TCP/IP data packets including control information and compressed data information, and

wherein the state machine is reset for each TCP/IP packet.

38. The system of claim **25**, wherein the state machine includes one or more global state machines, and the data server is further configured to selectively store data blocks in at least one of the one or more global state machines based on a priori knowledge of data block structure.

39. The system of claim **38**, wherein the compressed data blocks are to be transmitted in a packetized data stream, the packets having control and compressed data information and wherein the one or more local state machines are reset at a predetermined point of each data packet in the packetized data stream.

40. The system of claim **25**, wherein the state machine includes one or more local state machines, and the data server is further configured to store the data in the data block in at least one of the one or more local state machines such that the data is available to encode one or more other data blocks.

41. The system of claim **25**, wherein the state machine is a fixed table, and further comprising storing data in the fixed table based on a priori knowledge of the data block structure.

42. The system of claim **25**, wherein the state machine is an adaptive table, and the data server is further configured to store data from selected data block in the adaptive table such that the data is available to encode one or more other data blocks.

43. The system of claim **42**, wherein the compressed data blocks are to be transmitted in a packetized data stream, the packets having control and compressed data information, and wherein the adaptive table is reset at a point of each data packet in the packetized data stream.

44. The system of claim **25**, wherein the compressed data block is to be transmitted in a packetized data stream, the packets having control and compressed data information and wherein the state machine is an adaptive table reset at a point of each data packet in the packetized data stream.

45. The system of claim **25**, wherein the selected encoder is lossless.

46. The system of claim **25**, wherein the data server is further configured to compress the data block with a default lossless encoder when the analysis of the content of the data block is unable to identify a parameter, attribute, or value of the data block.

47. The system of claim **25**, wherein the data server is further configured to store the compressed data block in a buffer.

48. The system of claim **25**, wherein the data server is further configured to transmit the compressed data block, wherein the time of compression of the data block, storage of the compressed data block, and transmission of the compressed data block is less than the time of transmission of the data block in an uncompressed form.

* * * * *

CERTIFICATE OF COMPLIANCE

This brief complies with the type-volume limitation of Federal Circuit Rule 32(a). This brief contains 13,997 words, excluding the parts of the brief exempted under Federal Rule of Appellate Procedure 32(f) and Federal Circuit Rule 32(b).

This brief complies with the typeface requirements of Federal Rule of Appellate Procedure 32(a)(5) and the type-style requirements of Federal Rule of Appellate Procedure 32(a)(6). This brief has been prepared in a proportionally spaced typeface using Microsoft Word in 14-point Times New Roman font.

Dated: December 7, 2021

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