No. 2025-1045; 2025-1046

United States Court of Appeals for the Federal Circuit

OLLNOVA TECHNOLOGIES LTD.

Plaintiff-Appellant

v.

ECOBEE TECHNOLOGIES ULC, DBA ECOBEE,

Defendant-Cross-Appellant

Appeal from the United States District Court for the Eastern District of Texas in No. 2:22-cv-00072-JRG, Chief Judge J. Rodney Gilstrap

CORRECTED APPELLANT OLLNOVA TECHNOLOGIES LTD.'S OPENING BRIEF

December 17, 2024

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CERTIFICATE OF INTEREST

Pursuant to Federal Circuit Rule 47.4, the undersigned counsel for the appellant, Ollnova Technologies Ltd., certifies the following:

1. The full names of every party represented by counsel of record are Ollnova Technologies Limited, a corporation.
2. The name of the real parties in interest are Ollnova Technologies Limited.
3. There are no parent companies, subsidiaries (except wholly-owned subsidiaries), and affiliates that have issued shares to the public, of the party represented by me.
4. The names of all the law firms, partners and associates that appeared for the entities in the originating court or agency and have not entered an appearance in this Court are Seth Hasenour, Jonathan Yim, and Drew Hollander (BC Law Group, P.C.); and Andrea Fair and Garrett Parish (Miller Fair Henry PLLC).
5. The title and number of any case known to counsel to be pending in this or any other court or agency that will directly affect or be directly affected by this court's decision in the pending appeal is: *Ollnova Technologies Ltd. v. ecobee Technologies ULC d/b/a ecobee*, Case No. 2:22-cv-00072-JRG (E.D. Tex.).
6. Any information required under Fed. R. App. P. 26.1(b) and 26.1(c): none

Dated: December 17, 2024

/s/ Brett Cooper
Brett Cooper

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STATEMENT OF RELATED CASES

Under Fed. Cir. R. 47.5(a), counsel for Appellant certifies that no other appeal from the same proceeding is or was previously before this Court or any other appellate court, whether under the same or similar title.

Under Fed. Cir. R. 47.5(b), counsel for Appellant states that the Court's decision in this appeal may affect the following judicial matters: *Ollnova Technologies Ltd. v. ecobee Technologies ULC d/b/a ecobee*, Case No. 2:22-cv-00072-JRG (E.D. Tex.).

JURISDICTIONAL STATEMENT

The district court had jurisdiction pursuant to 28 U.S.C. §§ 1331 and 1338(a) and entered final judgment resolving all claims on September 5, 2024. Appx1. Ollnova timely filed its notice of appeal on October 4, 2024. Fed. R. App. P. 4(a)(1); Appx6707. This Court has jurisdiction pursuant to 28 U.S.C. § 1295(a)(1).

STATEMENT OF THE ISSUES

1. Whether prejudgment interest for a lump sum reasonable royalty damages award should be calculated from the time of the hypothetical negotiation, which coincides with the date of first infringement, or be limited to the time period allowed under 35 U.S.C. § 286.

STATEMENT OF THE CASE

This case involves a jury verdict finding infringement of Ollnova's patented technology, which relates to improvements in smart home and building energy management technology. Ollnova is a technology licensing company headquartered in Ireland and initially asserted U.S. Patent Nos. 8,224,282 ("the '282 Patent"), 7,746,887 ("the '887 Patent"), 7,860,495 ("the '495 Patent"), and 8,264,371 ("the '371 Patent") (collectively, the "patents-in-suit") against ecobee. Appx6571. Siemens was the original assignee of the patents-in-suit. Appx413-17. The patents-in-suit provide improvements to communication redundancy and resiliency among various smart controllers (*e.g.*, thermostats) and peripheral sensor components. Appx138; Appx152; Appx181.

This case proceeded through trial, during which the jury found ecobee liable for infringing the patents-in-suit, but also found that one of the four patents-in-suit (the ’282 Patent) was invalid. Appx2208-09. The jury awarded reasonable royalty damages in the form of a lump sum of $11.5 million. *Id.* In addition, the district court’s final judgment awarded Ollnova prejudgment interest on that lump sum calculated from the date “the infringement began.” Appx2. The sole issue Ollnova appeals is the district court’s subsequent decision to postpone that award of prejudgment interest to four years after the date of first infringement, *i.e.*, the date of the hypothetical negotiation, which is contrary to all evidence presented to the jury as well as this Court’s guidance on the importance of correctly setting the hypothetical negotiation, the resulting lump-sum reasonable royalty, and the role of prejudgment interest in making the patent holder whole as a remedy for the infringement found by the jury.

A. The Jury Awards Reasonable Royalty Damages as a Lump Sum

At trial, the jury heard both side’s damages experts agree that damages in this case would take the form of a reasonable royalty. Appx868, Appx1673. Both experts agreed that the hypothetical negotiation would have taken place in April 2012, the date of first infringement and that the April 2012 hypothetical negotiation would have involved Siemens, as the owner of the patents-in-suit at that time, opposite ecobee. Appx875, Appx1889. Ollnova did not acquire the patents-in-suit until October 2021. Appx1897.

Ollnova's damages expert, Mr. Jim Bergman, explained that "a lump sum royalty is when the royalty is paid all up front," when "the parties signed a contract and then immediately payment is made and then there's no more payment made after that, just that one-time payment." Appx870. Furthermore, he testified that Siemens's transfer of the patents-in-suit did not "change the ability for them to collect rights on these patents" and that Ollnova as the current patentholder "has the rights to those patents and can enforce them." Appx875. He also explained the application of the book of wisdom in this case. Appx559-60.

ecobee's damages expert, Mr. Todd Schoettelkotte, testified that he "chose to use a structure called an upfront one-time lump sum royalty." Appx1885. Mr. Schoettelkotte specifically explained that, with the lump sum structure, "the licensor, in this case Siemens, gets all the money up front." Appx1886. In response to ecobee's counsel's question, "Does what Ollnova would want in a negotiation with ecobee have any impact on the hypothetical negotiation?" Mr. Schoettelkotte answered: "No, it does not. It's what Siemens would have negotiated with ecobee in 2012, that being April." Appx1890. He clarified: "What this means is after the upfront lump sum is negotiated and paid, the parties can go their separate way after that and there's no longer any reason for them to continue interacting; they can just resolve the issue and move on." Appx1887. He also used the book of wisdom in this case. Appx1934.

The district court instructed the jury consistent with this testimony from both parties' damages experts: "A reasonable royalty is the amount of royalty payment that a patent holder and the alleged infringer would have agreed to in a hypothetical negotiation taking place at a time prior to when infringement first began. In this case, the patent holder for the purposes of the hypothetical negotiation is Siemens, and the alleged infringer is ecobee. In considering this hypothetical negotiation, you should focus on what the expectations of the patent holder and the alleged infringer would have been had they entered into an agreement at that time and had they acted reasonably in their negotiations." Appx2149.

The district court also explained how the book of wisdom relates to the 2012 hypothetical negotiation: "Evidence of things that happened after infringement first began can be considered in evaluating the reasonable royalty only to the extent that the evidence aids in assessing what royalty would have resulted from a hypothetical negotiation." Appx2150. Finally, the district court instructed the jury: "If you find that Ollnova is entitled to damages, you must decide whether the parties would have agreed to a running royalty or a fully paid-up lump-sum royalty at the time of the hypothetical negotiation." Appx2150.

The jury awarded Ollnova $11,500,000 in reasonable royalty damages, specifically in the form of a lump sum,[1] and this finding was adopted into the district court's March 1, 2024 final judgment. Appx2209-10, Appx2. In post-trial proceedings, the district court found that this amount fell within the maximum proven damages amount of $35.67 million, when considering that one of the patents-in-suit was invalidated by the jury. Appx41-42. The district court also confirmed that this award was consistent with Ollnova's substantial compliance with marking requirements, allowing it to claim damages on ecobee sales going back to March 2016, six years before the filing of the complaint. Appx45, Appx47.

B. The District Court Awards Prejudgment Interest as of the Time of First Infringement

The district court's March 1, 2024 final judgment further awarded "pre-judgment interest to Plaintiff to be recovered by Plaintiff from Defendant and applicable to all sums awarded herein, calculated at the five-year U.S. Treasury Bill rate, compounded monthly, adjusting the effective rate with each and every change in said five-year U.S. Treasury Bill rate from the date [] the infringement began." Appx2.

Thereafter, ecobee filed a motion that in relevant part sought an "amended judgment setting the appropriate start date for prejudgment interest," insisting that

[1] This was contrary to Ollnova's position, which was that a reasonable royalty should have taken the form of a running royalty. Appx871.

the proper start date for prejudgment interest was March 8, 2022, the date Ollnova filed the complaint in this case. Appx3750, Appx3764. ecobee's motion complained that Ollnova was "improperly seeking prejudgment interest from 2012, even though the statute of limitations dictates that damages began (at the earliest) in 2016, six years before Ollnova's complaint." Appx3765. ecobee did not complain that the underlying damages award is based on ecobee sales predating March 2016.

The district court denied ecobee's request to so amend the final judgment on September 5, 2024. Appx80. However, in denying ecobee's motion, the district court stated: "'[F]rom the date [] the infringement began' does not mean the agreed upon hypothetical negotiation date. It refers to the infringement for which 'sums [were] awarded'—*i.e.*, the infringement during the applicable damages period, as instructed by the Court. Accordingly, the Court finds that prejudgment interest accrues from March 8, 2016. The Final Judgment sufficiently ties the prejudgment interest to the damages accrued in this case. Given this language, and the Court's guidance, there is no need to amend the Final Judgment." Appx80.

Ollnova then filed a timely notice of appeal to reverse the district court's reinterpretation of its final judgment that moved the date of first infringement four years forward from its actual 2012 date. Appx6708.

SUMMARY OF ARGUMENT

This case poses a question on how to interpret 35 U.S.C. § 284 (titled "Damages") in line with this Court's precedents regarding the nature and purpose of reasonable royalty damages. More specifically, when a jury awards a lump-sum reasonable royalty as of the hypothetical negotiation date (April 2012), should 35 U.S.C. § 286 (titled "Time limitation on damages") foreclose prejudgment interest prior to six years before the complaint (March 2016)? The district court below held that there could be more than one date of first infringement, delayed the calculation of prejudgment interest to start at this second date of "first infringement" in March 2016, and thereby failed to fully compensate Ollnova for ecobee's infringement. Ollnova appeals that holding as contrary to the facts of this case and this Court's case law which aligns the date of first infringement and the hypothetical negotiation. Moreover, prejudgment interest from 2012 would fairly compensate Ollnova for the lost value from when ecobee should have paid the lump-sum royalty.

This case presents near-unanimous agreement among the parties regarding the lump sum awarded by the jury as a reasonable royalty. It is undisputed that the time of first infringement, meaning the time when ecobee first released a product meeting the asserted claim limitations, was April 2012. It is undisputed that this April 2012 time of first infringement indicates the timing of the hypothetical negotiation. It is undisputed that the jury heard evidence and instruction that a lump-sum reasonable royalty would have been fully paid up immediately following the April 2012 hypothetical negotiation. It is undisputed that the district court awarded prejudgment interest to be calculated as of when the "infringement began." And there is no allegation that the jury's award of $11.5 million as a lump-sum reasonable royalty was based on any infringing product sales prior to the date allowed by 35 U.S.C. § 286 (March 2016).

Ollnova respectfully submits that these undisputed facts answer the question posed in favor of maintaining a singular date of first infringement—April 2012—for purposes of calculating the district court's award of prejudgment interest. This is the straightforward, consistent application of the principles laid out in 35 U.S.C. § 284. There may be facial appeal to the argument that 35 U.S.C. § 286 cautions against a calculation predating six years prior to the filing of this case's complaint. But as shown below, that argument jettisons important distinctions among relevant law and fails to carry out 35 U.S.C. § 284's directive to ensure "damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and costs as fixed by the court." The district court's order that prejudgment interest should be calculated from March 2016 should be reversed, and this case should be remanded with instructions to calculate prejudgment interest as of the sole date of first infringement: April 2012.

STANDARD OF REVIEW

Statutory interpretation is a question of law reviewed de novo. *Click-to-Call Techs. LP v. Ingenio, Inc.*, 45 F.4th 1363, 1367 (Fed. Cir. 2022). The district court's final judgment awarded Ollnova prejudgment interest under 35 U.S.C. § 284, but the district court's subsequent order interpreted 35 U.S.C. § 286 to limit that award. Appx2, Appx79. It also acknowledged that the "Patent Act does not expressly provide the time period for calculating interest." Appx78 (citing *Transmatic, Inc. v. Gulton Indus., Inc.*, 180 F.3d 1343, 1347 (Fed. Cir. 1999)). This open question on how to interpret the patent statute therefore means the standard of review is de novo.

ARGUMENT

I. Calculating Prejudgment Interest from the Date a Lump Sum Royalty Is Owed Ensures that the Patent Holder Is Made Whole

The overarching goal of the patent damages statute and relevant case law is to put the patent holder back in the same financial position as if the infringement had not occurred. "Upon a finding for the claimant the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and costs as fixed by the court." 35 U.S.C. § 284. The Supreme Court makes clear that this applies to prejudgment interest: "The standard governing the award of prejudgment interest under § 284 should be consistent with Congress' overriding purpose of affording patent owners complete compensation." *Gen. Motors Corp. v.*

Devex Corp., 461 U.S. 648, 655 (1983). This means that "prejudgment interest is necessary to ensure that the patent owner is placed in as good a position as he would have been in had the infringer entered into a reasonable royalty agreement." *Id.* This Court has in turn held that the "normal procedure under *Devex* is to award prejudgment interest from the date of infringement to the date of payment, since only such award will satisfy 'Congress' overriding purpose [in section 284] of affording patent owners complete compensation.'" *Bio-Rad Lab'ys, Inc. v. Nicolet Instrument Corp.*, 807 F.2d 964, 967 (Fed. Cir. 1986).

A reasonable royalty is the amount agreed to at the hypothetical negotiation, which "tries, as best as possible, to recreate the *ex ante* licensing negotiation scenario and to describe the resulting agreement." *Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1325 (Fed. Cir. 2009) ("In other words, if infringement had not occurred, willing parties would have executed a license agreement specifying a certain royalty payment scheme."). The date of the hypothetical negotiation has always coincided with the date of first infringement. *LaserDynamics, Inc. v. Quanta Computer, Inc.*, 694 F.3d 51, 75 (Fed. Cir. 2012) ("We have consistently adhered to this principle," that "the date of the hypothetical negotiation is the date that the infringement began"); *Applied Med. Res. Corp. v. U.S. Surgical Corp.*, 435 F.3d 1356, 1363-64 (Fed. Cir. 2006) ("[T]he hypothetical negotiation relates to the date of first infringement."); *State Indus., Inc. v. Mor-Flow Indus., Inc.*, 883 F.2d 1573, 1580

(Fed Cir. 1989) ("The determination of a reasonable royalty . . . [is based] on what a willing licensor and licensee would bargain for at hypothetical negotiations on the date infringement started."). "The correct determination of [the hypothetical negotiation] date is essential for properly assessing damages." *Integra Lifesciences I, Ltd. Merck KGaA*, 331 F.3d 860, 870 (Fed. Cir. 2003).

This Court has also explained the key characteristic of a lump-sum reasonable royalty is that the payment is made up front at the time of the agreement: "A lump-sum license 'benefits the patentholder in that it enables the company to raise a substantial amount of cash quickly and benefits the target [i.e., the licensee] by capping its liability and giving it the ability, usually for the remainder of the patent term, to actually use the patented technology in its own products without any further expenditure.'" *Lucent Techs.*, 580 F.3d at 1326 (quoting Richard F. Cauley, *Winning the Patent Damages Case* 47 (2009)). This characteristic of an up-front payment at the time of the agreement removes uncertainty from the amount of future use of the invention, as "once a lump-sum license is duly executed, the licensee is obligated to pay the entire, agreed-upon amount for the licensed technology, regardless of whether the technology is commercially successful or even used." *Lucent*, 580 F.3d at 1326.

Read together, these precedents show that an award of prejudgment interest on a lump-sum reasonable royalty from when the "infringement began" must be calculated from the date of the hypothetical negotiation. Appx2. No case law states that a lump-sum resulting from a hypothetical negotiation is to be delayed to a time in the future. On the contrary, the lump-sum payment "enables the company to raise a substantial amount of cash quickly." *Lucent*, 580 F.3d at 1326. Thus, there cannot be any delay in realizing this payment after the hypothetical agreement, given that the patent damages statute and case law are clear that the purpose of damages and prejudgment interest thereon is to "satisfy 'Congress' overriding purpose [in section 284] of affording patent owners complete compensation.'" *Bio-Rad*, 807 F.2d at 967. Delaying the effective lump-sum payment date for purposes of calculating prejudgment interest would result in undercompensating the patent holder for the infringement.

This Court has confirmed the immutability of the date of the hypothetical negotiation and its independence from other dates relevant to patent law. *LaserDynamics*, 694 F.3d at 75 ("We have also been careful to distinguish the hypothetical negotiation date from other dates that trigger infringement liability"). Indeed, in *Wang Labs., Inc. v. Toshiba Corp.*, 993 F.2d 858, 870 (Fed. Cir. 1993), this Court found legal error where a district court timed the hypothetical negotiation to coincide with sales during the damages period, not earlier "when the infringement began." The Court explained:

> It is true that limitations may apply to the period for which damages may be recovered. As in the present case, failure to mark patented

> goods is a limitation on recovery of damages, in the absence of notice. 35 U.S.C. § 287 (1988). However, the court confused limitation on damages due to lack of notice with determination of the time when damages first began to accrue, and it is the latter which is controlling in a hypothetical royalty determination.

Id. This is because a "reasonable royalty determination for purposes of making a damages evaluation must relate to the time infringement occurred, and not be an after-the-fact assessment." *Riles v. Shell Exploration & Prod. Co.*, 298 F.3d 1302, 1313 (Fed. Cir. 2002) (citing *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075, 1079 (Fed. Cir. 1983)).

The reasoning underlying this strict adherence to relating a reasonable royalty to the time of first infringement is the need to "discern the value of the patented technology to the parties in the marketplace when the infringement began." *LaserDynamics*, 694 F.3d at 76.

Here, the value of $11.5 million in April 2012 dollars differs considerably from the value of $11.5 million in March 2016 dollars, and providing for the calculation of prejudgment interest from April 2012 ensures that that value is properly returned to the patent holder as provided for by statute. *See Integra*, 331 F.3d at 870 ("The value of a hypothetical license negotiated in 1994 could be drastically different from one undertaken in 1995 due to the more nascent state of the RGD peptide research in 1994"). The district court committed legal error in holding otherwise.

II. All Evidence and Instructions Heard by the Jury Were Consistent with This Court's Case Law Aligning the Dates of the Hypothetical Negotiation and First Infringement

The district court's legal error discussed above is sufficient grounds to reverse the holding that prejudgment interest is to be calculated from a date after first infringement. But the district court also based its decision on a clearly erroneous factual finding, namely that the payment of the resulting lump sum would not have occurred directly after the April 2012 hypothetical negotiation. This factual finding is contrary to the undisputed record.

The only evidence in the record, undisputed by either party, is that the hypothetical negotiation in this case would have taken place in April 2012, the date of first infringement. Appx875, Appx1889. The only evidence the jury heard about the timing of a lump sum is that it is "paid all up front," when "the parties signed a contract and then immediately payment is made and then there's no more payment after that." Appx870; *see* Appx1886, Appx1887, Appx1890. In accordance with this unanimity, the district court instructed the jury: "If you find that Ollnova is entitled to damages, you must decide whether the parties would have agreed to a running royalty or a fully paid-up lump-sum royalty at the time of the hypothetical negotiation." Appx2150. The jury decided that the parties would have agreed to a such a lump sum. Appx2209-10.

Based on this evidence and instruction, the final judgment's award of prejudgment interest from when "the infringement began" must reach back to April 2012. Appx2. Yet the district court failed to adhere to these undisputed facts when holding in its September 5, 2024 order denying ecobee's motion to amend the final judgment that "'from the date [] the infringement began' does not mean the agreed upon hypothetical negotiation date." Appx80. The district court reasoned that "from the date [] the infringement began" instead "refers to the infringement for which the 'sums [were] awarded'—*i.e.*, the infringement during the applicable damages period." *Id.* This improperly contradicts the undisputed facts that the date of first infringement occurred in April 2012, when the lump-sum amount would have been paid up front, as the district court instructed the jury. Appx2150 ("a fully paid-up lump-sum royalty at the time of the hypothetical negotiation").

The district court's September 5, 2024 order therefore is based on clearly erroneous facts in reinterpreting the March 1, 2024 final judgment and should be reversed.

III. Moving the Date of First Infringement According to a Time Limitation on Damages Is Unsupported by Law

The district court cited 35 U.S.C. § 286 as the basis for changing the date from which to calculate prejudgment interest from the April 2012 date of first infringement to March 2016, six years before the filing of the complaint. Appx79-80. But there is no prohibition in section 286 on calculating prejudgment interest as of when a lump sum is agreed to at the time of the hypothetical negotiation, as section 286 applies to only damages ("Time limitation on damages"). To be sure, the jury heard evidence of ecobee's infringing product sales going back to only March 2016, which is six years prior to the complaint per 35 U.S.C. § 286. Appx553. So there is no dispute that the jury's $11.5 million lump-sum reasonable royalty award is based on infringing product sales compliant with 35 U.S.C. § 286's "Time limitation on damages." Appx42-47.

Section 284's compensatory framework, however, has a broader scope than section 286's focus on only damages. It reads:

> Upon finding for the claimant the court shall award the claimant damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer, together with interest and costs as fixed by the court.

35 U.S.C. § 284. It delineates damages, specifically "in no even less than a reasonable royalty for the use made of the invention by the infringer," separately from the direction that the district court "shall award" "interest and costs as fixed by the court." The specification of "interest and costs as fixed by the court" in a clause separate from "damages adequate to compensate for the infringement, but in no event less than a reasonable royalty" means that the prejudgment interest awarded by the district court is not "damages," and thus not governed by section 286's "Time limitation on damages."

Setting the hypothetical negotiation before the triggering of infringement liability is proper and may result in a significantly different reasonable royalty outcome. For example, in *LaserDynamics*, this Court specifically held that "the six-year limitation on recovery of past damages under 35 U.S.C. § 286 does not preclude the hypothetical negotiation date from taking place on the date infringement began." 694 F.3d at 75. There, the district court erred by choosing the later 2006 date for the hypothetical negotiation based on when the defendant was first alleged to have induced infringement, coincident with the filing of the lawsuit and knowledge of the patent, rather than the proper 2003 date of first infringement. *Id.* This resulted in disregarding "almost all of LaserDynamics' twenty-nine licenses" that had been executed before the 2006 filing of the lawsuit, likely resulting in a reasonable royalty differing in amount and/or form. *Id.* ("the economic landscape had since changed"); *see Integra*, 331 F.3d at 870 ("factoring in the rapid development of biotechnological arts, a year can make a great difference in economic risks and rewards" for purposes of analyzing a reasonable royalty resulting from a hypothetical negotiation).

The import of *LaserDynamics* is that the district court is to conduct a reasonable royalty analysis based on a hypothetical negotiation independent of other limitations on liability. Thereafter, once a reasonable royalty has been established on sales during the damages period permitted by 35 U.S.C. § 286, the district court should fix interest on that damages amount pursuant to 35 U.S.C. § 284. Section

286 then has already applied to delimit the recovery principal in this case, and it should not be applied again in contravention of this Court's consistent direction that "'[t]he key element in setting a reasonable royalty . . . is the necessity for return to the date when the infringement began.'" *Id.* (quoting *Hanson v. Alpine Valley Ski Area, Inc.*, 718 F.2d 1075, 1079 (Fed. Cir. 1983)).

In addition, *Comcast IP Holdings I LLC v. Sprint Communications Co.*, 850 F.3d 1302, 1313-15 (Fed. Cir. 2017), presented a situation where prejudgment interest was calculated for a time when two of three infringed patents had not yet issued. In affirming the district court's prejudgment interest calculation, this Court held that "[p]rejudgment interest runs from the earliest date of infringement for any patent at the time of the hypothetical negotiation." *Id.* at 1315. The situation there is analogous to the case at bar because it involved the application of prejudgment interest to a lump-sum reasonable royalty to beginning from 2006, which was prior to when liability for the '046 or '008 patents had accrued as they did not issue until 2012. *Id.* at 1314. This holding demonstrates that prejudgment interest for a lump-sum reasonable royalty should be calculated as of the time of the hypothetical negotiation, regardless whether there is a separate legal reason for which infringement liability may not attach until a later time.

Just as in *Comcast*, both parties' damages experts agreed that the date of the hypothetical negotiation here coincided with the date of first infringement. *Id.*;

Appx875, Appx1889. Also similar to *Comcast*, both parties' damages experts agreed on use of the book of wisdom "looking forward in time from the date of the first hypothetical negotiation to account for 'all information that would have been relevant to the parties in coming to and arriving at a deal,'" and the jury was so instructed. 850 F.3d at 1314; *see* Appx559-60, Appx1934, Appx2150. And in both *Comcast* and in the case at bar, the jury awarded a lump sum as a reasonable royalty in view of this evidence and instruction. 850 F.3d at 1314; Appx2209-10. Based on these facts, this Court in *Comcast* affirmed the award of prejudgment interest calculated from the time of the earliest hypothetical negotiation in 2006, and the same reasoning should lead to a similar result here. Notably, this Court has previously held that "in each case there should be only a single hypothetical negotiation date, not separate dates for separate acts of infringement." *LaserDynamics*, 694 F.3d at 76. This further demonstrates the importance of fixing the date of the hypothetical negotiation and for calculating prejudgment interest for the resulting lump sum separate from other independent factors, such as section 286's limitation. *See id.* at 75.

The district court relied on two cases to justify postponing the calculation of prejudgment interest until 2016. Appx79 (citing *Beatrice Foods Co. v. New Eng. Printing & Lithographing Co.*, 923 F.2d 1576 (Fed. Cir. 1991); *Imperium IP Holdings (Cayman), Ltd. v. Samsung Elecs. Co., Ltd.*, No. 4:14-CV-00371, 2017 WL

1716589 (E.D. Tex. Apr. 27, 2017)). Neither of those cases justify the district court's holding. For example, *Beatrice Foods* did not involve a dispute regarding the time period for which prejudgment interest should be calculated. Rather, this Court there held merely that the principal eligible for prejudgment interest can be only the actual, compensatory damages amount—not an enhanced, punitive damages award. 923 F.2d at 1580. *Beatrice Foods* also involved damages in the form of lost profits, not a reasonable royalty with a hypothetical negotiation set as of the date of first infringement. *Id.* at 1577.

The district court in *Imperium IP* relied on *Beatrice Foods* in finding that prejudgment interest could be calculated from no earlier than six years prior to the filing of the complaint. 2017 WL 1716589, at *4. Beyond the fact that *Beatrice Foods* is not informative of the question presented, *Imperium IP* further involved a running royalty award. *Id.* at *2 ("Plaintiff claims—and Defendants do not contest—that the jury implicitly found that Defendants owed Plaintiff a royalty of four cents and two cents per accused product for the '884 and '029 Patents, respectively"). Because in a "standard running royalty license, the amount of money payable by the licensee to the patentee is tied directly to how often the licensed invention is later used or incorporated in products by the licensee," the payments do not accrue until the infringing sales are made. *Lucent*, 580 F.3d at 1326. It is thus understandable to schedule prejudgment interest for a running royalty award according to when each infringing sale is made during the damages period.

Neither of these cases is thus controlling or informative of when to begin calculating prejudgment interest on a lump-sum reasonable royalty to have been fully paid-up directly following the hypothetical negotiation. The district court therefore erred in relying on them to eliminate four years of prejudgment interest that are needed to fully compensate Ollnova for ecobee's infringement.

CONCLUSION

For the foregoing reasons, the Court should reverse the district court's erroneous reinterpretation of the final judgment and remand with instructions that prejudgment interest should be calculated from April 2012, the sole date of first infringement.

Dated: December 17, 2024

Respectfully submitted,

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ADDENDUM

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IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
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Defendant.	§	

FINAL JUDGMENT

A jury trial commenced in the above-captioned case on September 29, 2023, and on October 5, 2023 the jury reached and returned its unanimous verdict finding that Defendant ecobee Technologies ULC d/b/a ecobee ("Defendant") infringed one or more of: Claims 1, 11, 12, and 20 of U.S. Patent No. 7,746,887, Claims 1 and 2 of U.S. Patent No. 7,860,495, Claims 1, 3, 6, and 21 of U.S. Patent No. 8,224,282, and Claims 1, 5, and 17 of U.S. Patent No. 8,264, 371 (collectively, the "Asserted Claims"), that Claims 1, 3, 6, and 21 of U.S. Patent No. 8,224,282 were invalid as either being anticipated or obvious in light of the prior art, and that Plaintiff Ollnova Technologies Limited ("Plaintiff") is owed $11,500,00.00 for Defendant's infringement in the form of a one-time lump sum reasonable royalty. (Dkt. No. 225.)

Pursuant to Rule 58 of the Federal Rules of Civil Procedure, and in accordance with the jury's unanimous verdict and the entirety of the record, the Court hereby **ORDERS** and **ENTERS JUDGMENT** as follows:

1. Defendants have infringed one or more of the Asserted Claims;
2. Claims 1, 3, 6, and 21 of U.S. Patent No. 8,224,282 are invalid;

3. Plaintiff is hereby awarded compensatory damages from Defendant and shall accordingly have and recover from Defendant $11,500,00.00 US Dollars for Defendant's infringement, all of which is a reasonable royalty in the form of a one-time lump sum payment;

4. Pursuant to 35 U.S.C. § 284 and Supreme Court guidance that "prejudgment interest shall ordinarily be awarded absent some justification for withholding such an award,"[1] the Court awards pre-judgment interest to Plaintiff to be recovered by Plaintiff from Defendant and applicable to all sums awarded herein, calculated at the five-year U.S. Treasury Bill rate, compounded monthly, adjusting the effective rate with each and every change in said five-year U.S. Treasury Bill rate from the date of the infringement began;

5. Pursuant to 28 U.S.C. § 1961, the Court awards to Plaintiff from Defendant post-judgment interest applicable to all sums awarded herein, at the statutory rate, from the date of entry of this Judgment until paid; and

6. Pursuant to Federal Rule of Civil Procedure 54(d), Local Rule CV-54, and 28 U.S.C. § 1920, Plaintiff is the prevailing party in this case and shall recover its costs from Defendant. Plaintiff is directed to file its proposed Bill of Costs.

All other requests for relief now pending and requested by either party but not specifically addressed herein are **DENIED**.

[1] *General Motors Corp. v. Devex Corp.*, 461 U.S. 648, 657 (1983).

So ORDERED and SIGNED this 1st day of March, 2024.

RODNEY GILSTRAP
UNITED STATES DISTRICT JUDGE

US007746887B2

(12) **United States Patent**
McFarland

(10) **Patent No.: US 7,746,887 B2**
(45) **Date of Patent: Jun. 29, 2010**

(54) **DYNAMIC VALUE REPORTING FOR WIRELESS AUTOMATED SYSTEMS**

(75) Inventor: **Norman R. McFarland**, Palantine, IL (US)

(73) Assignee: **Siemens Industry, Inc.**, Alpharetta, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1112 days.

(21) Appl. No.: **11/402,743**

(22) Filed: **Apr. 12, 2006**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
H04L 12/413 (2006.01)

(52) **U.S. Cl.** **370/455**; 370/316

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

(56) **References Cited**

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Primary Examiner—Lester Kincaid
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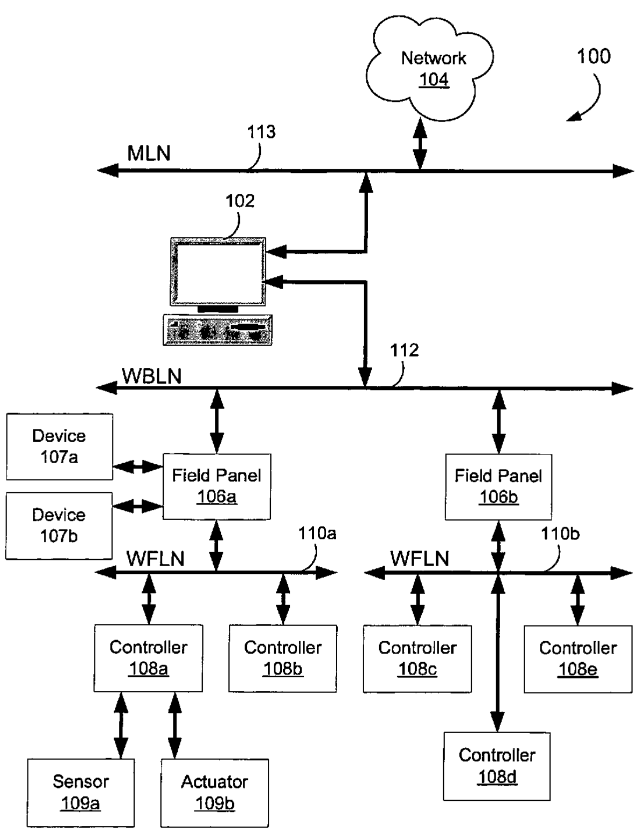
(74) *Attorney, Agent, or Firm*—Thomas J. Burton

(57) **ABSTRACT**

A wireless automation device monitors a condition and wirelessly reports an event over an automation network in response to detecting a change in the condition. The condition is sampled at a variable periodic interval, and the event reported during intervals when a change in the condition is determined. The change may be determined according to detecting a value for the condition outside a variable range. The change may also be determined according to detecting differences in the value from values detected in prior intervals. The range and the periodic interval may vary according to an analysis of multiple samples of the condition.

21 Claims, 4 Drawing Sheets



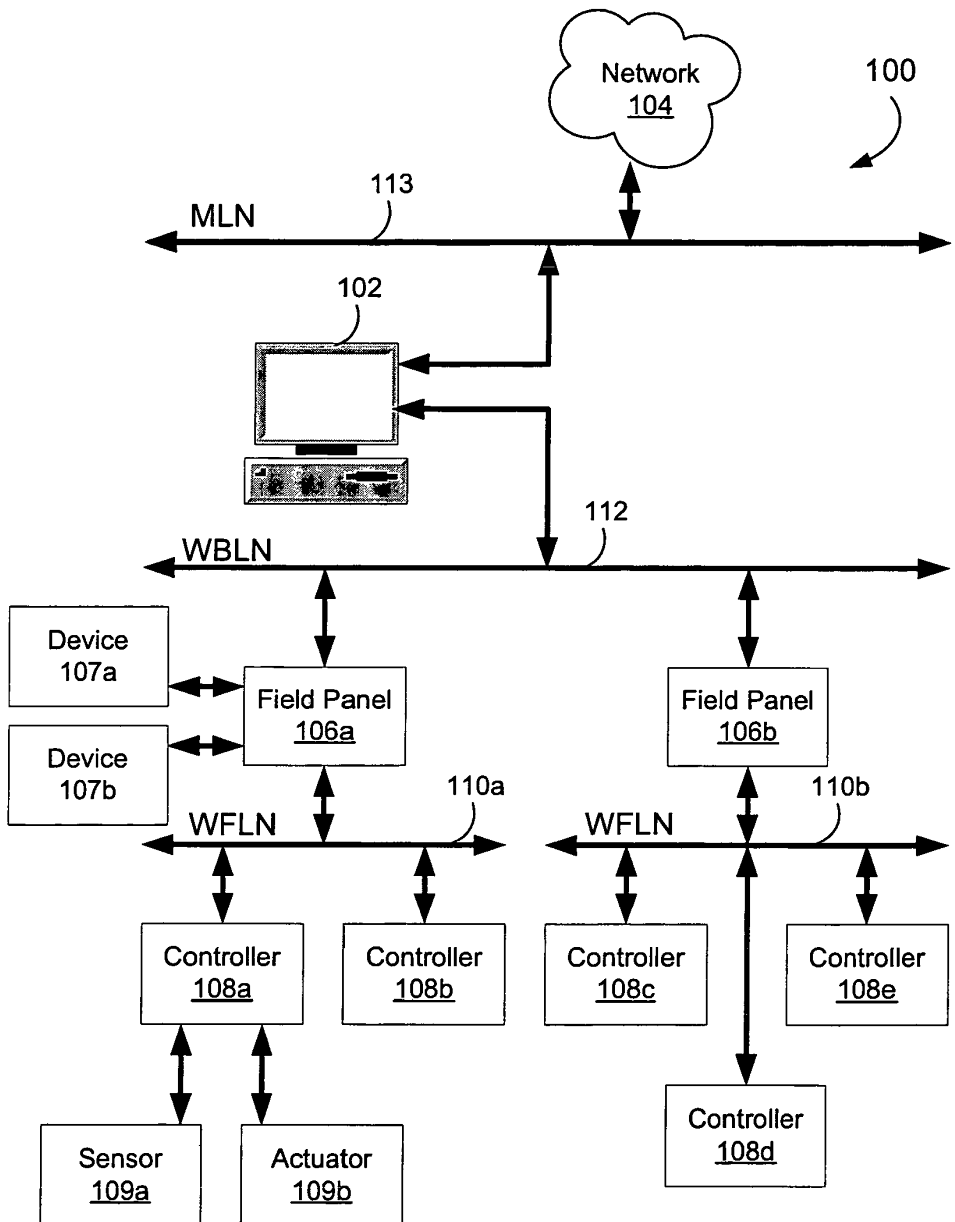

Network
104
100
113
MLN
102
112
WBLN
Device
107a
Device
107b
Field Panel
106a
Field Panel
106b
110a
110b
WFLN
WFLN
Controller
108a
Controller
108b
Controller
108c
Controller
108e
Controller
108d
Sensor
109a
Actuator
109b

Figure 1

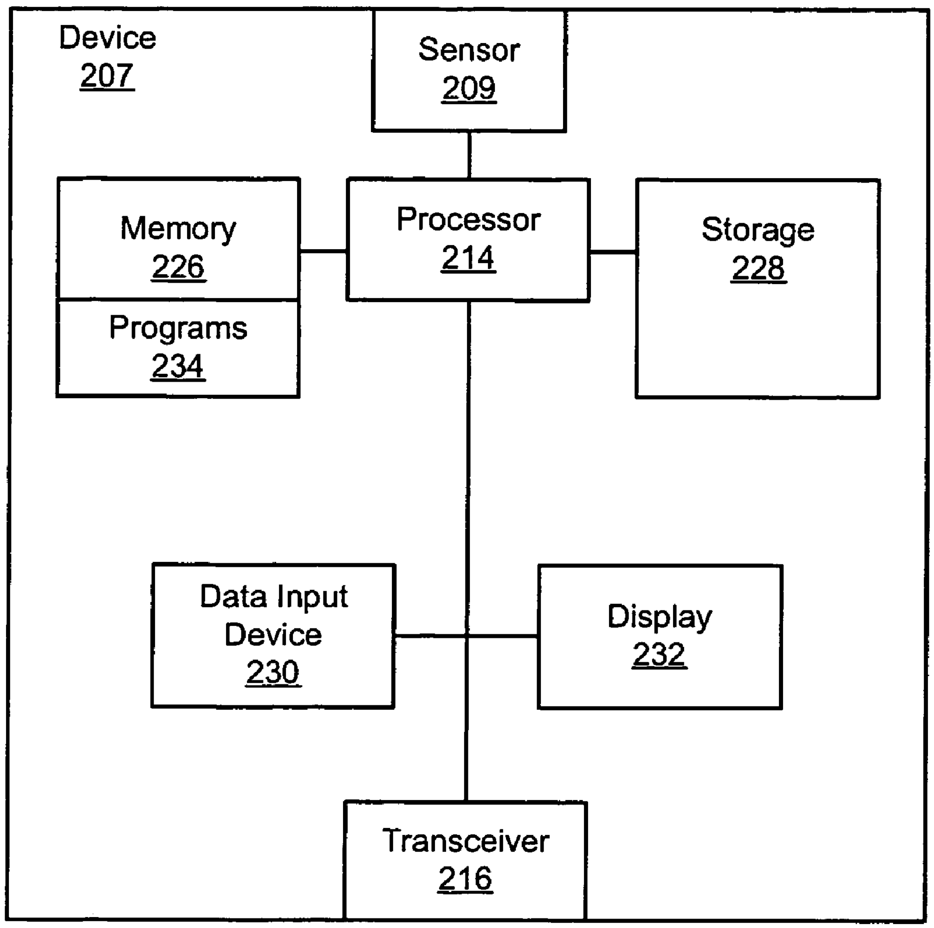

Device
207
Sensor
209
Memory
226
Programs
234
Processor
214
Storage
228
Data Input
Device
230
Display
232
Transceiver
216

Figure 2

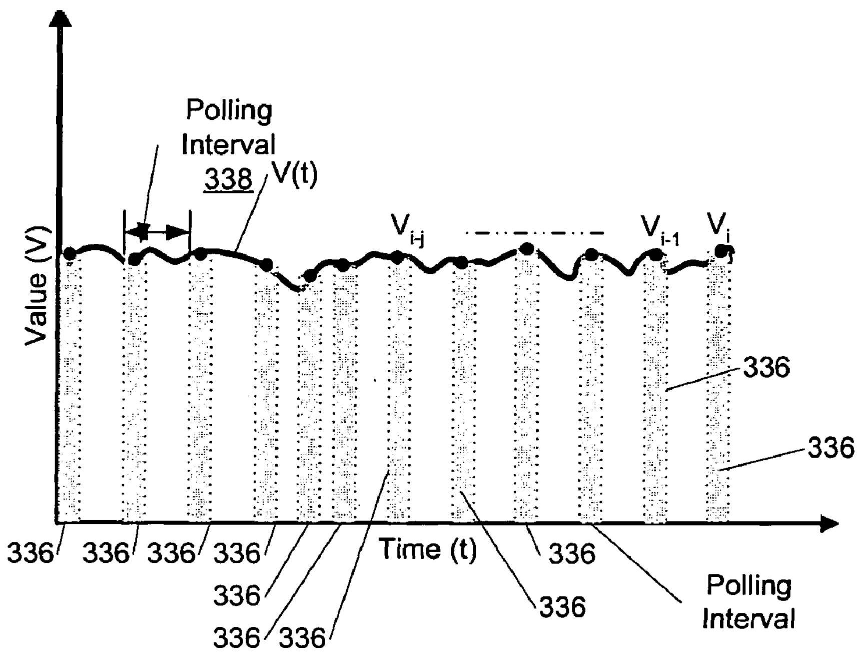


Figure 3

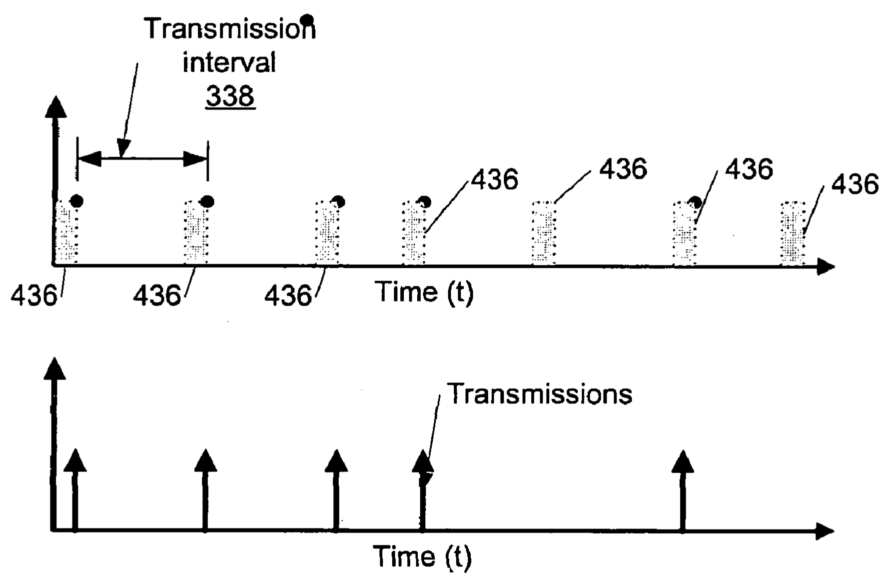


Figure 4

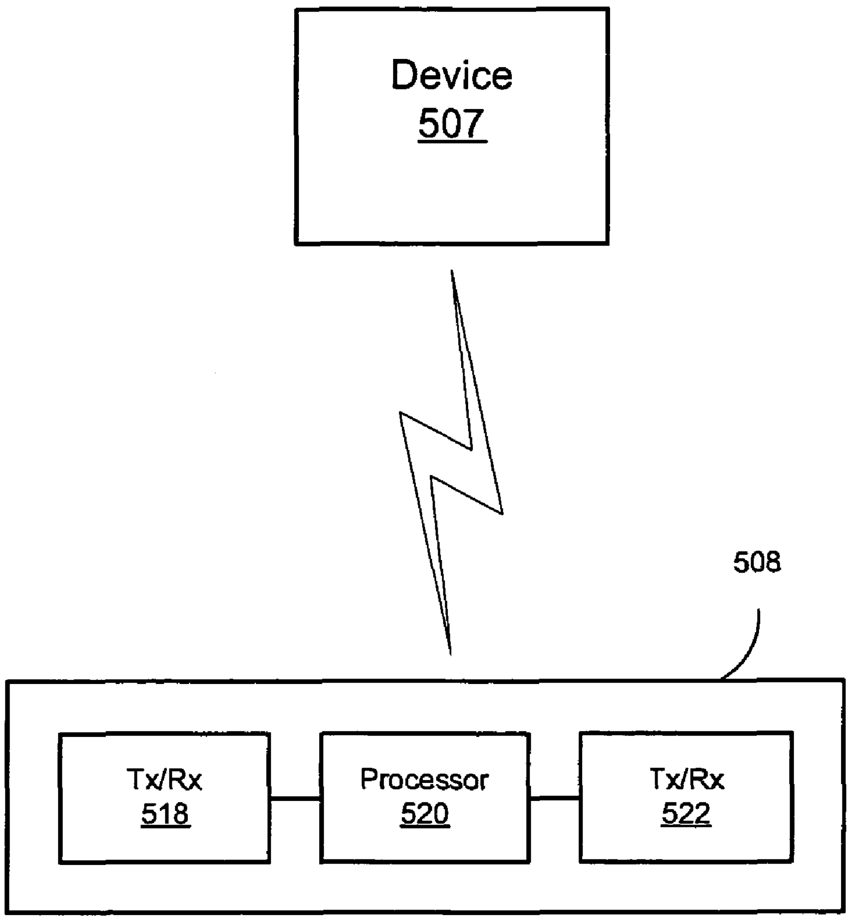


Figure 5

DYNAMIC VALUE REPORTING FOR WIRELESS AUTOMATED SYSTEMS

BACKGROUND

The invention relates to remote monitoring of conditions and more particularly to wirelessly reporting a sensed condition over a wireless communication network.

Automation systems include one or more distributed components and/or grouping of components that together form an integrated system for automating a process control. The components include controllers, sensors, switches, alarms, actuators, chillers, fans, humidifiers, and/or air handling units configured to automate process control for heating, ventilation, air conditioning (HVAC), environmental air quality, safety and security, fire, hazard prevention, or other processes for a building or facility. The devices may communicate information over a wired network and/or by wirelessly broadcasting information between and among the components.

The components may detect events, sense conditions, respond to detected events or changes in conditions, and/or control operation of other devices. An event may be detected by a sensor, which communicates related information to a controller. The controller generates control signals, which are communicated to a device for an appropriate responsive action. For example, a temperature sensor wirelessly broadcasts a temperature reading to a controller. The controller reads the information from the sensor and determines whether a responsive control action may be taken. The controller communicates a control signal, as appropriate, to an actuator to control airflow in the room. The controller also may communicate a feedback or status signal to a remote computer.

Wireless networks are limited by the amount of available bandwidth over which the devices may communicate. The number of devices and amount of information communicated over a wireless system may be constrained by the available bandwidth. Systems having many wireless devices may create a noisy environment in which data can be lost, dropped or not communicated with the targeted recipient. The continuous monitoring of conditions and broadcast of information consumes larges amounts of power, which may shorten a limited-lifetime power source. The continuous stream of information from and to devices uses a great amount processing power for a controller, and may provide redundant information that may need to be filtered before being processed.

Accordingly, there is a need for a system for reducing an amount of communication over a wireless automated system using dynamic value reporting.

BRIEF SUMMARY

The described embodiments include methods, processes, apparatuses, and systems for reporting information over a wireless automation system, and particularly to a wireless building automation system. An automated wireless system using dynamic value reporting provides for a robust process control that minimizes an amount of communications in the wireless network. The amount of wireless traffic in the system may be reduced, and/or the number of devices communicating over a wireless network increased, by minimizing or reducing the amount of information reported by a sensor.

Conditions are monitored, or sensed, during a variable periodic interval to determine whether a measurement for the condition has changed, is above, and/or below a limit or within or outside a range. The measurement may also be compared to measurements made during prior intervals, and/or statistics determined based on prior readings. A statistical analysis of the measurement may be made, and an appropriate control response determined and executed. The measurement, the change over a prior measurement, and/or the results of a comparison to a limit and/or range may be made according to a second periodic interval. The second periodic interval may coincide with the first periodic interval.

In an embodiment, a wireless automation device includes a wireless transceiver, such as a RF transceiver, RF transmitter, and/or RF receiver or other device that wirelessly communicates packets of information over a wireless network. A sensor generates a signal based on whether a sensed condition is within a predetermined range. In the device, a controller polls the sensor at a variable periodic interval to read the signal from the sensor. The sensor may be continuously activated, or may be activated upon a polling by the controller. The controller also controls the transceiver to selectively communicate information associated with the signal from the sensor. The information is transmitted during a variable periodic interval for transmitting the information. The information may be transmitted in response a change in a sensed condition, in response to a sensed condition being outside a predetermined range or limit, and/or in response to an externally received control signal. Transmission of information during an interval may be suspended in response to an externally received control signal. The controller and/or sensor may enter a stand-by or sleep mode during times other than the variable periodic interval.

The present invention is defined by the following claims. Nothing in this section should be taken as a limitation on those claims. Further aspects and advantages of the invention are discussed below in conjunction with the preferred embodiments and may be later claimed independently or in combination.

BRIEF DESCRIPTION OF THE DRAWINGS

The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. **1** is an example of a wireless automated system for building automation.

FIG. **2** is a diagrammatic representation for a sensor device.

FIG. **3** illustrates a timing chart illustrating the polling interval for a sensor configured for dynamic value reporting.

FIG. **4** illustrates a timing chart for the transmission of information for a device configured for dynamic value reporting.

FIG. **5** illustrates sensor device in communication with a controller.

DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

A wireless automation system configured for or using dynamic value reporting communicates data among and between devices related to changes in a value of a monitored condition and/or measured parameter (e.g., a wireless sensor for monitoring environmental temperature). A wireless automation device using dynamic value reporting monitors and wirelessly reports building automation information over a building automation network formed by multiple distributed devices. The distributed devices communicate information between and among the devices from a source device to a destination device.

A device that uses dynamic value reporting senses, samples and/or measures a condition during a period of a sampling or polling interval. A reading of the condition may be taken to identify an indicator associated with the current or present condition. The indicator of the current or present condition may be read during a current period of the sampling interval. The current reading of the indicator may be stored with prior readings of the indicator in a memory. The current readings and prior readings may be stored in memory in order in which the readings were read, such as in a stack manner. The current reading of the indicator also may be compared to prior readings of the indicator to determine a change. The indicator and/or the change may be compared to a limit or range, such as an absolute limit and/or a range for changes from one or more previous measured values.

The device wirelessly receives and transmits information over the network. The information may include a current indicator of the condition, a value or status for the condition and/or sensor, and/or the comparison of the indicator to a limit or range, the time or interval sequence number in which an indicator was made, the time or interval sequence in which an indicator is deemed to have changed beyond a limit or outside a range and like information. The information is routed as packets, such as according to a TCP/IP transmission protocol. The information is communicated to destination device, such as an actuator, and/or a controller that executes a process control such as executing a responsive action, and/or communicating an appropriate control signal. The device may communicate information during a period of a transmission interval. The device may communicate information during a transmission, or communication, interval. The information may be communicated in response to a comparison that identifies a change in the sensed condition, such as a change outside a band limit, or a reading of the indicator beyond a limit. Similarly, a transmission of information may be suspended for periods of a transmission interval for which no change in the indicator has been identified. The device may enter a sleep mode, or go into a standby mode, between periods of the transmission and/or polling interval. The transmission and polling intervals, the limits and ranges may be changed, varied, regulated, adjusted, extended and/or compressed according to the measured values and/or comparison to the limits.

FIG. **1** illustrates a block diagram for an example of a wireless automation system **100** configured for and/or using dynamic value reporting. The illustrated wireless automation system **100** automates a building control process for heating, ventilation, and air conditioning (HVAC) for one or more buildings and/or facilities. In an embodiment, the building automation system may be an APOGEE™ system provided by Siemens Building Technologies, Inc. of Buffalo Grove, Ill. The wireless automation system **100** using dynamic value reporting may be any of a variety of other automation systems, including air quality systems, industrial control systems, security and loss prevention systems, hazard detection and/or prevention systems, lighting systems, combinations and integrations thereof, and the like.

The automation system **100** provides process control functionality for one or more building, or facility operations. The automation system **100** includes one or more devices positioned, or distributed, throughout the building. The devices generate and/or receive information related to a specific event, condition, status, acknowledgement, control, combinations thereof and the like. The devices may also respond to control commands and/or execute an instruction received by or in a signal. The devices may also communicate or route the information between and among components of the system from a source to a destination.

The automation system **100** shown in FIG. **1** is a multi-tier architecture having a high-speed or high bandwidth communications level that includes aggregate collections of sensor and/or actuator data, video or other high bandwidth data or long range communications and a level for point-to-point communication between devices. The devices may be field panels, controllers, sensors, actuators and any other component of an automation system. Control processes are distributed to the field panels, controllers, sensors and actuators as appropriate for the particular operations or functions of the device.

The devices of the system **100** communicate information, data and commands according to an assigned binding association. That is, devices may be commissioned as an operating pair or group according to a binding association. Even though devices may be commissioned as an operating pair or group, communications between devices may be routed, or hopped, via one or more other devices of the network. That is, the communication of information between and among devices includes transmitting, routing, and/or information hopping using low-power wireless RF communications across a network defined by the devices. Multiple paths from a source to a destination may exist in the network.

A sensing device monitors a condition and/or status of an event. The sensing device may report appropriate sensor information, such as a current value or indicator of the condition, timing of a reading, prior measurements, status of the sensor and/or a comparison of a measured value to a desired limit, range or a previous measurement. Actuators may process sensor information to determine an appropriate action for the actuator. Controllers monitor the process or action of sensors and actuators, and may override the sensor and/or actuators to alter processing based on a regional or larger area control process.

The automation system **100** includes a supervisory control system or workstation **102**, one or more field panels **106***a*, **106***b*, and one or more controllers **108***a*-**108***e*. Each controller **108***a*-**108***e*, for example, corresponds to an associated localized, standard building control subsystem such as a space temperature control, air quality control, lighting control, hazard detection, security, combinations thereof, or the like. The controllers **108***a*-**108***e* communicate with one or more sensors **109***a* using two-way wireless communication protocol. The controllers **108***a*-**108***e* also may communicate information with one or more actuators **109***b* using two-way wireless communication protocol. For example, sensor **109***a* and actuator **109***b* are commissioned to communicate data and/or instructions with the controller **108***a*. Sensor **109***a* may also communicate information directly with actuator **109***b* using two-way wireless communications.

The controller **108***a* provides control functionality of each, one, or both of the sensor **109***a* and the actuator **109***b*. Controller **108***a* controls a subsystem based on sensed conditions and desired set point conditions. The controller **108***a* controls the operation of one or more actuators in response to an event reported by a sensor **109***a*. The controller **108***a* may drive the one or more actuator to a desired set point.

The controller **108***a* is programmed with the set points and a code setting forth instructions that are executed by the controller for controlling the actuators to drive the sensed condition to be with the set point. For example, the actuator **109***b* is operatively connected to an air conditioning damper and sensor **109***a* may be a room temperature sensor that reports information related to a temperature being monitored by the sensor. The sensor may report current temperature or a relative temperature change compared to a prior measurement. If the temperature sensed by the sensor **109***a* exceeds a threshold, the actuator may respond accordingly to open a damper, allowing air conditioning to flow into a room. The sensor **109***a* may communicate the sensed condition to the actuator **109***b* and/or to the controller **108***a*, which thereafter provides an appropriate control signal to the actuator **109***a*.

Sensor, actuator, and set point information may be shared among or common to, controllers **108***a*-**108***e*, field panels **106***a*-**106***b*, work station **102**, and any other components or elements that may affect control of the building automation system **100**. To facilitate sharing of information, groups of subsystems such as those coupled to controllers **108***a* and **108***b* are organized into wireless field (or floor) level networks ("WFLN's") and generally interface at least one field panel **106***a*. Controllers **108***c*, **108***d* and **108***e* along with the field panel **106***b* also may communicate via a low-level WFLN data network **110***b*.

The WFLN data networks **110***a* **110***b* are low-level data networks that may use any suitable proprietary or open protocol. The devices forming a WFLN communicate via two-way radio links. Interfaces, routers and bridges are provided for implementing the WFLN **110***a* and **110***b*. While shown as a common bus or interconnection structure, the WFLN may include multiple or different communication links between components with some or no redundancy in any of various patterns.

Any of a wide variety of WFLN architectures may be used. For example, the devices of the WFLN may utilize a wireless MESH technology to form a MESH network. For example, the WFLN configured as a wireless MESH network include multiple nodes that communicate via wireless communication links. The MESH network establishes a grid of nodes that create redundant paths for information flow between and among the nodes. In the MESH network, information may reach a destination either by a direct point-to-point communication or by an indirect communication where the information is routed or hops from node to node, among different paths from a source to the destination. The WFLN may be self-forming and/or self-healing. The WFLN also allows bi-directional routing for command and control information. Additional, different or fewer networks may be provided. For example, a WFLN may be wired, while other networks may be wireless, one or both wireless networks include wired components, or the networks may be distributed among only one, three or more levels.

The WFLN's **110***a* and **110***b* operate in accordance with distinguishable or the same wireless communications protocols. For example, the WFLN **110***a* operates pursuant to the 802.15.4 communications protocols, but IEEE 802.11x (e.g., 802.11a 802.11b, 802.11c . . . 802.11g), Wi-Fi, Wi-Max, Bluetooth, ZigBee, Ethernet, proprietary, standard, now known or later developed wireless communication protocols may be used. The WFLN **110***b* may operate using the same or different protocol as the protocol employed by WFLN **110***a*. Any now known or later developed network and transport algorithms may be used. Communication, transport and routing algorithms are provided on the appropriate devices. Any packet size or data format may be used.

The field panels **106***a* and **106***b* coordinate communication of data, information and signals between the controllers **108***a*-**108***e* and the workstation **102** and network **104**. In addition, one or more of the field panels **106***a* and **106***b* may control devices such as HVAC actuators **107***a* and **107***b*. The field panels **106***a* and **106***b* accept modification, changes, alterations, and the like from the user with respect to objects defined by the building automation system **100**. The objects are various parameters, control and/or set points, port modifications, terminal definitions, users, date/time data, alarms and/or alarm definitions, modes, and/or programming of the field panel itself, another field panel, and/or any controller in communication with a field panel.

The field panels **106***a* and **106***b* may communicate upstream via a wireless building level network ("WBLN") **112** to the workstation **102**. The workstation **102** includes one or more supervisory computers, central control panels or combinations thereof. The workstation **102** provides overall control and monitoring of the building automation system **100** and includes a user interface. The workstation **102** further operates as a building control system data server that exchanges data with one or more components of the building automation system **100**. The workstation **102** may also allow access to the building control system data by other applications. The applications are executed on the workstation **102** or other supervisory computers that may be communicatively coupled via a management level network (MLN) **113**.

The workstation provides user access to components of the building automation system **100**, such as the field panels **106***a* and **106***b*. The workstation **102** accepts modifications, changes, and alterations to the system. For example, a user may use the workstation **102** to reprogram set points for a subsystem via a user interface. The user interface may be an input device or combination of input devices, such as a keyboard, voice-activated response system, a mouse or similar device. The workstation **102** may affect or change operations of the field panels **106***a* and **106***b*, utilize the data and/or instructions from the workstation **102**, and/or provide control of connected devices, such as devices **107***a* and **107***b* and/or the controllers **108***a* and **108***b*. The field panels **106***a* and **106***b* therefore accept the modifications, changes, alterations and the like from the user.

The workstation **102** may process data gathered from the field panels **106***a* and **106***b* and including maintain a log of events and conditions. Information and/or data are gathered in connection with the polling, query or otherwise. The workstation **102** maintains a database associated with each field panel **106***a* and **106***b*, controllers **108***a*-**108***e*, and sensor **109***a*, actuator **109***b*, controller **108***d* and devices **107***a* and **107***b*. The database stores or records operational and configuration data.

The workstation **102** may be communicatively coupled to a web server. For example, the workstation **102** may be coupled to communicate with a web server via the MLN **113** through a network **104** such as an Ethernet network, a LAN, WLAN, or the Internet. The workstation **102** uses the MLN **113** to communicate building control system data to and from other elements on the MLN **113**. The MLN **113** is connected to other supervisory computers, servers, or gateways through the network **104**. For example, the MLN **113** may be coupled to a web server to communicate with external devices and other network managers. The MLN **113** may be configured to communicate according to known communication protocols such as TCP/IP, BACnet, and/or other communication protocols suitable for sharing large amounts of data.

FIG. **2** illustrate a block diagram of an automation device **207** for a wireless automation system using dynamic value reporting. The automation device **207** provides service functionality. The automation device **207** may be a function-specific device, or configured to provide one or more of a variety of functionalities. In an example, the automation device **207** monitors a condition or parameter and wirelessly reports dynamics in the condition or parameter. The automation device **207** may be a sensor that monitors a condition and/or event, such as a building environment. The automation device **207** may be installed, positioned, and/or located with, within, on, or around a building, facility, a plant, factory, assembly, edifice, structure, colliery, combinations or portions thereof or other environment having conditions to be monitored.

The automation device **207** communicates over a network which may include other automation devices, data processors, desktop computers, a mobile computers, a notebook computers, a tablet computers, controllers, personal computers, workstations, mainframe computers, servers, personal digital assistants ("PDA"), personal communications devices such as a cellular telephone, and like devices configured to communicate information over a communication network. The network may be any known or proprietary network of computers, such as a Local Area Network (LAN), a Wireless LAN (WLAN) a Personal Area Network (PAN), Wireless PAN (WPAN) and a Virtual Private Network (VPN), combinations thereof and the like. The automation device **207** may communicate according to any known or proprietary communication protocols such as TCP/IP, BACnet, and/or other communication protocols suitable for sharing large amounts of data. For example, the automation device **207** is a temperature sensor that monitors and reports information related to a temperature in a room or portion thereof. The sensor **207** reports information related to the temperature between and among devices of a building automation system.

The device **207** includes a processor **214**, a transceiver **216**, and a sensor **209**. Additional, different or fewer components may be provided, such as providing a plurality of different or the same types of sensors. For example, the device may also have a memory **226**, a storage device **228**, a data input device **230**, and a data output **232**. A program **234** resides in the memory **226** and includes one or more sequences of executable code or coded instructions. The program **234** may be implemented as computer software, firmware including object and/or source code, hardware, or a combination of software and hardware. The program **234** may be stored on a computer-readable medium, (e.g., storage device **228**) installed on, deployed by, resident on, invoked by and/or used by the processor **214**. The program **234** is loaded into the memory **226** from storage device **228**. Additionally or alternatively, code may be executed by the controller processor **214** from the storage device **228**. The program **234** may be implemented using any known or proprietary software platform or frameworks including basic, visual basic, C, C+, C++, J2EE™, Oracle 9i, XML, API based designs, and like software systems.

The processor **214** implements a control process for the device **207**. The control process may be implemented based on a signal that is read from and/or provided by the sensor **209**, such as a measured value of a parameter, an indicator of a sensed condition and/or status of an event. The processor **214** may be may be one or more devices including a general processor, digital signal processor (DSP), control processor unit (CPU), application specific integrated circuit (ASIC), field programmable gate array (FPGA), analog circuit, digital circuit, combinations thereof or other now known or later developed devices for implementing a control process. The processor **214** has a processing power or capability and associated memory corresponding to the needs of one or more of a plurality of different types of sensors **209** and transceiver **216**. The processor **214** implements a control process algorithm specific to the sensor **209**. Other control processes may be stored but unused due to a specific configuration.

The processor **214** executes one or more sequences of instructions of the program **234** to process data. Data and/or instructions may be preprogrammed to the device **207** and or provide to the device **207** using the data input device **230**. Data and/or instructions may also be received via the transceiver **216**. The processor **214** interfaces data input device **230** and/or the transceiver **216** to receive data and instructions. The processor **214** may also interface the storage device **228** for storage and retrieval of data. Data processed by the processor **214** may be stored in and retrieved from in storage device **228**, communicated via the transceiver **216**, and/or presented via data output device **232**. The data output device **232** may be a display, monitor, a printer, a communications port, an array of lights, combinations thereof and the like. For example, the processor may control a light array of the output device **232** to indicate an operation status, or read data status, a transmit status and the like. The light array may be internal to an enclosure for the device, and/or externally visible.

The transceiver **216** is a receiver, transmitter, combination receiver/transmitter, wireless communication port, wireless communication device, wireless modem and like device capable of wirelessly receiving, communicating, transmitting, and/or broadcasting information. In an embodiment, the transceiver **216** may receive and transmit control information from other components or devices. The information may be control information to alter the implemented control process.

The transceiver **216** wirelessly communicates information using one or a combination of one-way and/or two-way wireless communications. The information may be communicated using radio frequency (RF), infra-red (IR), ultra-sound communication, cellular radio-telephone communications, a wireless telephone, a Personal Communication Systems (PCS) and like wireless communication technologies. The transceiver **216** communicate information as packets of information according to one or more communications protocols or standards, including IEEE 802.11(x), 802.16, Wi-Fi, WiMax, ZigBee, Bluetooth, Voice Over Internet Protocol (VoIP). The transceiver **216** also or alternatively communicates information and/or packets of information in accordance with known and proprietary network protocols such as TCP/IP, Ethernet and like protocols over a Personal Area Network (PAN), Wireless PAN (WPAN), virtual private network (VPN), Wireless Local Area Network (WLAN) and like networks. The transceiver may also include an interrogator that wirelessly transmits signals to interrogate components of a building automation system. The transceiver also may receive a wirelessly transmitted interrogation signal from one or more other components.

The sensor **209** may include a device or a collection of devices that sense conditions, parameters and/or events such as an environmental condition in a building. The sensor **209** generates information or data related to the sensed or monitored condition. The information may be provided an output as one or more signals that may be read by the processor **214**. The information may be generated in response to a physical stimulus such as light, sound, pressure, heat, magnetism, motion and/or acceleration. The physical stimulus may be detected as the result of sensing or monitoring the conditions or parameters. The may be provided as an indicator of the sensed condition, parameter or event. In an example, the sensor **209** is configured as any of a temperature sensor, humidity sensor, fire sensor, pressure sensor, smoke sensor, occupancy sensor, air quality sensor, gas sensor, O_2, CO_2 or CO sensor, accelerometer, velocity sensor, combinations thereof, or other now known or later developed sensors. The sensor **209** may be a micro-electro-mechanical sensors ("MEMS") or larger sensors for sensing any condition or parameter.

The sensor **209** is responsive to the processor **214** and/or logic executed by the processor **214**. A signal generated by the sensor **209** may be an indicator of the sensed condition. The signal may be provided to or read by the processor as one or more electrical, electromagnetic, electrochemical, and/or radio frequency signals. The signal may be characterized as an impulse signal, a continuous signal, or discrete time signal. The signal may be an analog or digital signal provided in parallel or serially. The signal carries information or represents a value for a current condition, a past condition, a current change in a condition, a past change in a condition, a comparison of a current condition to a past condition, a comparison of a current condition to a standard, measure, or limit, a comparison of a change in the current condition to a limit, a comparison of the current condition to an extreme limit, a status of the sensor, any combination thereof, and like information that may be provided by sensing a condition or parameter.

FIG. **3** illustrates a chart **300** of signal V(t) generated by the sensor **209** representing an indicator of a sensed condition versus time (t). Although the signal is shown as a continuous curve, the signal V(t) may be discrete, or provided during discrete intervals of time.

In an embodiment, the processor **214** polls the sensor **209** during a recurring polling period **336**. During a polling period **336**, any one or each of the processor **214**, the sensor **209** and/or the transceiver **216** may be operable. Each period **336** recurs at a variable frequency or interval **338**. The interval **338** may be considered a time beginning at the start of a period **336** and ending at the start of the next consecutive interval **336**. A polling period **336** may be a short amount of time relative to the interval **338** or frequency of occurrence of the polling period. For example, a period **336** may extend for several microseconds for an interval **338** of in the range of milliseconds or more, may occur for one or more milliseconds every second or more, a second for every 10 or more seconds or more, or even in the range of minutes every several minutes. The period **336** also may extend for a large or substantial portion of the interval **338**. The relationship of the length of a period **336** to the recurrence of an interval **338** or the relationship to the variable interval **338** depends on one or more factors, such as the condition being monitored or sensed, past and current measurements, the control algorithm for the system or device, transmission frequency and strength of the transceiver, response of the sensor, bandwidth, response of a component with which the device **207** is in communication, amount of data to be sensed and/or communicated, power available to the device **207**, and any other factors that may contribute to an amount of time and recurrence of the period **336**.

A signal V(t) representing the sensed condition may be generated. The signal V(t) may be a continuous or discrete signal representing a current value for the sensed condition, or the status of the condition, during the current interval **336**. During a polling period **336**, the processor **214** reads the signal V(t) from the sensor **209**, and determines value, or most-current indicator V_i, for the current sensed condition. For example, the processor **214** may poll or sample the signal from the sensor **209** to read the most current indicator of the sensed condition. The indicator V_i may be a value for the signal V(t) at some point in time during the period **336**, such as at the beginning of the period **336**, the middle of the period **336**, or the end of the period **336**. The value V_i may also be an average, a mean, a median, or root mean squared (rms) of the signal V(t) over the period **336**. The indicator may be stored in memory **226**. The memory may also store prior readings V_{i-j}, or indicators read during prior periods **336**. Associated timing data or an interval sequence may be stored with the indicator V_i to identify a point in time or interval in which the indicator was read.

Between the intervals **336**, the processor **214** may enter a standby or sleep mode, where the processor operates at lower or with very little power consumption. The sensor **209** may also enter a standby or sleep mode between periodic intervals. In the event that the processor **214** is in a sleep mode prior to an polling period **336**, the processor **214** will wake up to read or sample the signal V(t) to identify a most current indicator V_i for the sensed condition.

The value V_i is processed by the processor **214** according to a control algorithm to identify whether the sensed condition has changed. For example, the most current indicator V_i may be compared to one or more indicators read during a prior periods V_{i-j}. Thus, a change in the sensed condition may be identified by comparing indicators V_i and V_{i-j} read during different periods **336**. The change or difference may be compared to a limit. For example, an absolute difference D_i between the indicator V_i for the most current period to the indicator V_{i-j}. read during a prior period is determined (e.g. $|V_i-V_{i-j}|$). The current difference D_i is compared to a difference limit D_l. The current difference may also be compared to a multiple of the difference limit D_l (e.g., $3\times D_l$) to identify whether an extreme condition may be present, such as a large temperature increase do to a fire. Where the current difference D_i greater than the difference limit D_l (i.e., $D_i>D_l$) the difference between the current value V_i and the value V_{i-j} in the prior interval may be considered outside a control range or band limit.

Similarly, a negative difference between a most current indicator V_i and a prior indicator period V_{i-j} (i.e., $V_i<V_{i-j}$) may be compared to a lower limit LL, and a positive difference between a most current indicator V_i and a prior indicator V_{i-j} (i.e., $V_i>V_{i-j}$) may be compared to an upper limit UL. An absolute value for the lower limit LL may be the same or different than the absolute value for the upper limit UL. The difference may be compared to the LL and UL, and the absolute difference compared to an absolute difference limit D_l to identify changes in the sensed condition. Where a change has been determined, a flag may be set, and/or stored in memory, identifying a change in the sensed condition has been detected. The most current indicator V_i also or alternatively may be compared to a limit V_{max} and/or V_{min}. The flag may be set if the most current indicator is determined to be greater than V_{max} or less than V_{min}. A time or interval identifier associated with when the flag was set may also be identified and stored in memory.

In an embodiment, the prior interval is a most previous interval where the current indicator V_i is compared to an indicator V_{i-1} read in the most previous period to determine an absolute difference $|V_i-V_{i-1}|$, and/or a difference V_i-V_{i-1}. In another embodiment, the current value V_i is compared to a running average or mean V_{avg} of previous values to determine an absolute difference between the current value and the running average.

The processor **214** controls the transceiver **216** to selectively communicate information during a period of a transmission interval. FIG. **4** illustrates a transmission interval for a device configured for dynamic value reporting. For example, a processor **214** may control or trigger the transceiver **214** to communicate information during a transmission period **436**. The transceiver may communicate the information during the transmission period in response to a triggering event such a detecting whether a flag. The flag may be set in response to detecting or identifying a change in the sensed condition beyond a limit, outside a range, or a reading of an indicator above an upper limit or below a lower limit, or in response to an external stimulus, such as a control signal received by the sensor. The triggering event additionally or alternatively may be the start of the interval, a determination that the current difference D_i exceeds the difference limit D_l, the current difference D_i exceeds a multiple of the difference limit D_l, the current value V_i exceeds a limit such as V_{max} and/or V_{min}, combinations thereof, and the like. Similarly, the processor **214** may control the transceiver **216** to suspend the transmission of information, notwithstanding a flag being set identifying a transmission may be pending. The transceiver may also transmit information in response to a number of successive transmission periods in which information was not transmitted. The event also may be an absence of a value for the sensed condition from the sensor **209**.

The transceiver communicates the information as packets of information that are routed over the network. The information may include routing or carrier information for the communication, such as a destination address, packet size, source address and the like. The information may also include one or more of the triggering event, the most current indicator V_i, one or more prior indicators current value V_{i-1}, V_{i-j}, the current difference D_i,, the difference limit D_l, and/or the limits V_{max} and/or V_{min}, timing data, and or number of indicators being transmitted, and/or a packet count. The transceiver **216** may communicate the information during each transmission period **436**. Alternatively, the transceiver **216** may be controlled to communicate the information in response to a triggering event such as the flag being set. For example, the information may be communicated only during a transmission period **436** for which a change in the sensed condition has been determined. Similarly, the information may be transmitted only after a predetermined number of indicators V_i have been read, or after a predetermined number of indicators associated with a change over a prior indicator V_i have been read. For example, transceiver **216** may transmit information only during a transmission period in which a current difference D_i exceeds the difference limit D_l, and may not transmit during intervals in which the current difference D_i does not exceed the difference limit D_l. The transceiver **216** also may transmit information in an interval or subsequent interval in which an external control signal is received from another device.

The information may include multiple indicators such as the most current indicator V_i and one or more indicators V_{i-j} read during one or more prior polling periods **336**. A counter may count a number of successive polling periods **336** for which a flag or triggering event has not been set, and thus a transmission of information may not have been made. If the counter exceeds a maximum, the transceiver may communicate information such as a current time during a current or successive transmission period. The counter also or alternatively may counter a number of polling intervals when a change has been detected, such as when a flag has been set. When the count reaches a maximum or a limit. The transceiver may be controlled to suspend the transmission of information transmission period, until the counter reaches a send limit. For example, the send limit may be set at five. During each polling period **336** in which a change in the sensed condition is determined, the indicator V_i is stored and the count incremented. The transmission of information is suspended during a transmission period **436** until the counter is increment to the send limit (i.e., 5). When the counter reaches the send limit, each of the five stored indicators V_i are communicated. The information may include timing information or date associated with the indicators V_i and the counter information. Similarly, the information may be transmitted, notwithstanding the status of the counter, in response to other stimulus or determinations.

The most current indicator V_i, prior indicators V_{i-j}, the differences D_i,, past differences, the difference limit D_l, and/or the limits V_{max} and/or V_{min} may be stored in the storage **228**, memory **226**, and/or a buffer for the processor. The indicator V_i and limits may be may be stored with associated timing data or information identifying a corresponding time or period in an interval during which the value was or difference was determined. The processor **214** may process consecutive differences D_i and indicators V_i to determine control limits and distribution. For example, an analysis may be performed on the indicators V_i for multiple polling intervals **336**. By statistically analyzing consecutive or a series of indicators V_i and differences D_i, an estimate for the quality of the control of the sensed condition may be made. For example, a sequence of zero differences or small differences will be associated with a sensed condition that has little or no change over time. Conversely, a series of large differences will be associated with a sensed condition that has greater change over time.

The difference limit D_l may vary according to a determination of the change between differences. For example, when the change between differences D_i to D_{i-j} is minimal or below a predetermined threshold, the difference limit D_l may be reduced. By reducing the difference limit D_l, the range in which the value may vary is compressed. With the reduced difference limit D_l, the device **207** may detect smaller changes to provide a more robust control of the sensed condition. When the changes between differences D_i to D_{i-j} is large or above a predetermined threshold, the difference limit may be increased.

In addition or alternatively, the variable interval **338** may change in response to a determination of the change between differences. For example, when the change between differences D_i to D_{i-j} is minimal or below a predetermined threshold, the difference limit interval may be extended. That is, the small change between consecutive differences may indicate that the frequency with which sensed condition is monitored may be reduced by extending the interval **338**. With the extended interval **338**, the device **207** may have a reduced number of communications, and thus energy consumed by and bandwidth used by the device **207** may also be reduced. When the changes between differences D_i to D_{i-j} is large or above a predetermined threshold, the period **338** may be shortened. With the shortened period, the sensor may respond to greater changes in the sensed condition.

The difference limit D_l and the period **338** may also be adjusted in accordance with state of the control algorithm for the system. For example, in a heating, ventilation, and air conditioning system, a temperature sensor may be controlled to ignore greater temperature fluctuations during a ramp-up condition. That is, there may times when the system may be warming up a room from a low temperature to a higher or warmer temperature. Similarly, the room may be cooled down. During these times, there may be greater changes of the temperature between intervals **336**. The device may be controlled to compare a value to a larger difference limit D_l, to only report information after a predetermined number of intervals, or to report after a difference D_i below a threshold is detected, or other condition when it is appropriate for the device to report a condition.

The difference limit D_l and the period **338** may also be adjusted controlled in accordance a statistical process control algorithm. For example, the difference limit D_l and the period **338** may be controlled according to a Statistical Process Control. The indicators V_i and the differences D_i will vary over time and form. The values V_i and the differences D_i may be plotted as a distribution. The distribution may provide a measure of the dispersion, or spread. For example, a range for the values V_i and the differences D_i (highest to lowest), a mean or average, a mode, and a standard deviation (sigma) may each be determined. The standard deviation may be used to set as an upper limit UL and lower limit LL. A Z-score variable for multiple indicators V_i may be determined and used to identify a tolerance of interval. The statistical analysis may be compared with other statistics or information for reporting the condition (e.g., time of day, occupancy, alarm, failure status, start up). The difference limit D_i and the period may be varied according to an analysis of the dispersion of the values V_i and the differences D_i. For example, the difference limit DL may be set to a value associated with three standard deviations from a mean of the differences Di in either direction of the mean to provide an economical measure of control of the condition, while minimizing a risk of reacting to a false signal. Other variable data or attribute data may be used as well. The values may be plotted on a chart, and listed in a table to provide a visual representation of the control of the condition. Using the Statistical Process Control Cpk values may be determined and compared to requirements for controlling the automated process. A reaction plan may be developed to guide the actions and reactions in the event of an out-of-control or out-of-specification condition. Filters such as Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters may be applied to screen the information. Frequency response of the process may be determined, such as by using a Fast Fourier transform of for the sensed values or read indicators. Filtered data may be used as a comparison to the most-current indicator V_i to identify changes and whether to set a flag for transmitting information.

FIG. **5** illustrates an exemplary controller **508** of a building automation system in communication with a device **507**. The device **507** is configured for dynamic value reporting as described above with respect to FIGS. **1-4**. The controller **508** includes one or more processors **520** and at least one transceiver **518**. The controller may also include a second transceiver **522**, where a transceiver **518** is communicates over a WFLN and a second transceiver **522** communicates with one or more devices **407**. The transceivers **518** and **522** send and receive information to and from the device **507** on the WFLN. The transceivers **518** and **522** may also send and receive information to and from and field panels. The controller **507** may transmit data and information addressed to a specific device **507** according to a binding association. The information may include control instructions, communications settings or other information transmitted from another device **507** or controller. Additional, different or fewer components of the controller **508** may be provided, such as providing a single transceiver operable to transmit and receive pursuant to one or two different communications protocols.

The processor **520** may be an application specific integrated circuit, general processor, digital signal processor, control processor, field programmable gate array, analog circuit, digital circuit, combinations thereof or other now known or later developed device for monitoring, controlling and/or routing. The processor **520** may be a 16, 32 or 64 bit processor operable to route or perform aggregate processing on multiple packets or a packet from multiple data sources. The controller **508** may be configured to interface with the device **507**. The controller **508** receives information communicated from the device **507**. The controller **508** processes the information according to a control algorithm for the system and for the device **507**. The controller **508** may be configured to communicate instructions to the device **507**. For example, when a sequence of differences does not change or varies relatively little, the controller **508** may instruct or reprogram the device **507** to a smaller difference limit D_l. Similarly, the controller **508** may instruct the device to increase the difference limit D, to ignore the difference limit D_l, to increase and/or decrease the polling interval **338** and/or the transmission interval **336**.

The controller **508** may also communicate a report instruction to the device **507**. In response to a report instruction, the device **507** may wake up from a sleep mode, and sense and report a current indicator V_i or other requested information. The controller **508** may also synchronize the timing of the polling periods **336** and/or transmission periods **436**. For example, the controller may communicate synchronization or timing information to the device **507**. By communicating the synchronization or timing information, the device **507** and the controller will have synchronized intervals for report and receiving information. The controller **508** may also be configured or programmed to communicate information with other devices in response to the information received from device **507**.

The description and illustrations are by way of example only. While the invention has been described above by reference to various embodiments, it should be understood that many changes and modifications can be made without departing from the scope of the invention. Many more embodiments and implementations are possible within the scope of this invention and will be apparent to those of ordinary skill in the art. For example, the various embodiments have a wide variety of applications including integrated building control systems, environmental control, security detection, communications, industrial control, power distribution, and hazard reporting. The wireless device may be synchronized with other devices. The wireless device may be used with integrated systems where, for example, an environmental control system may be integrated with a fire detection and prevention system.

It is intended that the appended claims cover such changes and modifications that fall within the spirit, scope and equivalents of the invention. The invention is not to be restricted except in light as necessitated by the accompanying claims and their equivalents. Therefore, the invention is not limited to the specific details, representative embodiments, and illustrated examples in this description.

I claim:

1. A wireless automation device, comprising:

a transceiver operable to wirelessly communicate packets of information over a wireless network;

a sensor operable to generate a indicator for a sensed condition;

a controller configured to poll the sensor at a polling interval to read the indicator during a current period of the polling interval and to selectively operate the transceiver to communicate information associated reading of the indicator; and

a memory, the controller storing a reading of the indicator during the current period in the memory, where the memory stores at least one prior reading of the indicator, the prior reading of the indicator made during a prior period of the polling interval,

wherein the transceiver is configured to transmit a most recent reading of the indicator stored in the memory during a period of a transmission interval in response to detecting a change in the sensed condition outside a predetermined range and wherein transmission of the most recent reading of the indicator stored in the memory during the period of the transmission interval is suspended in response to detecting a chance in the sensed condition within the predetermined range.

2. The wireless automation device of claim **1** where the transceiver transmits a still-alive current data after a predetermined maximum number of successive periods in which the most recent reading of the indicator stored in the memory during a period of the transmission interval is suspended.

3. The wireless automation device of claim **1** where an upper limit and a lower limit of the predetermined range may be varied.

4. The wireless automation device of claim **3** where the upper limit and lower limit may be varied according to an analysis of the most current reading of the indicator and the at least one prior reading of the indicator.

5. The wireless automation device of claim **1** where the transceiver is configured to transmit the most recent reading of the indicator stored in the memory during a period of the transmission interval in response to detecting a sensed condition beyond a band limit.

6. The wireless automation device of claim **5** where an upper band limit and a lower band limit may be varied.

7. The wireless automation device of claim **5** where the upper band limit and lower band limit may be varied according to an analysis of the most current reading of the indicator and the at least one prior reading of the indicator.

8. The wireless automation device of claim **1** where the transceiver is configured to transmit the most recent reading of the indicator stored in the memory in response to an externally-received transmission control signal received over the wireless network.

9. The wireless automation device of claim **1** where the transceiver is configured to transmit the at least one prior reading of the indicator stored in memory at the transmission interval.

10. The wireless automation device of claim **9** where the transceiver is configured to transmit the at least one prior reading of the indicator stored in memory in response to detecting a change in the sensed condition.

11. The wireless automation device of claim **1** where the transmission interval is variable.

12. The wireless automation device of claim **11**, where the polling interval is variable.

13. The wireless automation device of claim **12**, where the transmission interval and the polling interval vary according to a statistical analysis of the most current reading of the indicator and the at least one prior reading of the indicator.

14. The wireless automation device of claim **1** where the memory stores timing data associated with the most recent reading and the at least one prior reading of the indicator.

15. The wireless automation device of claim **1** where the transceiver is configured to transmit the timing data.

16. The wireless automation device of claim **1** comprising a counter associated with a number of prior readings stored in memory and not yet transmitted.

17. The wireless automation device of claim **16** where the most recent reading of the indicator and the at least one prior reading of the indicator are transmitted in response the counter reaching a maximum count.

18. The wireless automation device of claim **1**, where the sensor is configured to sense an environmental condition.

19. The wireless automation device of claim **18**, where the communication network comprises automation devices configured as a distributed building automation system.

20. The wireless automation device of claim **1** where the controller is configured to poll the sensor during a period of the transmission interval to read the indicator during a current period of the transmission interval.

21. The wireless automation device of claim **20** where the controller is configured to operate the transceiver to communicate information associated reading of the indicator during the current period of the transmission interval.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,746,887 B2
APPLICATION NO. : 11/402743
DATED : June 29, 2010
INVENTOR(S) : Norman McFarland

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

In the Claims

In Column 15, Claim 1, Line 3:
Change “chance” to --change--.

Signed and Sealed this
Eighth Day of February, 2022

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office

US007860495B2

(12) **United States Patent**
McFarland

(10) **Patent No.: US 7,860,495 B2**
(45) **Date of Patent: Dec. 28, 2010**

(54) **WIRELESS BUILDING CONTROL ARCHITECTURE**

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(73) Assignee: **Siemens Industry Inc.**, Alpharetta, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1906 days.

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H04M 3/00 (2006.01)

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(58) **Field of Classification Search** 455/404.1, 455/418, 419, 420, 41.2, 552.1, 553.1; 340/500, 340/501, 522, 523, 524, 539.26, 539.27, 340/539.28, 539.29, 540, 541, 545.2, 545.3, 340/545.4, 546, 545.6, 548, 539.22, 539.24, 340/539.25

See application file for complete search history.

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(57) **ABSTRACT**

On a first level of the wireless building automation architecture, sensors and associated actuators communicate directly. The sensor performs control processes appropriate for the sensor and regardless of the type of actuator being used. The actuator performs control processes specific to the actuator regardless of the type of sensor being used. By direct wireless communication between sensors and actuators, the opportunity for a failed communications link using a hub and spoke arrangement may be avoided. Communication redundancy is provided by receiving the outputs of sensors at a controller, such as a controller on a second high speed or high bandwidth tier of the architecture. Regional control is implemented in the higher level tier. The higher level tier may override or control operation of components of the lower level tier as needed. The distributed control processing allows for more convenient room level integration. Where a problem is detected, such as a fire, corrective action begins within the immediate region of the sensor generating an alarm signal. The corrective action occurs without routing the alarm signal to upper levels of control processes or across different systems. The alarm signal is also propagated to upper level control systems for generating appropriate responses in other zones. To provide the different zones and avoid interference, the transmit power of the sensors and actuators is controlled as a function of two or more other devices.

33 Claims, 2 Drawing Sheets

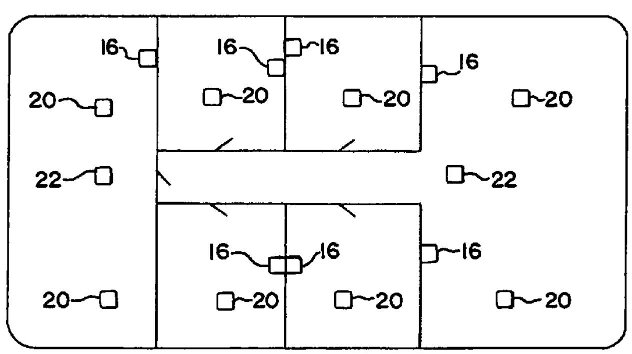

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FIG. 1

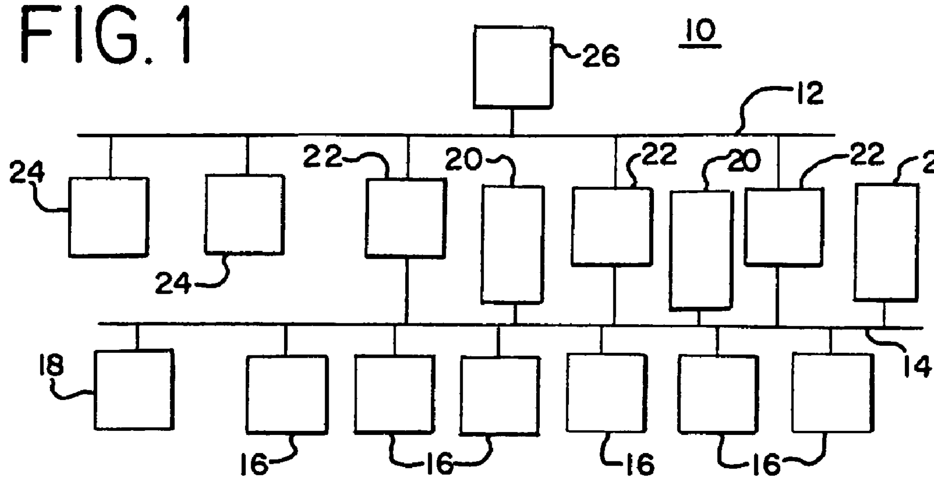


FIG. 2

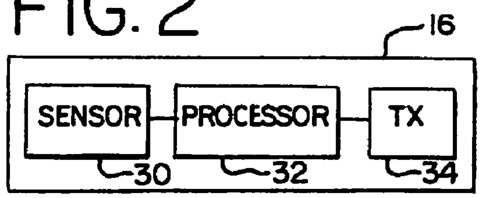


FIG. 3

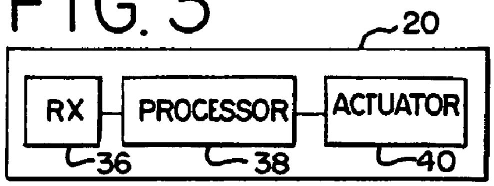


FIG. 4

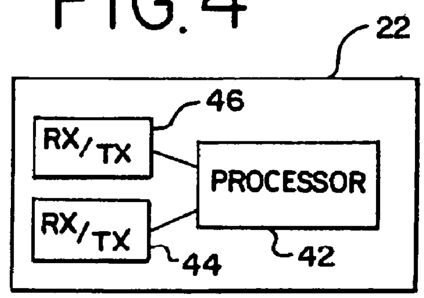


FIG. 5

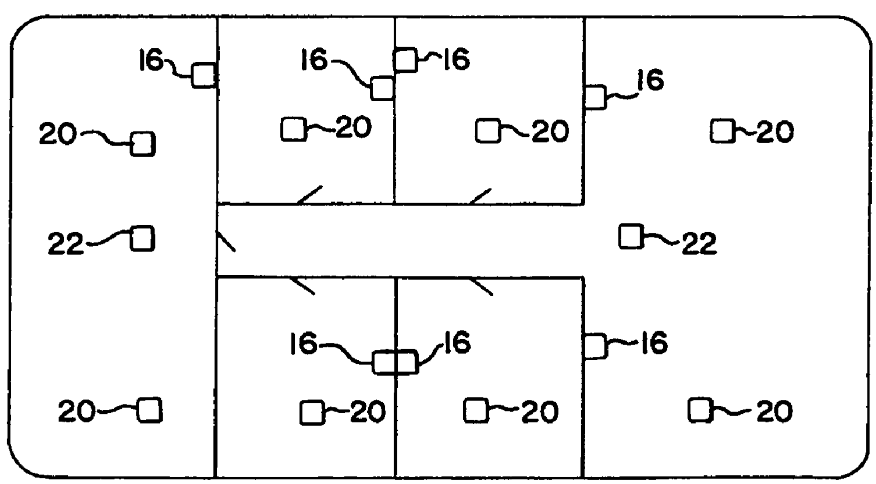


FIG. 6

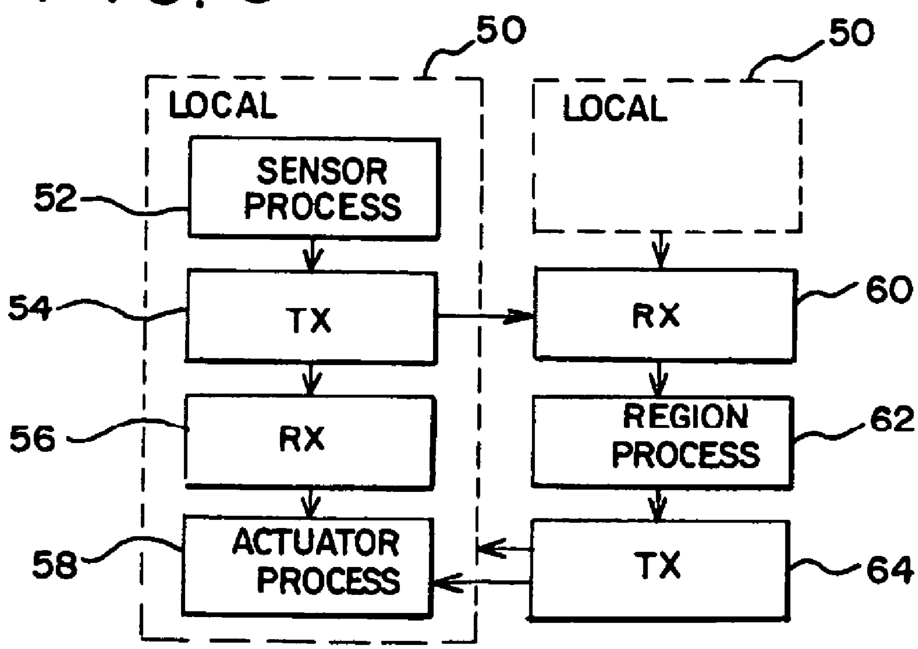
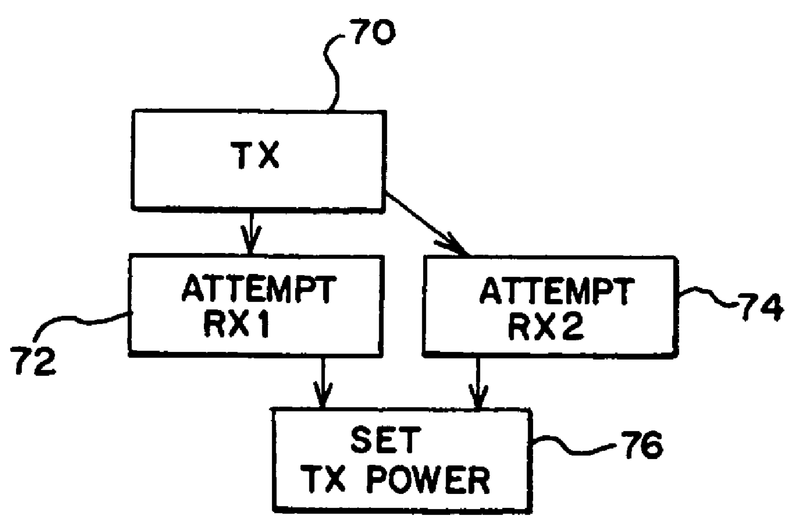

50
50
LOCAL
LOCAL
SENSOR PROCESS
52
54
TX
RX
60
56
RX
REGION PROCESS
62
58
ACTUATOR PROCESS
TX
64

FIG. 7


70
TX
ATTEMPT RX1
ATTEMPT RX2
72
74
SET TX POWER
76

WIRELESS BUILDING CONTROL ARCHITECTURE

BACKGROUND

The present invention relates to building automation systems. In particular, a wireless building control architecture implements automation of building systems.

Building automation systems include heating, ventilation and air conditioning (HVAC) systems, security systems, fire systems, or other systems. The systems are typically formed from distributed components wired together. HVAC systems may be formed with up to three separate tiers or architectural levels. A floor level network provides general control for a particular floor or zone of a building. Controllers of the floor level network provide process controls based on sensor inputs to operate actuators. For example, a temperature sensor is read. An adjustment of a damper, heating element, cooling element or other actuator is determined by a separate controller based on a set point and the measured temperature. Other basic control functions for room comfort may be provided, such as by using single input, single output feedback loops employing proportional-integral-derivative methods. The building level network integrates multiple floor level networks to provide consistent control between various zones within a building. Panels or other controllers control distribution systems, such as pumps, fans or other central plants for cooling and heating. Building level controllers may communicate among themselves and also access floor level controllers for obtaining data. The management level network integrates control of the building level networks to provide a high level control process of the overall building environment and equipment. The controllers, such as a personal computer, provide supervisory and management of the building automation system. Single or dual level architectures may also be provided.

Wired building automation systems have substantial installation costs. Controllers on a floor level network are bound through installed wiring between sensors and actuators. In addition to the cost of installing wiring between the various devices, the maintenance and establishment of a network hierarchy also introduces additional cost. Further wiring connects floor level controllers to building level controllers and building level controllers to management level controllers. Further wiring adds additional costs and complication for networking. If a device within the system fails, the physical location of the device is determined manually, such as by following wiring runs from a controller reporting failure to a failed component. Manual maintenance may be expensive. Changes to the system may require additional wiring or rerouting of wiring, adding further costs.

To reduce costs associated with wiring, wireless architectures for building automation systems have been proposed. Wireless standards provide single tier networks or multiple tier networks for implementing a single building automation process. For example, a multi-tier wireless network emulates current wired building automation systems. A controller wirelessly communicates with sensors and associated actuators. The lower level sensors and actuators provide mere input and output functions controlled by controllers. As another example, a hub and spoke control in proposed in U.S. patent application Ser. No. 10/672,527 titled "Building Control System using Integrated MEMS Devices", the disclosure of which is incorporated herein. A controller may be integrated with an actuator, a sensor or combinations thereof. An additional layer or tier uses wireless communications for management of local functions as well as management of building wide subsystems, such as chiller or building fan.

IEEE 802.15.4 standardizes wireless integrated building automation systems. Reduced function devices (RFD) with limited processing power communicate with full function devices. Full function devices (FFD) provide pier-to-pier wireless communication for controlling other reduced function devices. The standard contemplates a hub and spoke configuration between an RFD and associated FFDs while using peer-to-peer communication between FFDs.

BRIEF SUMMARY

By way of introduction, the preferred embodiments described below include methods and systems for wireless building automation control. The wireless architecture maximizes control capabilities and optional or available communications paths. On a first level of the wireless architecture, sensors and associated actuators communicate directly. The sensor performs control processes appropriate for the sensor and regardless of the type of actuator being used, and the output from the sensor is wirelessly communicated to an actuator. The actuator performs control processes specific to the actuator regardless of the type of sensor being used. By direct communication between sensors and actuators, the opportunity for a failed communications link using a hub and spoke arrangement may be avoided. Communication redundancy may be provided by also receiving the outputs of sensors at a controller, such as a controller on a second high speed or high bandwidth tier of the architecture. Regional control is implemented in the higher level tier. The higher level tier may override or control operation of components of the lower level tier as needed, such as during a communications failure or to implement a control process accounting for a larger region of operation than individual communication between sensors and actuators on the lower level tier.

The distributed control processing allows for more convenient room level integration. Where a problem is detected, such as a fire, corrective action begins within the immediate region of the sensor generating an alarm signal. The corrective action occurs without routing the alarm signal to upper levels of control processes or across different systems. The alarm signal is also propagated outward through the network to upper level control systems for generating appropriate responses in other zones.

To provide the different zones and avoid interference, the transmit power of the sensors and actuators is controlled as a function of two or more other devices. For example, a signal strength is set to provide reception of the signals at more than one device for communication redundancy, but to limit reception by more distant devices to avoid interference with communications for that distant device.

In a first aspect, a control system is provided for wireless building automation control. A first wireless network in a building has a first wireless communications protocol. A second wireless network in the building has a second wireless communications protocol different than the first wireless communications protocol. The first wireless network is operable in control, free of communications with the second wireless network, building components in response to sensors. The first network is also operable to control the building components in response to data from the second wireless network.

In a second aspect, a method is provided for wireless building automation control. Building actuator outputs are wirelessly controlled in response to sensor inputs without an intervening controller. The wireless communications for control of outputs are performed pursuant to a first communications protocol. The building actuator outputs may also be wirelessly controlled with an intervening controller in response to sensor inputs. The building actuator outputs operate free of the intervening controller in one time period and operate in response in the intervening controller in a different time period.

In a third aspect, a control system is provided for wireless building automation control. A sensor arrangement includes a sensor, a sensor processor and a radio frequency transmitter. An actuator arrangement includes an actuator, an actuator processor and a radio frequency receiver. The sensor arrangement is spaced from the actuator arrangement such that the radio frequency receiver is operable to receive information from the radio frequency transmitter. A control algorithm is distributed on both the sensor processor and the actuator processor. The portion of the control algorithm on the sensor processor is specific to the sensor and the portion of the control algorithm on the actuator processor is specific to the actuator. The sensor processor is free of control algorithms for other devices. The control algorithm is operable to control, free of input from an external controller, a parameter as a function of the sensor and the actuator.

In a fourth aspect, a method is provided for wireless building automation control. A sensor control process is performed on a sensor. The sensor control process is specific to the sensor without control processes for other sensors or other actuators. An output is wirelessly transmitted from the sensor responsive to the sensor control process. The output is received at an actuator. The actuator performs a control process as a function of the output. The actuator control process is specific to the actuator without control processes for other sensors or other actuators. The sensor and actuator control processes are operable without control from any external controller.

In a fifth aspect, a system is provided for wireless building automation control. A first building control system device has a transmitter. Second and third building control systems devices have receivers. A control processor is operable to set a transmit power of the transmitter as a function of information from both the second and third receivers.

In a sixth aspect, a method is provided for wireless building automation control. A radio frequency signal is transmitted from a building control system device. Additional building system control devices attempt receipt of the radio frequency signal. A transmit power of the transmitter is set as a function of information from the other devices.

In a seventh aspect, a method is provided for wireless building automation control. An alarm signal is wirelessly transmitted from a sensor within a room of the building. The alarm signal is directly received from the sensor at an actuator associated with the room. The actuator operates in response to the alarm signal. The alarm signal is wirelessly propagated outside the room and within the building. The alarm signal is responded to differently in another room.

In an eighth aspect, a device is provided for wireless building automation control. A first transceiver connects with a processor. The first transceiver is operable for wireless communication with building control sensors, building control actuators or combinations thereof. A second transceiver connects with the processor. The second transceiver is operable for wireless communication different than the wireless communication of the first transceiver.

The present invention is defined by the following claims, and nothing in this section should be taken as a limitation on those claims. Further aspects and advantages of the invention

are discussed below in conjunction with the preferred embodiments and may later be claimed independently or in combination.

BRIEF DESCRIPTION OF THE DRAWINGS

The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. **1** is a block diagram of one embodiment of a multi-tier wireless building automation control system architecture;

FIG. **2** is a block diagram of one embodiment of a sensor arrangement;

FIG. **3** is a block diagram of one embodiment of an actuator arrangement;

FIG. **4** is a block diagram of one embodiment of a controller;

FIG. **5** is a top plan view of one embodiment of distribution of components of the wireless network of FIG. **1**;

FIG. **6** is a flow chart diagram of one embodiment of a method for control in a wireless building automation system; and

FIG. **7** is a flow chart diagram of one embodiment of a method for setting a transmit power in a wireless architecture.

DETAILED DESCRIPTION OF THE DRAWINGS AND PRESENTLY PREFERRED EMBODIMENTS

Wireless building automation control is provided for safety, environmental, security, hazard, combinations thereof or other building systems. The control processes for automation are distributed. For example, control processes are distributed between two tiers or levels of the architecture. Associations between the controllers, sensors and actuators may be modified and updated with changing needs of the system. A further distributed control is provided by allowing for direct or peer-to-peer communication between devices on a lowest level, such as sensors and actuators.

Using a two-tier architecture, one level provides for high speed, or high bandwidth communications of aggregate collections of sensors or actuator data, video or other high bandwidth data or long range communications. A lower level associated with point-to-point communications may have a lower bandwidth for communicating between specific sensors and actuators. Control processes are distributed to the controllers, sensors and actuators as appropriate for the particular operations of each device, such as using an object oriented control distribution. The sensor reports information appropriate or specific to the sensor, such as reporting the result of a comparison of a measured value to a desired or set point value. Actuators use the output sensor data to provide a response appropriate for the actuator. Controllers monitor the process or action of sensors and actuators without control in one mode of operation. In another mode of operation, the controllers override the sensor and/or actuators to alter processing based on a regional or larger area control process.

FIG. **1** shows one embodiment of a control system **10** for wireless building automation control. The control system **10** includes two different wireless networks **12**, **14** for use in a building. One of the wireless networks **12** is a high level control network, and the other wireless network **14** is a lower level operations network. Interfaces, routers and bridges are provided for implementing wireless network **12**, **14**. While shown as a common bus or interconnection structure, each of the networks **12**, **14** may be associated with a plurality of different links between components with some or no redundancy in any of various patterns. Additional, different or fewer wireless networks may be provided. For example, one network is wired and another network is wireless, one or both wireless networks include wired components, or the networks may be distributed amongst only one, three or more levels.

Each network operates pursuant to different wireless communications protocols. For example, the lower level network **14** operates pursuant to the 802.15.4 communications protocols, but Bluetooth, proprietary, standard, now known or later developed wireless communication protocols may be used. The high level network **14** operates pursuant to the 802.11x protocol (e.g., 802.11a 802.11b, 802.11c . . . 802.11g), but wifi, computer network, Ethernet, proprietary, standard, now known or later developed protocols may be used. 802.15.4 and 802.11x provide medium access control and a physical interface to wireless medium. Any now known or later developed network and transport algorithms may be used. Communication, transport and routing algorithms are provided on the appropriate devices. Any packet size or data format may be used. The bandwidth for any given communications of the lower level network **14** is less than for the higher level network **12**. For example, the protocol of the lower level network **14** is adapted for small data packets transmitted over short distances as compared to the higher level network adapted for larger data packets at higher rates and for longer distances. In alternative embodiments, the same communications protocol is used for both the higher level and lower level networks **12**, **14**.

Differences in transmit power, packet structure, bandwidth, baud rates, routing, interference avoidance, data format, distances of transmission and reception, or other network characteristics may distinguish the high level network protocol from a lower network protocol. For example, the high and low level wireless networks **12**, **14** operate pursuant to a same or different collision avoidance. Any of time division multiplexing, frequency division multiplexing spread spectrum, code division multiplexing, dynamic collision avoidance or other now known or later developed wireless interference schemes may be used. In one embodiment, the high level wireless network **12** uses CDMA interference avoidance. The low level wireless network **14** uses collision avoidance by transmitting when a channel is clear with or without frequency modulation. Routing is performed within either or both of the networks **12**, **14** using any protocol, such as a MESH routing, token, or a protocol provided by Dust Networks. For example, time division multiplexing is used to assign infrequent contact times between bound components and allow for sleeping or reduced function of components at other times for saving battery life.

Different frequencies, codes or other communications differences may be used for different groups of components, such as by floor, by type (e.g., HVAC versus security or temperature versus air flow) or by other zones. By dividing up portions of the network, the communications processing load on the network may be minimized. Communications between the different nodes on the network may then be performed by adjusting a transmit and/or receive function for communication with the node of interest. By providing differences in communications for different zones, different customers in the same building may be isolated using the same wireless network. Different types of systems may be isolated from each other as well. Alternatively, the systems or customers are integrated and operate together.

The low level wireless network **14** includes a plurality of building control system devices or processors **16**, **18**, **20**. For example, sensor arrangements **16** communicate with actuator arrangements **20** pursuant to a communications protocol for the low level wireless network **14**. Paired or larger groupings of actuator arrangements **20** and sensor arrangements **16** are operable together using point-to-point or peer communications without further control by other controllers. Other processors or building devices **18** operating on the lower level network **14** include personal computers, panels, monitors, or other devices. For example, the device **18** is an actuator for controlling a building wide component, such as a chiller, boiler, building intake vent, or building air flow out take vent. A paired or grouped sensor arrangement **16** and actuator arrangements **20** are dynamically, automatically or manually associated with each other. For example, a sensor arrangement **16** within a room is bound to a actuator arrangement **20** associated with the room, such as for temperature sensing within the room to control a damper and/or heating or cooling elements associated with air flowing into the room. The low level network **14** controls major or building wide equipment, individual spaces or local input and output points.

In one embodiment, sensor arrangements **16**, other devices **18** and/or the actuator arrangements **20** operate as full function devices of 802.15.4 allowing for dynamically assigned communications with different devices over a single or multiple communications path but without the ability to route routing communications from other devices. Reduced functionality devices of 802.15.14 are provided with the increased capability of direct communication with each other and the ability to address other devices for routing to the other device. For example, a temperature sensor arrangement **16** is provided with a plurality of network address locations to receive temperature information. The temperature sensor arrangement **16** communicates directly with an actuator arrangement **20** for implementing local control processes. Transmissions addressed to other devices, such as one or more of the controllers **22** are also transmitted. The receiving controller **22** then routes the signals to the desired or addressed controller **22**. The assigned addresses may be dynamically programmed by one or more controllers **22** or are established during installation or manufacturing. By avoiding routing functions, less memory, less processing, less power and cheaper cost sensor arrangement **16** may be provided.

FIG. **2** shows one embodiment of a sensor arrangement **16**. The sensor arrangement **16** includes a sensor **30**, a sensor processor **32** and a transmitter **34**. Additional, different or fewer components may be provided, such as providing a plurality of different or the same types of sensors. The components of the sensor arrangement **16** are connected together on a same circuit board, in a same housing, connected with a same power source or otherwise arranged for operation together. In one embodiment, the sensor **30** is spaced from the processor **32**, such as connecting through a length of wire.

The sensor **30** is a temperature sensor, humidity sensor, fire sensor, smoke sensor, occupancy sensor, air quality sensor, gas sensor, CO_2 or CO sensor or other now known or later developed sensors, such as an oxygen sensor for use in hospitals. Micro-electro-mechanical sensors or larger sensors for sensing any environmental condition may be used. In one embodiment, the sensor **30** includes a suit of sensors for sensing multiple environmental conditions.

The processor **32** is a general processor, digital signal processor, control processor, application specific integrated circuit, field programmable gate array, analog circuit, digital circuit, combinations thereof or other now known or later developed device for implementing a control process on a signal measured by the sensor **30**. The processor **32** has a processing power or capability and associated memory corresponding to the specific sensor **30** or corresponding to the needs of one of a plurality of different types of sensors **30** with a maximum desired processing power, such as an 8 or 16 bit processor. By minimizing the processor requirements and associated memory, the cost of the sensor arrangement **16** may be reduced. The processor **32** implements a control process algorithm specific to the sensor arrangement **16**. Other control processes are either not stored on the sensor arrangement **16** or are stored but unused due to a specific configuration.

The transmitter **34** is a radio frequency transmitter. In one embodiment, the transmitter **34** is part of a transceiver such that control information from other components may be received by the sensor arrangement **16** to alter the implemented control process or the transmission of data. The transmitter **34** is responsive to the processor **32** or other logic for increasing or decreasing transmitted power. Alternatively, a set transmit power is used. The transmitter **34** is responsive to the processor **32** or other logic for changing a frequency, data format, interference avoidance technique or other transmission or reception property either automatically or in response to control signals.

FIG. **3** shows one embodiment of an actuator arrangement **20**. The actuator arrangement **20** includes a receiver **36**, an actuator processor **38** and an actuator **40**. Additional, different or fewer components may be provided, such as additional actuators **40** within the actuator arrangement **20**. The components of the actuator arrangement **20** are positioned on the same circuit board, within a same housing, adjacent to each other, or spaced from each other. For example, the actuator **40** is a mechanical or electromechanical device attached in a separate housing to the processor **38** and the receiver **36**. As shown in FIG. **5**, the actuator arrangement **20** is spaced from sensor arrangement **16** such that the radio frequency receiver **36** of the actuator arrangement **20** is operable to receive information from the radio frequency transmitter **34** of the sensor arrangement **16**. The actuator arrangement **16** is placed within a room or associated with a room. For example, the actuator arrangement **20** is positioned above a ceiling of a room or in a hallway near the room for controlling a damper, heating element, cooling element, sprinkler, alarm or other device.

The receiver **36** is a radio frequency receiver. In one embodiment, the receiver **36** is a transceiver for transmitting acknowledgments or other data. The receiver **36** is operable to receive information at different frequencies, different formats, or other transmitting characteristics.

The actuator processor **38** is a general processor, digital signal processor, application specific integrated circuit, field programmable gate array, analog circuit, digital circuit, combinations thereof or other now known or later developed device for implementing a control process appropriate for the actuator **40**. The actuator processor **38** is of a similar processing power and memory capability as the sensor processor **32**, but it may be larger or smaller. The actuator processor **38** implements a control process specific to the actuator **40** in the actuator arrangement **20**. The actuator processor **38** is free of control processes for other devices, such as remotely spaced devices, sensors or other actuators. Communications protocols are also implemented by the actuator processor **38** or a separate processor, such as a protocol for measuring a received signal and transmitting a response. The algorithm may be responsive to other input signals, such as from a remotely spaced controller. Other control processors, such as for different actuator structures, may be stored in a memory but unused after configuration of the processor **38** for operation with a specific actuator **40**.

The actuator **40** is a valve, relay, solenoid, speaker, bell, switch, motor, motor starter, damper, pneumatic device, combinations thereof or other now known or later developed actuating devices for building automation. For example, the actuator **40** is a valve for controlling a flow of fluid or gas in a pipe. As another example, the actuator **40** is a relay or other electrical control for opening and closing doors, actuating lights, or starting/stopping motors. As yet another example, the actuator **40** is a solenoid to open or close a door or damper, such as for altering air flow.

The lower level wireless network **14** implements local area control processes in a programmable powerful processing control language (PPCL) or other language. For example, control processes for each specific room or other region within a floor or building are implemented by the lower level wireless network **14**. Building components in an area may be automatically controlled without communication from the high level wireless network **12**. Since the controls are room and/or function specific, the communications of the lower level wireless network **14** are specific to the particular functions. The communications may exclude aggregate communications corresponding to packets for a plurality of sensors, actuators or combinations thereof. Each communication corresponds to individual or groups of sensor arrangements **16**, actuator arrangements **20** or other devices **18**.

Building components are controlled in response to sensors and free of communications with the high level wireless network **12**. The control is implemented by distributing a control algorithm in an object oriented approach or specific to the device using the control algorithm. Rudimentary control algorithms are partitioned into device specific pieces for implementation by the specific devices **16**, **18**, **20**. For example, a control algorithm is distributed on both a sensor processor **32** and an actuator processor **38** for performing a single or multiple functions. The portion of the control algorithm corresponding to a specific device **16**, **18**, **20** is then operated or implemented at the specific device without the need of further control. For example, a temperature within a room is controlled using a temperature sensor arrangement **16** and one or more corresponding actuator arrangements **20**. One actuator arrangement **20** may be used for controlling air flow or a damper, and a different actuator arrangement **20** used for controlling a heating or cooling element. The control algorithm for the temperature function with in the room is distributed on the different sensor arrangement **16** and actuator arrangements **20**. The portion of the control algorithm on the sensor processor **32** is specific to the sensor **30**. For example, a measured or sensed value is compared with a manually provided, programmed in or network provided set point. The sensor arrangement **18** outputs a result of the comparison, such as information indicating that the temperature is too high or too low and by how many degrees. Different types of temperature sensors may output the same information for use by any of various different types of actuators. The sensor arrangement **16** in this corresponding control algorithm outputs information specific to the sensing function without information indicating an act to be performed. Alternatively, information corresponding to an act to be performed may be output, such as an indication of a damper function relative to a heating or cooling element function.

The portion of the control algorithm implemented by the actuator processor **36** receives the temperature information output by the temperature sensor arrangement **16**. The control algorithm is specific to the actuator, such as determining an adjustment as a function of the needed or desired temperature change. Different actuators **40** may be associated with different types or amounts of adjustments to provide a given temperature change. The portion of the control algorithm specific to the actuator **40** allows determination of the appropriate adjustment without having to program other elements of the network **10** with specific characteristics of a given actuator **40**.

Where more than two actuators are associated with a same room and same function, such as temperature adjustment, the corresponding actuator arrangements **20** may operate independently of each other. Alternatively, the actuators arrangements **40** have control processes that receive inputs from other actuator arrangements for automatically determining network or distributed adjustments for achieving the desired temperature change.

Other control functions may similarly be implemented by distributed control processes with device specific processing. Any input or sensing function within a feedback loop is performed by a sensor arrangement **16**, such as determining a difference from a desired set point. If a sufficient magnitude of difference exists, the difference of value is transmitted. Alternatively, a command is transmitted for specific operation by a specific type of device. An actuating device **20** receives the difference value and implements a control process to bring the function within the desired operating condition. Other functions controlled with distributed control processing include fire detection, such as a smoke detector or temperature sensor for actuating an alarm or actuating control of air flow. Temperature, gas or air flow sensors may be used to actuate air flow, door position, window shade position or other motors or actuators. An occupancy sensor may be used to trigger lighting or other temperature controls. Any other now known or later developed combination of sensing by one or more senses and performing actions by one or more actuators may be used.

The low level wireless network **14** includes a plurality of actuator arrangements **20** and sensor arrangements **16**. Each of the devices **16**, **18** and **20** are operable to process control information specific only to the device. The sensor arrangements **16** and actuator arrangements **20** are free of control algorithms for other devices. Within a room or other area, one or multiple functions are implemented by the distributed control processes, such as security, hazard, HVAC or other automated systems. Information from a given sensor arrangement **16** may be used by different systems, such as a temperature sensor arrangement **16** being used for both HVAC as well as hazard or fire systems. The temperature sensor arrangement **16** is operable to output a same type of data for each of the different systems or different types of data. The same actuator arrangement **20** may be operable in response to different sensor arrangements **16** or different systems, such as a door release or damper actuator being responsive to an HVAC temperature sensor as well as a fire system smoke detector.

To implement a control function or process, the distributed control processes are bound together. Sensor arrangements **16** are bound to actuator arrangements **20**. For example, a particular sensor arrangement **16** is bound to a particular actuator arrangement **20** within a room. Other sensor arrangements **16** and actuators **20** in other rooms, or the same room may likewise be bound together. Pairs, triplets or other groupings of various devices **16**, **18**, **20** are bound together. In one embodiment, the binding is implemented by network address. For example, a sensor arrangement **16** transmits information addressed to a specific actuator arrangement **20**. Alternatively, particular frequency or spread spectrum coding is used. An actuator device **20** identifies a transmission as being from a specific sensor arrangement **16**. In alternative embodiments, bound devices **16**, **18**, **20** are operated through time division multiplexing, such as a specific sensor arrangement **16** transmitting at a same time as a specific actuator arrangement **20** is operable to receive transmitted information. The binding is programmed by network communications, such as a controller **22** implementing the binding. The bindings are generated in response to user input after installation of a system. Alternatively, each of the specific devices **16**, **18**, **20** on the lower level network **14** are individually programmed, created, manufactured or otherwise set with a desired binding. In alternative embodiments, the devices **16**, **18**, **20** on the lower level network **14** are self-binding, such as identifying a closest device of a particular type for binding. The binding connections may then be adjusted or altered as needed.

Multiple bindings may be provided for any given device **16**, **18**, **20** of the lower level network **14**. For example, a binding is assigned with a primary status with a backup binding assigned. Using acknowledgments of transmissions, a device **16**, **18**, **20** may recognize when there is a failure of communications, switching to the backup binding. Once sensor arrangement **16** may be bound to two actuator arrangements **20**, one operating as a primary actuator and the other as a back up actuator. Similarly, an actuator arrangement **20** may be bound to multiple sensor arrangements **16** in a primary and backup configuration. As yet another example, multiple bindings are provided for implementing a given function. The bindings may be arranged in a serial communications process, such as from one sensor arrangement **16** to a first actuator arrangement **20** and then to a second actuator arrangement **20**. Alternatively, a parallel or combination of parallel and series binding connections are provided.

The components of the lower level network **14** are operable to control the various functions free of input from separate controllers, such as the controllers **22** of the high level network **12**. In another mode of operation, the control processes are implemented with input from the controllers **22**. For example, the controllers **22** implement region wide or other modification of local processes. As another example, the devices **16**, **18**, **20** of the lower level network **14** implement local control only after communications failure with the higher level network **12**. Alternatively, control by the higher level network **12** is provided only as needed or to override any local control. In one mode, a parameter is controlled as a function of sensors and actuators without control of the function by an external controller **22**, but in another mode, communications from an external controller **22** are used to control the function and associated devices **16**, **18**, **20**.

The high level wireless network **12** includes controllers **22**, management processor or computer **26**, and/or other devices **24**. Additional, different or fewer devices **22**, **24**, **26** may be used. The devices **22**, **24** and **26** are distributed throughout a building for interacting with the lower level wireless network **14**, each other and users of the system **10**. For example, FIG. **5** shows various controllers **22** spaced throughout a floor of a building for transmitting to and receiving from devices **16**, **18**, **20** of the low level wireless network **14**. The devices **22**, **24** and **26** of the high level wireless network **12** include processors for implementing various control functions with or without input or outputs points of building control.

FIG. **4** shows one embodiment of the controllers **22**. The controllers **22** include one or more processors **42** and two transceivers **44**, **46**. Additional, different or fewer devices may be provided, such as providing a single transceiver operable to transmit and receive pursuant to one or two different communications protocols.

One transceiver **44** is operable for connecting with the lower level network **14**. The transceiver **44** is operable to send and/or receive information to and/or from any of the sensor arrangements **18**, actuator arrangements **20**, or other devices

18. Information from various ones of the devices **16**, **18** and **20** may be received at the same or different times by the transceiver **44** for aggregate processing and routing by the processor **42**. The transceiver **44** is also operable to transmit information to multiple or specific ones of the devices **16**, **18**, **20**. For example, binding associations, control instructions, communications settings or other information is transmitted.

Similarly, the transceiver **46** is operable to transmit and receive information to and from other controllers **22**, or other devices **24** and **26** of the high level wireless network **12**. The transceiver **46** is operable to transmit large data packets corresponding to routing of aggregate information. Similar data packets may be received for routing or use by the controller **22**.

The processor **42** is an application specific integrated circuit, general processor, digital signal processor, control processor, field programmable gate array, analog circuit, digital circuit, combinations thereof or other now known or later developed device for monitoring, controlling and/or routing. In one embodiment, the processor **42** is a full function device pursuant to the 802.15.4 standard implanting a programmable power process language application. The processor **42** has a greater processing power and storage capacity than processors of the devices **16**, **18** and **20** of the lower level network. For example, the processor **42** is a 16, 32 or 64 bit processor. In alternative embodiments, the processor **42** is of a same or smaller size than one or more of the devices **16**, **18**, **20** of the lower level wireless network **14**. While individual packets of data from the lower level wireless network **14** may be routed or processed by the processor **42**, the processor **42** is also operable to route or perform aggregate processing on multiple packets or a packet from multiple data sources.

The processor **42** routes data from the devices **16**, **18**, **20** of the lower level network **14** to devices **22**, **24** or **26** of the higher level network. For example, raw data is routed for use by monitoring, reporting or region-specific control by other controllers **22**. As shown in FIG. **5**, the controllers **22** and other components of the high level wireless network **12** may have a greater spacing than components of the low level network **14**. More than one controller **22** may be positioned to receive data from a same device **16**, **18**, **20** of the lower level wireless network **14**. The devices **22**, **24** and/or **26** are located in mechanical rooms or building infrastructure outside of occupied spaces, but may be located elsewhere in the building. The communications capability of the high level wireless network **12** is configured or provided for longer distance transmissions than on the lower level wireless network **14**. In alternative embodiments, the controller **22** causes data to be routed over the lower level wireless network **14**.

The management computer **26** coordinates activities of the various controllers **22**. The management computer **26** is a personal computer, application-specific processor, workstation, panel or other device for receiving user input or programming for control of the system **10**.

The other devices **24** may be inputs, such as from a utility, or outputs, such as printers or display monitors. In one embodiment, one or more of the other devices **24** is a high bandwidth sensor or actuator arrangement. For example, the other device **24** is a video camera or a video monitor. The increased bandwidth of the high level wireless network **22** is used to provide the high bandwidth video data. Both levels of the network **12**, **14** are then used for interacting between the sensor or actuator device in other sensors and actuator arrangements **16**, **20** of the lower level wireless network **14**. For example, a video camera is turned on or moved to image in response to actuation by an actuator arrangement **20** or sensing by a sensor arrangement **16**. For security use, the sensing of an opening or closing door may activate the other device **24** through communications through multiple levels of the network **10**. As another example, actuation of a door release or sensing of a fire may also cause activation of the video camera.

The controllers **22** are operable to override operation of the bound actuator arrangements **20** and sensor arrangements **16**. Individual controllers **22** or networks of the controllers **22** implement control processes for a plurality of local areas, such as a plurality of rooms. The control processes may be implemented for a wing of the building, a floor of the building, an entire building, other areas or combinations thereof. The areas are larger than the local areas addressed by specific bindings of devices **16**, **18**, **20** of the lower level wireless network **14**. Alternatively, the areas are the same size or smaller. By implementing control processes for a plurality of local areas, the controller **22** is operable to receive or transmit aggregate communications corresponding to a plurality of sensors, actuators or both. The aggregate communications are provided in a single data package structure as compiled by the same or another controller **22**. Alternatively, raw data is received from other controllers **22** acting as routers.

In overriding local control, the higher level wireless network **12** and controllers **22** are operable to instruct redirection of data, such as sensor data from the sensor arrangement **16** to the higher level wireless network **12**. Alternatively, transmissions from sensor arrangement **16** are monitored by the controllers **22** without redirection or changing bindings. As another alternative, the sensor and/or actuator arrangements **16**, **20** request control input from one or more controllers **22**. For example, an actuator arrangement **20** receives one or more transmissions from a sensor arrangement **16**. The actuator arrangement **20** forwards the transmitted information alone or in aggregate to a controller **22**. The controller **22** outputs control instructions for the actuator arrangement **20** or another device or uses the transmitted information without further control output. The actuator arrangement **20** either performs the actuator specific control process without input from the controller **22**, later receives control input from the controller **22** for later operation or waits until control input from the controller **22** is received.

The controllers **22** may output instructions or information for the actuator or sensor arrangements **20**, **16** to control the processes for building components. By dynamically assigning control processing among the various components of the high level wireless network **12** and the low level wireless network **14**, dynamic control processing is provided amongst any combinations of devices. The control processing is distributed across components **16**, **18**, **20** of the low level network **14** as well as between the devices **22**, **24**, **26** of the high level wireless network **12**.

By distributing control processing for a region with the controllers **22**, region wide control processes may be used to influence, override or alter the local control processing implemented as discussed above by the low level wireless network **14**. For example, one or more controllers **22**, other devices **24** or management computer **26** provide control processes for peak demand limiting. Peak demand limiting is used to control an overall power usage by a building, such as controlling power used by chillers, boilers, air handlers, lighting, or other building components. For example, in response to a required or requested limitation on power demands, a controller **22** or other device **24**, **26** may instruct one or more sensor arrangements **16** to adjust a set point for temperature maintenance. Alternatively or additionally, an actuator device **20** or one of the other devices **24** of the higher level network **12** are operated to control a system, such as by shutting down or limiting operation of one of multiple cooling or heating plants. Another example of regional control is for variable volume and pressure control. Overall operation of a fan is based on room pressures sensed in multiple rooms. An example of regional processing are reporting for a wing, floor, building or other region. Another example for overall or aggregate control processing is providing an overall control, such controlling different zones in response to security or hazard situations. Any use of data from multiple sensors and/or actuators, such as data from multiple rooms or other aggregates of data outside of or different than the bindings established for the lower level wireless network **14**, are performed by one or more controllers **22**. By causing control processes for sensor arrangements **16** or actuator arrangements **20** to alter or perform differently, the controllers **22** and the associated control processes of the high level wireless network **12** are used to operate, override or influence local control processes.

Processing redundancy is provided by having multiple controllers **22**. Where one controller **22** fails or communications with the controller **22** fails, the control processing implemented by the failed controller **22** may be transferred to a different controller **22**. Processing may alternatively be transferred for load balancing, resource balancing or scheduled maintenance. The new address associated with the transfer to a different controller **22** is communicated to the network components in need of the information, such as transferring the address to other controllers **22** for routing, or sensor or actuator arrangements **16**, **20** for addressing data intended for a specific location.

The control process implemented by the high level wireless network **12** may be hierarchal, such as having the management processor **26** or one or more of the controllers **22** implement control processes for controlling the various controllers **22**. Data and processing may be redirected to the appropriate controller **22** or management computer **26** for implementing an even higher level control process. For example, more complex or more integrated building processes are performed on higher performance units. As another example, results from different control processes are input to yet another control process. Similarly, the controllers **22** may instruct the sensor arrangement **16** or actuator arrangement **20** to provide outputs different than used for the functional control of a building automation. For example, the sensor arrangement **16** is instructed to output a sensed temperature rather than the need for and magnitude of a temperature change.

The controllers **22** are operable to assign bindings and/or reassign bindings. Dynamic binding between any of the sensor arrangements **16**, actuator arrangements **20** or other devices **18** with one or more controllers **22** is dynamically controlled. A binding is created as needed for implementing a particular control function or process. Other bindings may subsequently be created between different devices or with different controllers **22** as needed, such as for implementing different control functions. The regional or other integrated or aggregate control is provided in one embodiment by causing a sensor arrangement **16** to transmit to a controller **22**, and the controller **22** or a different controller **22** to then provide information to an actuator arrangement **20**. For example, a paired binding is disrupted to provide different combinations of devices to operate with each other. The controller **22** may include information from other sources, such as adjusting a room temperature as a function of the temperatures of adjacent rooms. The controller **22** implements processes for a region, to provide an average temperature within a wing, floor or other region. The controller **22** may override local functions or alter bindings. Similarly, a controller **22** may be assigned to specific devices **16**, **18**, **20** of the lower level wireless network **14**. A backup controller **22** may also be assigned for use during a communications failure. Alternatively or additionally, the devices **16**, **18**, **20** of the lower level wireless network **14** are provided with a default binding for local control without communications from any controllers **22**. Upon a communications failure with the controllers **22**, the local or default bindings are implemented to provide a rudimentary or fail-safe control.

FIG. **6** shows one embodiment of a method for wireless building automation control. The method is implemented using the system **10** described above for FIG. **1** or different systems. Additional, different or fewer acts may be provided, such as providing addition local processes **50**, additional region processing **62** or different transmit and receive schemes.

In act **50**, one or more local functions are implemented. Building outputs are wirelessly controlled in response to sensor inputs without an intervening controller. Controllers associated with the sensors and actuators perform the automation without a separate controller for managing or providing control instructions for the building automation or environment function. In the local process of act **50**, room level or other local area level processes are implemented. One or a plurality of different functions for controlling a building environment or providing other automated responses within a building are provided within the local process. The local process may be programmed or established in response to control instructions, but is operable subsequently without further control instructions from a separate or intervening controller. Different or the same local processes are provided for different areas, such as for different rooms. The same or different control algorithms may be used for each of the different local areas. Within a building, one, two or many more different local area processes may be performed.

In act **52**, a sensor control process is performed on a sensor. The sensor control process is specific to the sensor and avoids implementing control processes for other sensors or actuators. The control process processes sensed or measured information based on the type of sensor and outputs data appropriate for the type of sensor with units and information common to any of various specific sensors of a same type. For example, a mercury-based temperature sensor converts the sensed mercury position or level into an indication of a specific temperature or an indication of an amount of difference in temperature from a set point. A micro-electromechanical temperature sensor, such as a bi-metal beam with electrical conductivity sensing, converts a current, voltage or capacitance into a temperature value. Mercury and micro-electromechanical measurements may have different values, but the resulting compared or determined output is the same for each of the two different sensors due to the control process. The common units or output allows for the switching of different sensor structures to operate with the same actuators. During maintenance or replacement of sensors, replacement of the actuators is avoided since the actuators are operable with the common output.

In act **54**, the output from the sensor is wirelessly transmitted. The output from the sensor is responsive to the control process of the sensor as well as the transmit format, transmit power, binding or other communication characteristic. Using an interference control mechanism and desired transmit power, the output is provided to a desired component or plurality of components. For example, one or more actuators receives the output data. One or more controllers may also receive the transmission for monitoring the local process.

In act **56**, the output is received at an actuator for local control without an intervening controller. Based on address assignment or other information indicating a binding, the actuator receives the data from a particular sensor and may discard signals from other sensors. The wireless communications performed in acts **54** and **56** are performed pursuant to a communications protocol. In one embodiment, wireless communications are performed directly between actuator outputs and sensor inputs. The communication is free of routing by a controller or other structure. In alternative embodiments, one or more sensors, actuators, controllers or other structure routes data without or with alteration between a sensor and actuator. The communications provide a desired bandwidth, such as a bandwidth minimized to save power but maximized to provide the needed standardized communication. The communications allow for wirelessly paired or otherwise grouped building actuators and sensors to be operable without further control.

In act **58**, the actuator control process is performed on the actuator as a function of the output from the sensor. The standardized sensor output is converted to information for the specific structure of the actuator being used. For a given type of actuator, more than one structure may be available. The control process alters the standardized output into a setting or adjustment signal specific to the actuator. The control process of the actuator is specific to the actuator without including control processes for other sensors or other actuators. The actuator control process is performed for only controlling the given actuator. In alternative embodiments, control processes for other sensors or actuators are included on the actuator. In addition to the actuator control process, communications processes are implemented on the actuator for receiving information and/or communicating status information. For example, every time the actuator makes an adjustment, an indication of the adjustment is output for monitoring by a controller or for use by other actuators or sensors. The output is in a standard or common format for the type of actuator. Alternatively or additionally, information specific to the actuator structure used is output.

The control processes for the sensor and actuator implemented in acts **52** and **58** are performed without control in real time from an external controller. An external controller may have previously programmed a set point or other function of either the sensor or actuator, but the sensor and actuator are operable to function free of further control. A default may be provided for performing building automation function free of any or initial control.

In one mode, the local process **50** is operated free of control from another controller or another wireless network. Acts **60**, **62** and **64** represent processes in a different mode where the sensor and actuator operate as a function of control from a controller or other wireless network. The controller or other wireless network is used to implement new control, regional control, override control, or other alterations in control.

In act **60**, information from one or more local processes or signal processors are received. For example, a transmission of a sensor intended for a specific actuator is monitored at a different location. Act **60** also represents receiving information pursuant to a different communications protocol, such as receiving information from a management computer or other controllers. Aggregate data corresponding to a plurality of sensors, actuators or combinations thereof is communicated pursuant to the different communications protocol. A larger bandwidth is used for providing the aggregate information. The information is aggregated within a single packet structure or format or is provided as separate packets from a plurality of information sources. Different controllers may implement different control functions and communicate pursuant to the second communications protocol.

In act **64**, information is transmitted to a local process. Information responsive to an intervening controller with zero, one or more other communications pursuant to a different protocol is used to generate control instructions. The control instructions are then provided to the actuator process **58**, to the sensor process **52** or other process of the local processing in act **50**. The output of the building actuators then respond to the wireless communication from the sensors in act **52** and/or information from the communications on a different network or pursuant to a different communications protocol.

In act **62**, a regional or other process is implemented. The process allows wireless control of building actuator outputs with an intervening controller in response to sensor inputs. For example, a regional control process for a plurality of local areas is performed. Where needed, a room control or other local control process is overridden with the control process for a wing of the building, a floor of the building, the building, a plurality of local areas or combinations thereof. By overriding the operation of paired or other grouped building actuators and sensors, the controller intervenes in the local process. In other modes of operation, the controller merely monitors or originally establishes the local process without any intervening control in a building automation function.

In addition to controlling building automation functions, a regional process or other controller may alter the bindings or other communication properties. For example, data from sensor inputs are redirected to an intervening controller by establishing a binding between the controller and the sensor. The binding between the sensor and the actuator is also redirected so that the actuator receives data from the intervening controller or another controller and not the sensor. For example, redirection is performed in response to a communication failure. As another example, redirection is provided for dynamically implementing different control processes at different times. The control processing is dynamically assigned among a plurality of different components, such as components including an intervening controller or components without an intervening controller. As different regional control processes operate to affect a given function, different intervening controllers or dynamic assignments may be performed. Where a communications failure with one or more intervening controllers occurs, a different intervening controller may be bound to a given actuator or sensor. Alternatively, the actuator and sensor default to operation together without an intervening controller. Other controllers monitoring network traffic or bindings may note a communications failure. The communications failure is provided to a monitoring or reporting algorithm. The components associated with a failure may be identified and replaced with minimum efforts.

FIG. **5** shows one example of a distribution of components for building automation within a building, floor or region. Different schemes may be used to avoid interference for communications from any of the various components. In one embodiment, transmit power for the sensor arrangements **16**, actuator arrangements **20** or other devices **18** of the lower level wireless network **14** shown in FIG. **1** is minimized to avoid interference.

The transmit power is set as a function of other building system control devices, such as two or more other building system control devices. The transmit power of one of the components is responsive to communications from the controllers **22** or other devices **24** of the high level wireless network **12**. For example, a sensor arrangement **16** has a variable transmit power that is controlled in response to communications from one or more controllers **22**. Alternatively or additionally, the transmit power of one of the components or devices **16**, **18**, **20** is set in response to information from other devices **16**, **18**, **20** on the same lower level wireless network. Devices **16**, **18**, **20** from a lower level wireless network **14** or devices **22**, **24** or **26** from the higher level wireless network **12** may be used. For example, one or more of the receiver devices is an actuator arrangement **20**. The signals or lack of signals at the two or more receivers is communicated to a control process.

The control process is located at one of the receivers, such as at a controller or at an actuator. Alternatively, the control process is located at the device transmitting to establish a transmit power. In yet another embodiment, the control process is a separate controller or device than either of the transmitter or receivers. A distributed control process may be used as well. The control process determines the transmit power of the transmitter as a function of information from two or more receivers. The control processor is operable to set a transmit power to avoid interference. For example, the transmit power is set to provide consistent or reliable reception at one device while minimizing the signal provided to another device, such as device spaced further away or on another side of a wall. By avoiding reception at the other device, less interference with signals meant for the other device may occur.

The control process may limit the transmit power for reception by a closest controller and minimize reception by other controllers. For redundant communications, the transmit power may be increased or reduced for reception by multiple devices. For example, an actuator and back up actuator are both operable to receive transmitted signals. As another example, a controller and a back up controller are operable to receive transmitted signals while minimizing the reception of signals at yet another or further spaced away controller or actuators.

FIG. **7** shows one method for determining a transmit power. The acts of FIG. **7** are implemented using the system and components of FIG. **1** or a different system or components. Additional, different or fewer acts may be provided, such as attempting to receive at third, fourth or other numbers of receivers. The transmit power of at least one sensor input, sensor arrangement or other component is set as a function of signals received or attempted to be received at a plurality of other devices.

In act **70**, a radio frequency signal is transmitted from a building control system device. The signal is transmitted with a default transmit power, such as a maximum or minimum transmit power. A sensor arrangement, actuator arrangement, controller, combinations thereof or other device transmits the radio frequency signal.

In acts **72** and **74**, the receipt of the frequency signal is attempted at two or more different building control system devices, such as associated with two different locations. For example, a sensor arrangement, actuator arrangement, controller, combinations thereof or other devices are used for receiving or attempting receipt of the radio frequency signal. The receive signal is measured, such as measuring an amplitude or signal-to-noise ratio of the receive signal strength. The measured information is then communicated to a control process for setting the transmit power.

In act **76**, the transmit power of the transmitter is determined as a function of the information from the other building control system devices. Using a one calculation or an iterative approach, the transmit power is set in response to a single transmission or a plurality of transmissions, respectively. The measured signal strength is used to increase or decrease the transmit power to avoid interference and/or increase communications redundancy. By limiting the transmit power, transmissions with reliable communications may be received at one device but not received or received with lesser signal strength at another device, avoiding or limiting interference at the other device. The desired reception may be for any of likely bound devices, such as a controller and back up controller, an actuator and a back up actuator, and a sensor and back up sensor. By setting the transmit power to provide reliable signal strength at any of various or likely bound components, redundant communications may be provided. By limiting the signal strength, other nodes or bound groupings may operate using a same signal format, frequency or time slot. Parallel communications outside of a transmitter's sphere of influence may allow for higher network throughput. Any level of reliability for reception may be used, such as 90 percent, 95 percent or 100 percent. Less reliable settings may be used, such as where an acknowledgment signal may be provided for requesting retransmission until accurate information is received.

The controllers **22** or other devices of an upper level wireless network **12** are also configured for limited transmission range. Alternatively, the devices are configured for maximum transmission range. The same transmit power process or different transmit power processes may be used. In one embodiment, the transmit power of each controller is set to provide for reliable reception of transmitted information at least two other controllers **22** on a same floor or on different floors.

Distributed control processing on the local level as well as between the local and regional areas may allow for more immediate response to problems and/or provide for different responses in different locations. Controllers or other devices of the upper level wireless network **12** instruct control of building components in different areas in different ways. In response to control of building components in a local area, such as by a sensor arrangement **16** and actuator arrangement **20** without interference by other controllers, the controller **22** may cause an actuator **20** in a different area to perform a function. For example, the adjustment of a damper or air flow in one room without interference from a controller may be monitored and used to control the air flow in an adjacent room to counteract pressure differential or to derive more consistent temperature adjustments. The monitoring controller or other controller interferes in the local control process of the other room to provide the adjustment.

A problem may be identified locally and dealt with locally. For example, a sensor senses a fire or smoke. This alarm triggers an immediate threat signal. Actuators corresponding to a valve for releasing water, a door release for closing a fire door, a damper for altering air flow or other actuators may respond without interference from a controller to the sensed fire. The output devices or actuators within the room are operated without authorization from a controller located outside of the room. The alarm signal may be monitored by a controller and propagated to other controllers or other actuators. For example, a controller receives the alarm signal and causes an alarm to sound in a different area in the same or different way. A less threatening alarm is sounded in a remote area to indicate that a concern may exist in the building but that the concern is not of immediate threat to the area. The propagated signal may alternatively or additionally be used for adjusting other actuators, such as fire door and air flow in adjacent or remote areas as a function of the spatial relationship to the area associated with the generated alarm or problem. As an alternative to a fire problem, a security problem may be identified. The immediate response within a local area may be the locking of doors, triggering of a security camera, moving of a security camera or activation of an audio system. The propagated signal from the local area is used to trigger actuators in other locations, such as switching a security guard monitor to view information from a location where the alarm signal was generated.

Transmitted fire, security or other signals from a sensor within a room of a building is received directly from the sensor at an actuator associated with the room. The alarm signal is received free of routing through a controller remote to the sensor and the actuator for more immediate response. Alternatively, routing within the room or even externally to the room may occur.

While the invention has been described above by reference to various embodiments, it should be understood that many changes and modifications can be made without departing from the scope of the invention. It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.

I claim:

1. A control system for wireless building automation control, the control system comprising:

a first wireless network in a building having first wireless communications protocol; and

a second wireless network in the building having a second wireless communications protocol, the first wireless communications protocol different than the second wireless communications protocol;

wherein the first wireless network is operable to control, free of communications with the second wireless network, building components in response to sensors operable within the first wireless network, and wherein the first wireless network is also operable to control the building components in response to data from the second wireless network.

2. The control system of claim **1** wherein the first wireless communications protocol has a first bandwidth and the second wireless communications protocol has a second bandwidth, the first bandwidth less than the second bandwidth.

3. The control system of claim **1** wherein the first wireless network comprises a first plurality of first processors and the second wireless network comprises a second plurality of second processors, the second processors having a greater processing power and storage capacity than the first processors.

4. The control system of claim **1** wherein the first wireless network implements local area control processes and wherein the second wireless network implements control processes for a plurality of local areas.

5. The control system of claim **4** wherein the first wireless network implements control processes for rooms and wherein the second wireless network implements control processes for one of a wing of the building, a floor of the building, the building and combinations thereof, the second wireless network including aggregate communications corresponding to a plurality of sensors, actuators or combinations thereof, and the first wireless network excluding aggregate communications corresponding to the plurality of sensors, actuators and combinations thereof, the communications of the first wireless network corresponding to individual sensors or actuators.

6. The control system of claim **1** wherein at least one processor of the second wireless network wirelessly communicates with the first wireless network, processors of the first wireless network only capable of communication pursuant to the first communications protocol.

7. The control system of claim **1** wherein the first wireless network comprises wirelessly paired building actuators and sensors operable without further control and the second wireless network comprises controllers operable to override the operation of the paired building actuators and sensors.

8. The control system of claim **1** wherein the first wireless network comprises a plurality of actuators and sensors, each of the sensors operable to process control information specific only to the sensor, each of the actuators operable to process control information specific only to the actuator, each of the actuators responsive to a wireless output of at least on of the sensors.

9. The control system of claim **8** wherein each of the sensors is operable to wirelessly output data representing a comparison of a respective set value to a sensed value, the output data being independent of a type of actuator, and wherein each of the actuators is operable to determine a setting as a function of the output data of at least one of the sensors and the type of actuator.

10. The control system of claim **1** wherein the second wireless network is operable to instruct a redirection of first wireless network sensor data to the second wireless network, the building components responsive to communications from the second wireless network.

11. The control system of claim **10** wherein the first network controls the building components in response to the sensors in response to a communications failure with the second wireless network.

12. The control system of claim **1** wherein the second wireless network is operable to dynamically assign control processing among a plurality of components and to instruct components of the first wireless network to be responsive to the dynamically assigned control processing.

13. The control system of claim **1** wherein a transmit power of a component of the first wireless network is responsive to communications from the second wireless network.

14. The control system of claim **1** wherein the first wireless network is operable to control building components in a first area without communications from the second wireless network, wherein the second wireless network is operable to instruct control of building components in a second area different than the first area in response to control of the building components in the first area by the first network, and wherein the first network is operable to control the building components in the second area as a function of the instructed control from the second wireless network.

15. The control system of claim **1** wherein the second wireless network is responsive to sensor data forwarded from the first wireless network by an actuator arrangement.

16. A method for wireless building automation control, the method comprising:

(a) wirelessly controlling building actuator outputs in response to sensor inputs without an intervening controller;

(b) performing the wireless communications of (a) pursuant to a first communications protocol; and

(c) wirelessly controlling the building actuator outputs in response to sensor inputs, the building actuator outputs operating free of any intervening controller in a first time period and being in response to an intervening controller in a second, different time period;

(d) communicating with the intervening controller with a second communications protocol different than the first communications protocol; wherein the control of the building actuator outputs of (c) is responsive to wireless communication from the sensors pursuant to the first communications protocol and information of the communications of (d).

17. The method of claim **16** wherein (b) comprises performing the wireless communications directly between actuator outputs and sensor inputs with a first bandwidth and (d) comprises communicating with a second bandwidth, the first bandwidth less than the second bandwidth.

18. The method of claim **16** wherein (a) comprises implementing local area control processes and wherein (c) comprises implementing control processes for a plurality of local areas.

19. The method of claim **18** wherein the local area control processes comprise room control processes;

wherein (c) comprises overriding the room control processes with control processes for one of a wing of the building, a floor of the building, the building and combinations thereof.

20. The method of claim **16** wherein (b) comprises communicating for individual sensors or actuators and wherein (d) comprises communicating data being an aggregate corresponding to a plurality of sensors, actuators or combinations thereof.

21. The method of claim **16** wherein (a) and (b) are performed for wirelessly paired building actuators and sensors operable without further control and wherein (c) comprises overriding the operation of the paired building actuators and sensors.

22. The method of claim **16** wherein (a) comprises:

(a1) processing control information specific only to a sensor on the sensor;

(a2) transmitting an output of the sensor to an actuator; and

(a3) processing control information specific only to the actuator on the actuator.

23. The method of claim **16** further comprising:

(d) redirecting data from the sensor inputs to the intervening controller.

24. The method of claim **23** wherein (d) comprises redirecting the data in response to a communications failure.

25. The method of claim **16** further comprising:

(d) dynamically assign control processing among a plurality of components, one of the components being the intervening controller; and

(e) instructing the building actuator outputs to be responsive to the dynamically assigned control processing.

26. The method of claim **16** further comprising:

(d) setting a transmit power of at least one of the sensor inputs as a function of a signal received at a plurality of other devices.

27. The method of claim **16** wherein (a) comprises controlling the building actuator outputs in a first area without communications from the intervening controller;

further comprising:

(d) controlling building actuator outputs in a second area different than the first area in response to control of the building actuator components in the first area, the control in the second area being performed with the intervening controller.

28. The method of claim **16** wherein (c) comprises controlling the building actuator outputs in response to the sensor inputs forwarded by an acuator arrangement.

29. A control system for wireless building automation control, the control system comprising:

a sensor arrangement having a sensor, a sensor processor and a radio frequency transmitter;

an actuator arrangement having an actuator, an actuator processor and a radio frequency receiver, the sensor arrangement spaced from the actuator arrangement such that the radio frequency receiver is operable to receive information from the radio frequency transmitter; and

a control algorithm distributed on both the sensor processor and the actuator processor;

a first wireless network comprising the sensor and actuator arrangements, the first wireless network operable pursuant to a first wireless communications protocol; and

a second wireless network operable pursuant to a second wireless communications protocol different than the first wireless communications protocol;

wherein the portion of the control algorithm on the sensor processor is specific to the sensor and the portion of the control algorithm on the actuator processor is specific to the actuator, the sensor processor being free of control algorithms for other devices;

wherein the control algorithm is operable to control, free of input from an external controller, a parameter as a function of the sensor and the actuator; and

wherein the control algorithm is operable in a first mode free of control from the second wireless network and in a second mode as a function of control from the second wireless network.

30. The control system of claim **29** wherein the sensor processor, with the portion of the control algorithm on the sensor processor, is operable to generate a request as a function of a comparison of a first set point with a signal input by the sensor, and wherein the actuator processor, with the portion of the control algorithm on the actuator processor, is operable to determine an adjustment as a function of the request.

31. A method for wireless building automation control, the method comprising:

(a) performing a sensor control process on a sensor, the sensor control process specific to the sensor without control processes for other sensors and other actuators;

(b) wirelessly transmitting an output from the sensor responsive to the sensor control process;

(c) receiving the output at an actuator;

(d) performing an actuator control process on the actuator as a function of the output, the actuator control process specific to the actuator without control processes for other sensors and other actuators;

(e) performing (b) and (c) pursuant to a first wireless communications protocol of the first wireless network;

(f) receiving the output at a second wireless network operable pursuant to a second wireless communications protocol different than the first wireless communications protocol;

(g) operating the sensor and actuator in a first mode free of control from the second wireless network and in a second mode as a function of control from the second wireless network;

wherein the sensor and actuator control processes are operable without control from any external controller.

32. The method of claim **31** wherein (a) comprises generating the output as a function of a comparison of a first set point with a measured signal, and wherein (d) comprises determining an adjustment specific to the actuator as a function of the output.

33. The method of claim **31** further comprising:

(e) transmitting by the actuator the output from the sensor to an external controller.

* * * * *

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Songkakul et al.

(10) **Patent No.: US 8,224,282 B2**
(45) **Date of Patent: Jul. 17, 2012**

(54) **METHOD AND DEVICE TO MANAGE POWER OF WIRELESS MULTI-SENSOR DEVICES**

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(73) Assignee: **Siemens Industry, Inc.**, Alpharetta, GA (US)

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(22) Filed: **Mar. 18, 2009**

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Related U.S. Application Data

(60) Provisional application No. 61/037,739, filed on Mar. 19, 2008.

(51) **Int. Cl.**
G06F 17/00 (2006.01)
G08B 1/00 (2006.01)
G08B 21/00 (2006.01)

(52) **U.S. Cl.** **455/343.1**; 340/286.01; 340/540

(58) **Field of Classification Search** 455/343.1; 340/286.01, 540, 521, 539.17, 539.22, 683, 340/870.01
See application file for complete search history.

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2002/0125998	A1 *	9/2002	Petite et al.	340/286.01

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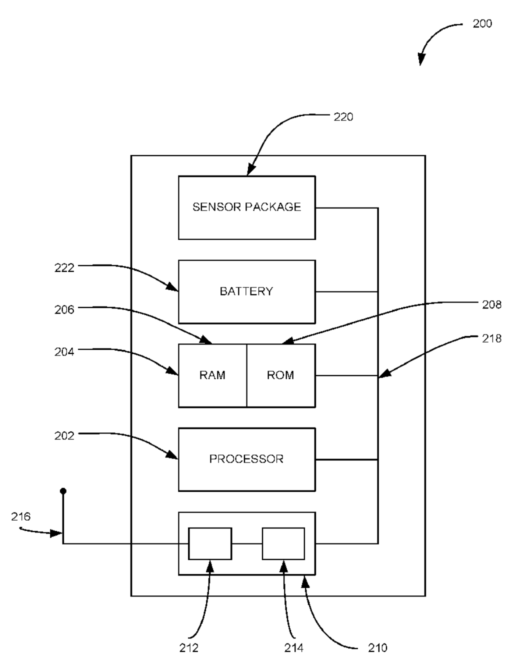
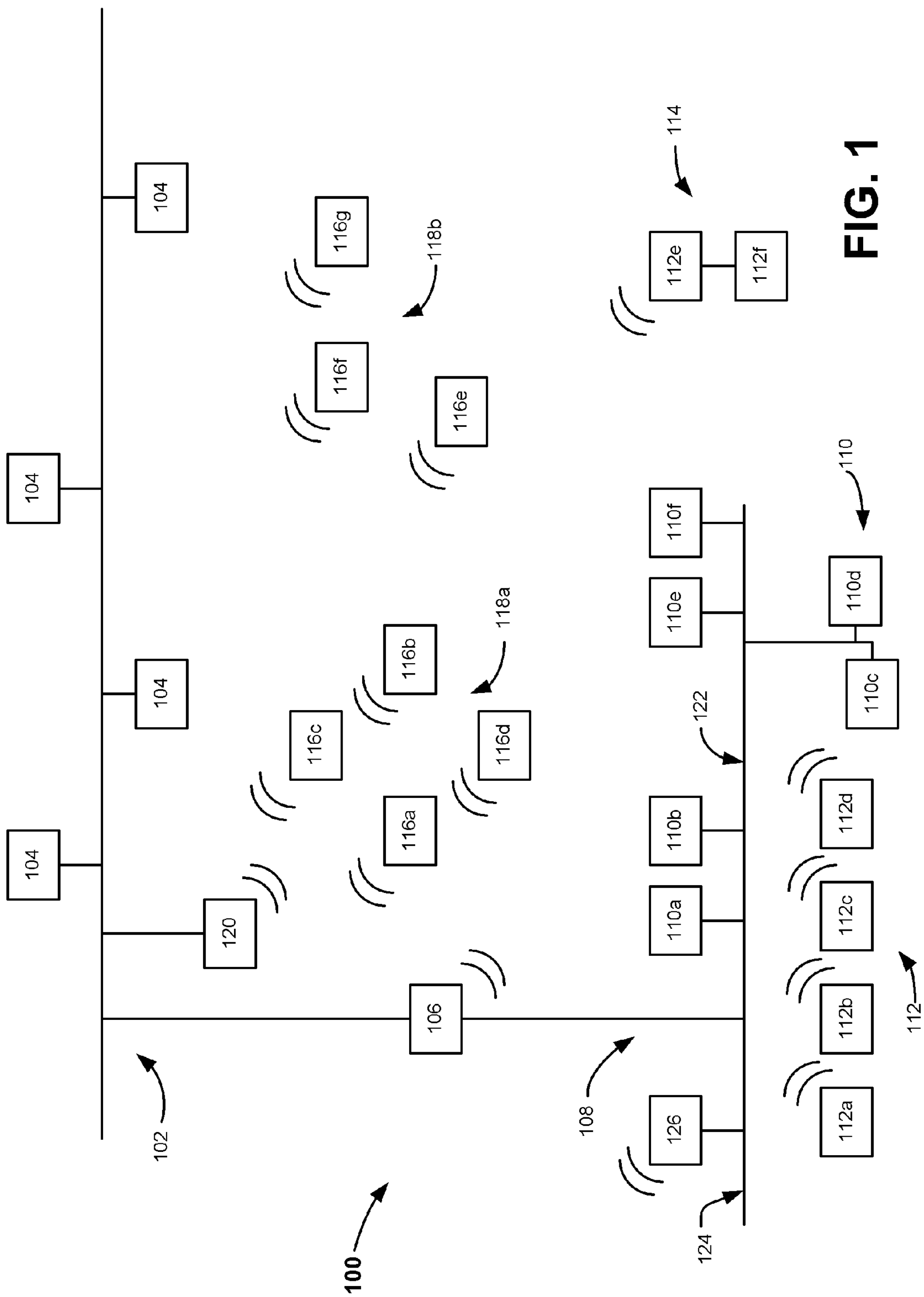
Primary Examiner — Daniel D Chang

(57) **ABSTRACT**

An automation component configured for wireless communication within a building automation system is disclosed. The automation component includes a multi-sensor package, a wireless communications component, a processor in communication with the wireless communications component and the sensor package, and a memory in communication with the processor. The memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor, wherein the computer readable instructions are programmed to receive status information related to sensor data in control at a second automation component in communication with the building automation system, and communicate a portion of the stored sensor data corresponding to the received status information to the second automation component.

25 Claims, 7 Drawing Sheets





100
102
104
104
104
104
106
108
110
110a
110b
110c
110d
110e
110f
112
112a
112b
112c
112d
112e
112f
114
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116b
116c
116d
116e
116f
116g
118a
118b
120
122
124
126

FIG. 1

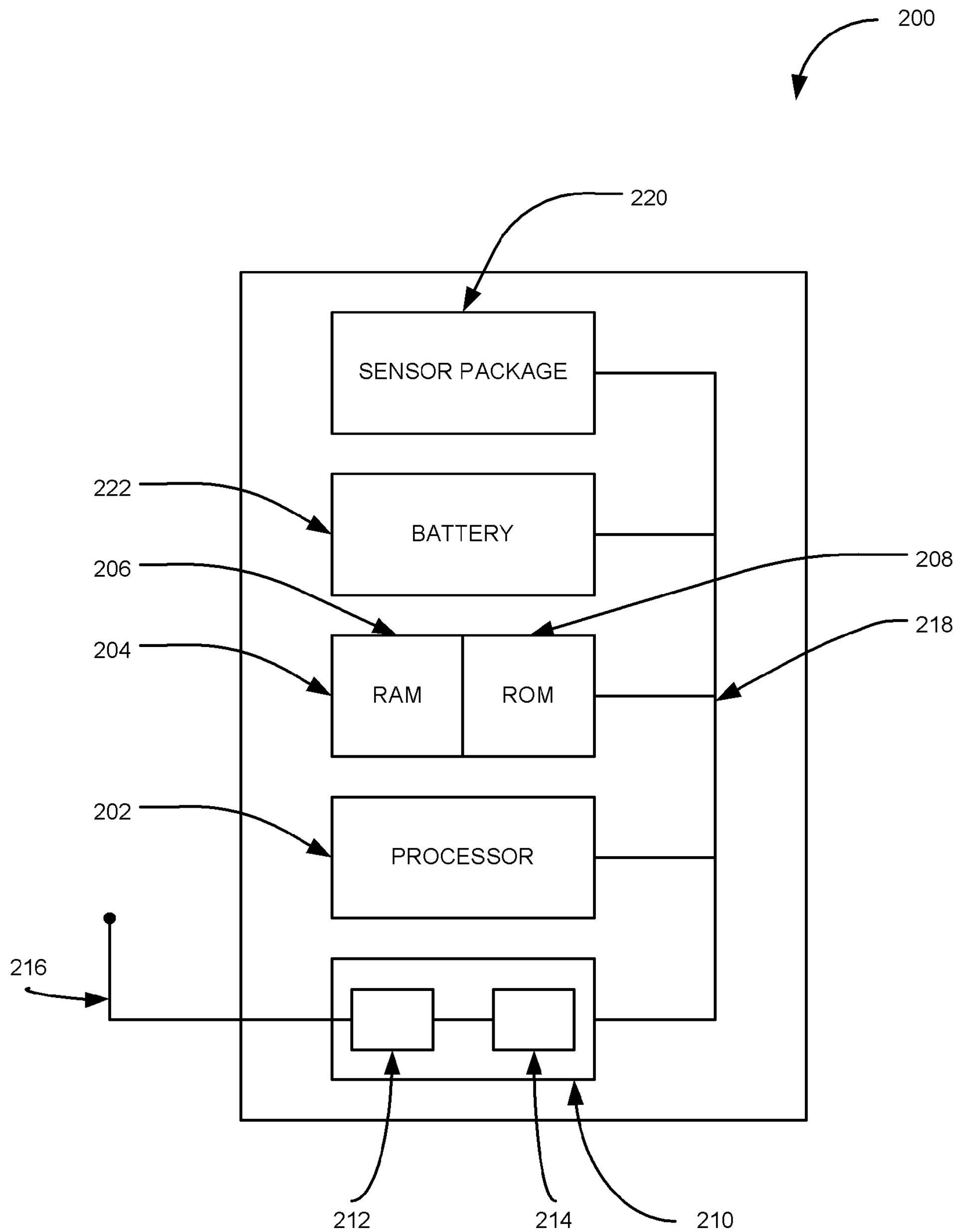
200
220
SENSOR PACKAGE
222
BATTERY
206
208
218
204
RAM
ROM
202
PROCESSOR
216
212
214
210

FIG. 2

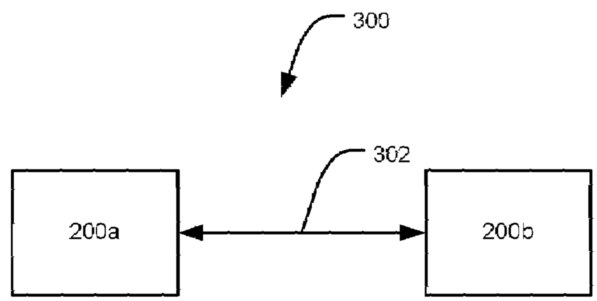
300
302
200a
200b

FIG. 3

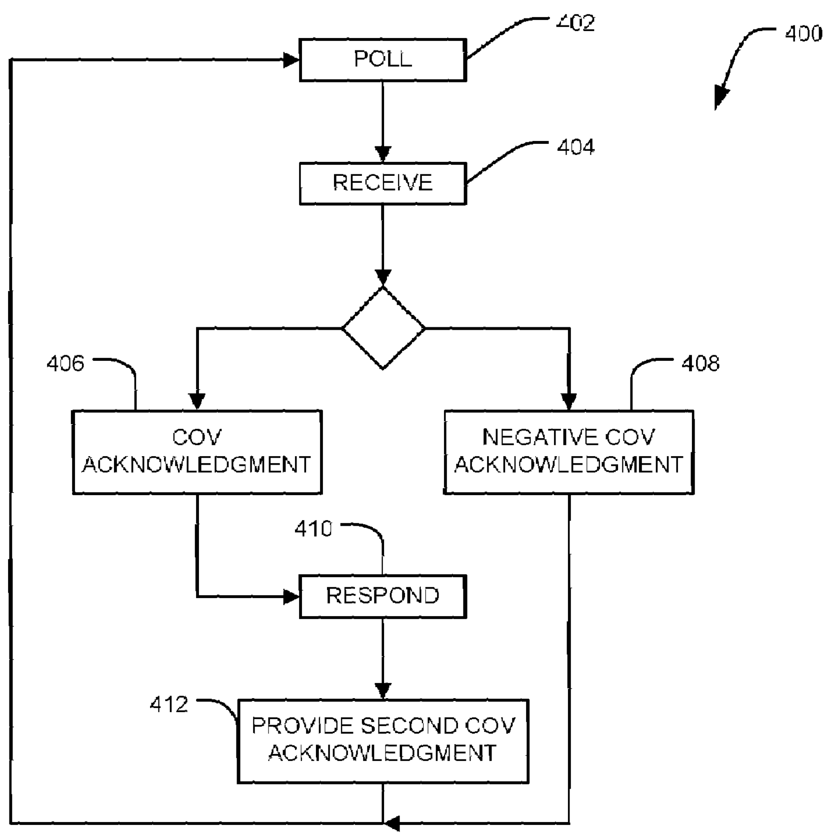
402
400
POLL
404
RECEIVE
406
408
COV ACKNOWLEDGMENT
NEGATIVE COV ACKNOWLEDGMENT
410
RESPOND
412
PROVIDE SECOND COV ACKNOWLEDGMENT

FIG. 4

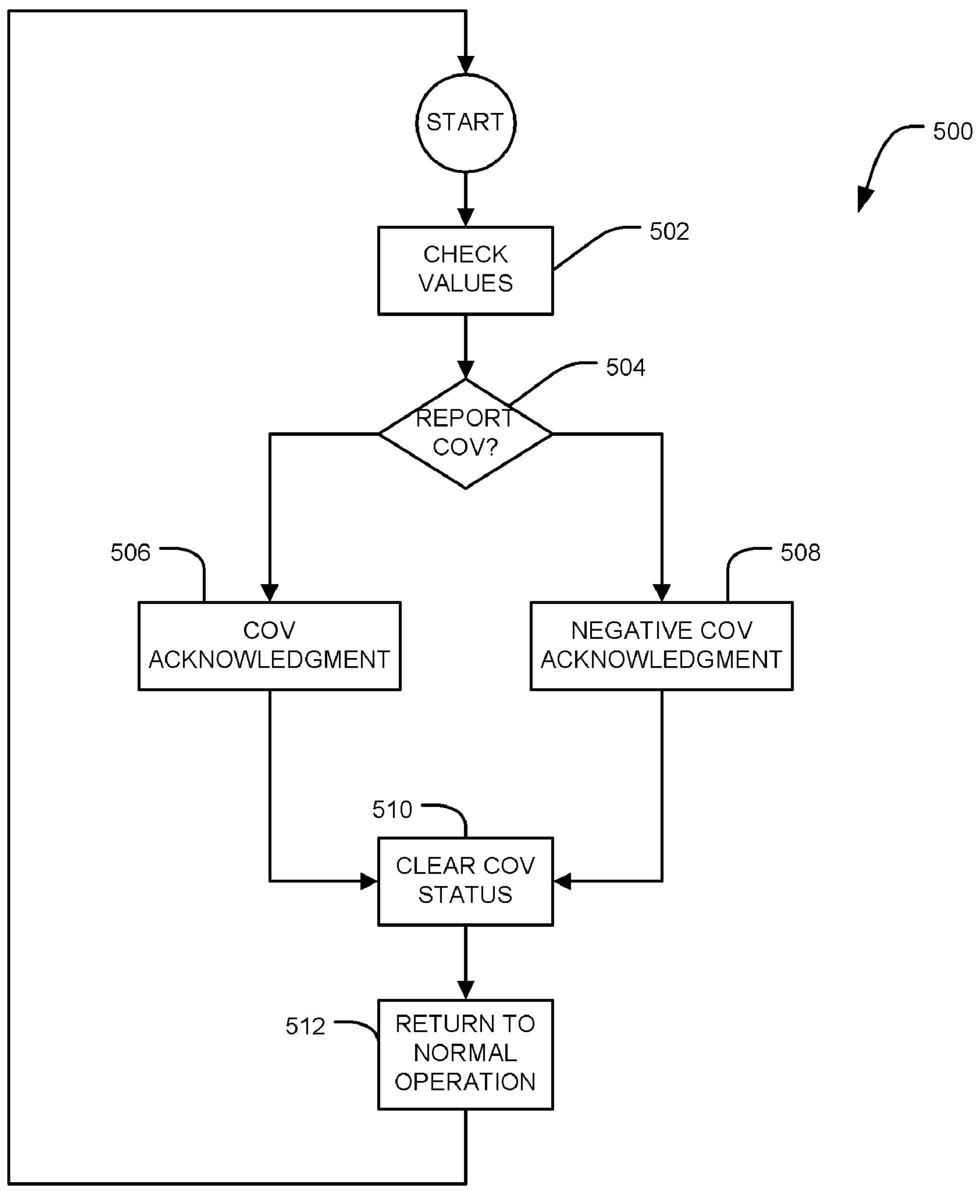
500
START
CHECK VALUES
502
REPORT COV?
504
506
COV ACKNOWLEDGMENT
508
NEGATIVE COV ACKNOWLEDGMENT
510
CLEAR COV STATUS
512
RETURN TO NORMAL OPERATION

FIG. 5

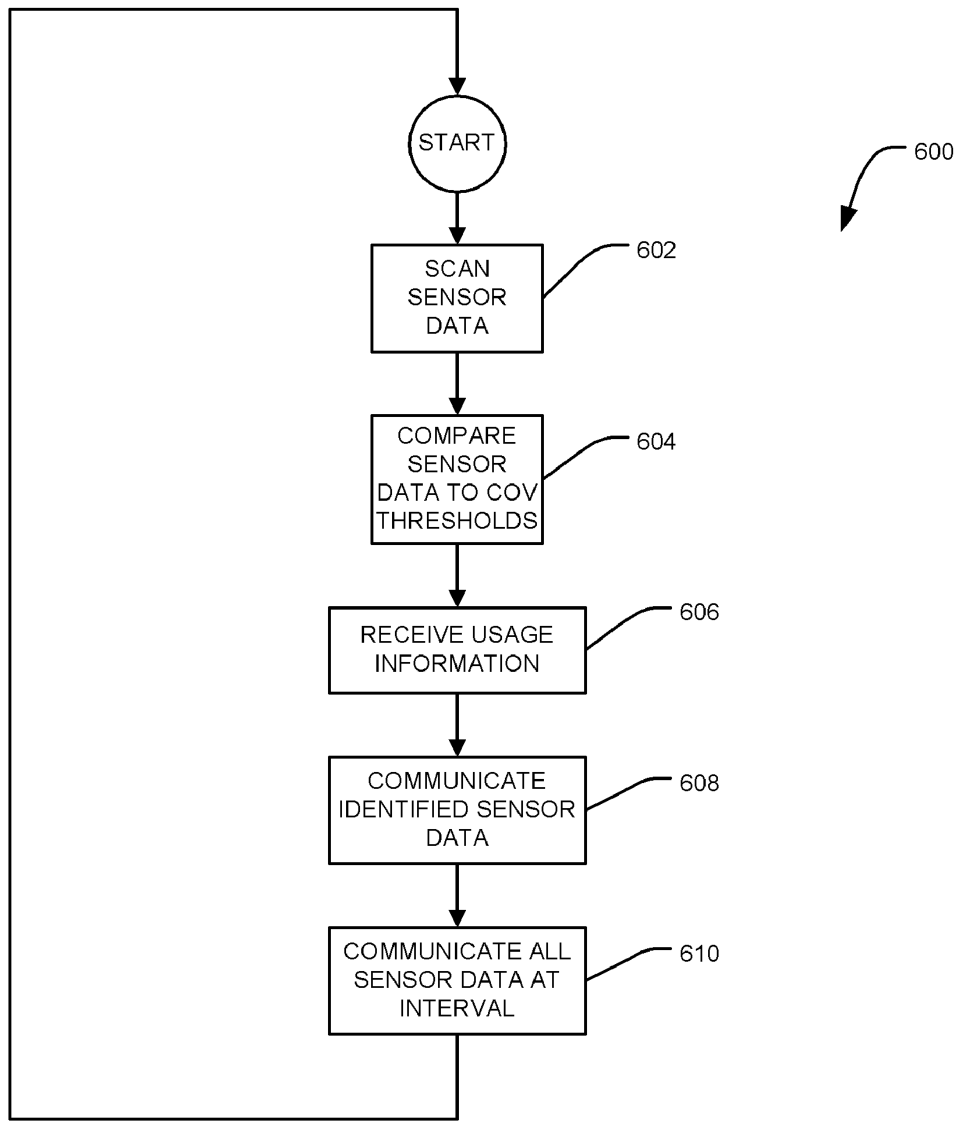
START
SCAN SENSOR DATA
602
COMPARE SENSOR DATA TO COV THRESHOLDS
604
RECEIVE USAGE INFORMATION
606
COMMUNICATE IDENTIFIED SENSOR DATA
608
COMMUNICATE ALL SENSOR DATA AT INTERVAL
610
600

FIG. 6

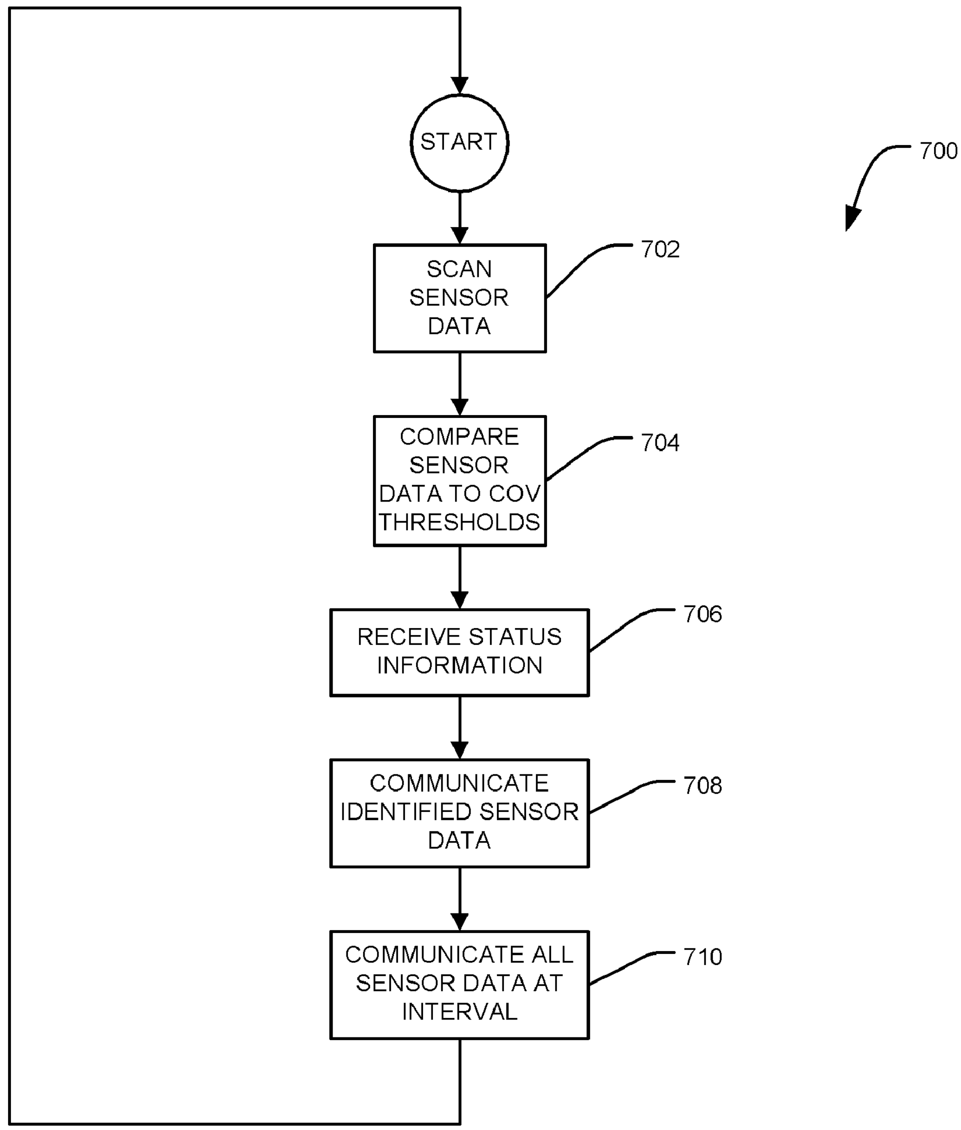
START
SCAN SENSOR DATA
702
COMPARE SENSOR DATA TO COV THRESHOLDS
704
RECEIVE STATUS INFORMATION
706
COMMUNICATE IDENTIFIED SENSOR DATA
708
COMMUNICATE ALL SENSOR DATA AT INTERVAL
710
700

FIG. 7

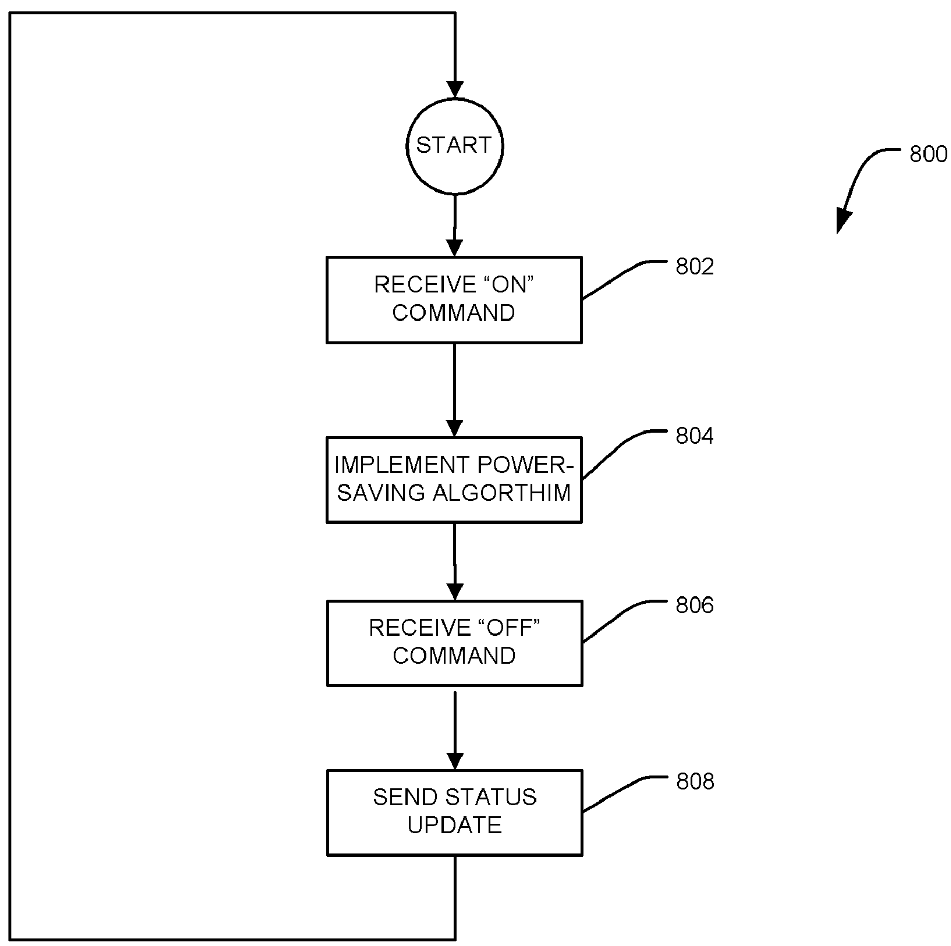
800
START
RECEIVE "ON" COMMAND
802
IMPLEMENT POWER-SAVING ALGORTHIM
804
RECEIVE "OFF" COMMAND
806
SEND STATUS UPDATE
808

FIG. 8

METHOD AND DEVICE TO MANAGE POWER OF WIRELESS MULTI-SENSOR DEVICES

PRIORITY CLAIM

This patent document claims the priority benefit provided under 35 U.S.C. §119(e) to U.S. provisional patent application Ser. No. 61/037,739, filed on Mar. 19, 2008. The content of this provisional patent application is incorporated herein by reference for all purposes.

BACKGROUND

The present disclosure generally relates to communications within a building automation system. In particular, the present disclosure relates to methods and devices for communicating change-of-value information within a building automation system.

A building automations system (BAS) typically integrates and controls elements and services within a structure such as the heating, ventilation and air conditioning (HVAC) system, security services, fire systems and the like. The integrated and controlled systems are arranged and organized into one or more floor level networks (FLNs) containing application or process specific controllers, sensors, actuators, or other devices distributed or wired to form a network. The floor level networks provide general control for a particular floor or region of the structure. For example, a floor level network may be an RS-485 compatible network that includes one or more controllers or application specific controllers configured to control the elements or services within floor or region. The controllers may, in turn, be configured to receive an input from a sensor or other device such as, for example, a room temperature sensor (RTS) deployed to monitor the floor or region. The input, reading or signal provided to the controller, in this example, may be a temperature indication representative of the physical temperature. The temperature indication can be utilized by a process control routine such as a proportional-integral control routine executed by the controller to drive or adjust a damper, heating element, cooling element or other actuator towards a predefined set-point.

Information such as the temperature indication, sensor readings and/or actuator positions provided to one or more controllers operating within a given floor level network may, in turn, be communicated to an automation level network (ALN) or building level network (BLN) configured to, for example, execute control applications, routines or loops, coordinate time-based activity schedules, monitor priority based overrides or alarms and provide field level information to technicians. Building level networks and the included floor level networks may, in turn, be integrated into an optional management level network (MLN) that provides a system for distributed access and processing to allow for remote supervision, remote control, statistical analysis and other higher level functionality. Examples and additional information related to BAS configuration and organization may be found in the co-pending U.S. patent application Ser. No. 11/590,157 (2006P18573 US), filed on Oct. 31, 2006, and co-pending U.S. patent application Ser. No. 10/915,034 (2004P13093 US), filed on Aug. 8, 2004, the contents of these applications are hereby incorporated by reference for all purposes.

Wireless devices, such as devices that comply with IEEE 802.15.4/ZigBee protocols, may be implemented within the control scheme of a building automation system without incurring additional wiring or installation costs. ZigBee-compliant devices such as full function devices (FFD) and reduced function devices (RFD) may be interconnected to provide a device net or mesh within the building automation system. For example, full function devices are designed with the processing power necessary to establish peer-to-peer connections with other full function devices and/or execute control routines specific to a floor or region of a floor level network. Each of the full function devices may, in turn, communicate with one or more of the reduced function devices in a hub and spoke arrangement. Reduced function devices such as the temperature sensor described above are designed with limited processing power necessary to perform a specific task(s) and communicate information directly to the connected full function device.

Wireless devices for use within the building automation system must operate for an extended period on a limited battery charge. Systems, devices and methods to maximize power conservation may be desirable to extend and/or maximize the operating life of wireless devices and the network in which they operate.

SUMMARY

The present disclosure generally provides for communicating information between wireless devices and/or automation components operating within a building automation system (BAS). Wireless devices and/or automation components may be configured to optimize radio and/or data communications to extend battery life.

In one embodiment, an automation component configured for wireless communication within a building automation system is disclosed. The automation component includes a multi-sensor package, a wireless communications component, a processor in communication with the wireless communications component and the sensor package, and a memory in communication with the processor. The memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor, wherein the computer readable instructions are programmed to receive status information related to sensor data in control at a second automation component in communication with the building automation system, and communicate a portion of the stored sensor data corresponding to the received status information to the second automation component.

In another embodiment, an automation component configured for wireless communication within a building automation system is disclosed. The automation component includes a multi-sensor package, a wireless communications component, a processor in communication with the wireless communications component and the sensor package, a memory in communication with the processor, the memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor. The computer readable instructions are programmed to receive status data related to sensor data in control at a second automation component in communication with the building automation system, determine the sensor data in control at the second automation component based on the received status data, and communicate the stored sensor data corresponding the sensor data in control at the second automation component.

In another embodiment, an automation component configured for wireless communication within a building automation system is disclosed. The automation component includes, a multi-sensor package, a wireless communications component, a processor in communication with the wireless communications component and the sensor package, a memory in communication with the processor, the memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor. The computer readable instructions are programmed to receive a wake-up command from a second automation component, communicate stored sensor data related to the sensor data in control at a second automation component, and receive a power-down command from the second automation component.

A method for providing power saving wireless communication within a building automation system is disclosed. The method includes scanning sensor data associated with a multi-sensor package of a first automation component, identifying changed sensor values within the sensor data, receiving a first communication from a second automation component in communication with the first automation component and the building automation system, and communicating a portion of the identified changed sensor values associated with the first communication received from the second automation component.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description and the figures.

BRIEF DESCRIPTION OF THE FIGURES

The method, system and teaching provided relate to binding automation components within a building automation system (BAS).

FIG. **1** illustrates an embodiment of a building automation system configured in accordance with the disclosure provided herein;

FIG. **2** illustrates an embodiment of a wireless device or automation component that may be utilized in connection with the building automation system shown in FIG. **1**;

FIG. **3** illustrates an exemplary flowchart representative of a communications and updating configuration;

FIG. **4** illustrates an exemplary flowchart representative of a communications algorithm;

FIG. **5** illustrates an exemplary flowchart representative of another communications algorithm;

FIG. **6** illustrates an exemplary flowchart representative of a communications and power saving configuration;

FIG. **7** illustrates an exemplary flowchart representative of a communications and power saving algorithm; and

FIG. **8** illustrates an exemplary flowchart representative of another communications and power saving algorithm.

DETAILED DESCRIPTION

The embodiments discussed herein include automation components, wireless devices and transceivers. The devices may be IEEE 802.15.4/ZigBee-compliant automation components such as: a personal area network (PAN) coordinator which may be implemented as a field panel transceiver (FPX); a full function device (FFD) implemented as a floor level device transceiver (FLNX); and a reduced function device (RFD) implemented as a wireless room temperature sensor (WRTS) that may be utilized in a building automation system (BAS). The devices identified herein are provided as an example of automation components, wireless devices and transceivers that may be integrated and utilized within a building automation system embodying the teachings disclosed herein and are not intended to limit the type, functionality and interoperability of the devices and teaching discussed and claimed herein. Moreover, the disclosed building automation system describes automation components that may include separate wireless devices and transceivers, however it will be understood that that the wireless device and transceiver may be integrated into a single automation component operable within the building automation system.

I. Building Automation System Overview

One exemplary building automation system that may include the devices and be configured as described above is the APOGEE® system provided by Siemens Building Technologies, Inc. The APOGEE® system may implement RS-485 wired communications, Ethernet, proprietary and standard protocols, as well as known wireless communications standards such as, for example, IEEE 802.15.4 wireless communications which are compliant with the ZigBee standards and/or ZigBee certified wireless devices or automation components. ZigBee standards, proprietary protocols or other standards are typically implemented in embedded applications that may utilize low data rates and/or require low power consumption. Moreover, ZigBee standards and protocols are suitable for establishing inexpensive, self-organizing, mesh networks which may be suitable for industrial control and sensing applications such as building automation. Thus, automation components configured in compliance with ZigBee standards or protocols may require limited amounts of power allowing individual wireless devices, to operate for extended periods of time on a finite battery charge.

The wired or wireless devices such as the IEEE 802.15.4/ZigBee-compliant automation components may include, for example, an RS-232 connection with an RJ11 or other type of connector, an RJ45 Ethernet compatible port, and/or a universal serial bus (USB) connection. These wired, wireless devices or automation components may, in turn, be configured to include or interface with a separate wireless transceiver or other communications peripheral thereby allowing the wired device to communicate with the building automation system via the above-described wireless protocols or standards. Alternatively, the separate wireless transceiver may be coupled to a wireless device such as a IEEE 802.15.4/ZigBee-compliant automation component to allow for communications via a second communications protocol such as, for example, 802.11x protocols (802.11a, 802.11b . . . 802.11n, etc.) These exemplary wired, wireless devices may further include a man-machine interface (MMI) such as a web-based interface screen that provide access to configurable properties of the device and allow the user to establish or troubleshoot communications between other devices and elements of the BAS.

FIG. **1** illustrates an exemplary building automation system or control system **100** that may incorporate the methods, systems and teaching provided herein. The control system **100** includes a first network **102** such as an automation level network (ALN) or management level network (MLN) in communication with one or more controllers such as a plurality of terminals **104** and a modular equipment controller (MEC) **106**. The modular equipment controller or controller **106** is a programmable device which may couple the first network **102** to a second network **108** such as a floor level network (FLN). The second network **108**, in this exemplary embodiment, may include a first wired network portion **122** and a second wired network portion **124** that connect to building automation components **110** (individually identified as automation components **110*a*** to **110*f***). The second wired network portion **124** may be coupled to wireless building automation components **112** via the automation component **126**. For example, the building automation components **112** may include wireless devices individually identified as automation components **112*a*** to **112*f***. In one embodiment, the automation component **112*f*** may be a wired device that may or may not include wireless functionality and connects to the automation component **112***e*. In this configuration, the automation component **112***f* may utilize or share the wireless functionality provided by the automation component **112***e* to define an interconnected wireless node **114**. The automation components **112***a* to **112***f* may, in turn, communicate or connect to the first network **102** via, for example, the controller **106** and/or an automation component **126**. The automation component **126** may be a field panel, FPX or another full function device in communication with the second wired network portion **124** which, in turn, may be in communication with the first network **102**.

The control system **100** may further include automation components generally identified by the reference numerals **116***a* to **116***g*. The automation components **116***a* to **116***g* may be configured or arranged to establish one or more networks or subnets **118***a* and **118***b*. The automation components **116***a* to **116***g* such as, for example, full or reduced function devices and/or a configurable terminal equipment controller (TEC), cooperate to wirelessly communicate information between the first network **102**, the control system **100** and other devices within the mesh networks or subnets **118***a* and **118***b*. For example, the automation component **116***a* may communicate with other automation components **116***b* to **116***d* within the mesh network **118***a* by sending a message addressed to the network identifier, alias and/or media access control (MAC) address assigned to each of the interconnected automation components **116***a* to **116***g* and/or to a field panel **120**. In one configuration, the individual automation components **116***a* to **116***d* within the subnet **118***a* may communicate directly with the field panel **120** or, alternatively, the individual automation components **116***a* to **116***d* may be configured in a hierarchal manner such that only one of the components for example, automation component **116***c*, communicates with the field panel **120**. The automation components **116***e* to **116***g* of the mesh network **118***b* may, in turn, communicate with the individual automation components **116***a* to **116***d* of the mesh network **118***a* or the field panel **120**.

The automation components **112***e* and **112***f* defining the wireless node **114** may wirelessly communicate with the second network **108**, and the automation components **116***e* to **116***g* of the mesh network **118***b* to facilitate communications between different elements, section and networks within the control system **100**. Wireless communication between individual the automation components **112**, **116** and/or the subnets **118***a*, **118***b* may be conducted in a direct or point-to-point manner, or in an indirect or routed manner through the nodes or devices comprising the nodes or networks **102**, **108**, **114** and **118**. In an alternate embodiment, the first wired network portion **122** is not provided, and further wireless connections may be utilized.

FIG. **2** illustrates an exemplary automation component **200** that may be utilized within the control system **100**. The automation component **200** maybe be a full function device or a reduced function device and may be utilized interchangeably with the automation components **110**, **112** and **116** shown and discussed in connection with FIG. **1**. The automation component **200** in this exemplary embodiment may include a processor **202** such as an INTEL® PENTIUM, an AMD® ATHLON™, an Atmel® ATMega, or other 8, 12, 16, 24, 32 or 64 bit classes of processors in communication with a memory **204** or storage medium. The memory **204** or storage medium may contain random access memory (RAM) **206**, flashable or non-flashable read only memory (ROM) **208** and/or a hard disk drive (not shown), or any other known or contemplated storage device or mechanism. The automation component may further include a communications component **210**. The communications component **210** may include, for example, the ports, hardware and software necessary to implement wired communications with the control system **100**. The communications component **210** may alternatively, or in addition to, contain a wireless transmitter **212** and a receiver **214** communicatively coupled to an antenna **216** or other broadcast hardware.

The sub-components **202**, **204** and **210** of the exemplary automation component **200** may be coupled and able to share information with each other via a communication bus **218**. In this way, computer readable instructions or code such as software or firmware may be stored on the memory **204**. The processor **202** may read and execute the computer readable instructions or code via the communication bus **218**. The resulting commands, requests and queries may be provided to the communications component **210** for transmission via the transmitter **212** and the antenna **216** to other automation components **200**, **112** and **116** operating within the first and second networks **102** and **108**. Sub-components **202-218** may be discrete components or may be integrated into one (1) or more integrated circuits, multi-chip modules, and/or hybrids.

The automation component **200** may be a multi-sensor wireless device that includes a sensor package **220** in communication with the sub-components **202**, **204** and **210** via the communication bus **218**. The sensor package **220** may be configured to sense or detect a variety of variables such as, for example, temperature, humidity, carbon dioxide, carbon monoxide, volatile organic compounds, etc. Sensed values, signals and other data may be stored within the memory **204** and accessible to the processor **202**. Moreover, the signal or indication may be flagged to indicate that a change-of-value has occurred within the automation component **200**. In other words, the detection or reception of the signal or indication may operate as a change-of-value flag which denotes that the information, setting, signals and/or indications stored within the memory **204** have been altered, updated or otherwise changed. Alternatively, a separate change-of-value flag may be set and/or correspond to each detected or received signal or indication.

A battery **222** may power the sub-components **202**, **204**, **210** and **220** via the communication bus **218**, direct or hard-wired connections via a circuit board, one or more wires or conduits or any other suitable power communication medium. Communication of the stored sensor readings and/or data via the communication component **210** is a power intensive operation that may drain the battery **222**. Moreover, some of the sensors within the sensor package **220** may require a great deal of power to operate. In order to increase the life of the battery **222**, the high power requirement sensors within the sensor package **220** may be configured to operate periodically or on a set schedule.

II. Automation Component Communication and Updating

FIG. **3** illustrates an exemplary communications and updating configuration **300** that may be implemented between automation components **200**. In this exemplary configuration, the automation components **200***a* may be configured to implement a request-response (polling) communication **302** in order to pull information from **200***b* device(s) to the polling device or for the **200***b* device to push values up to the **200***a* device. For example, the automation component **200***a* may represent a field panel, FPX or another full function device. Similarly, the automation component **200***b* may represent a TEC, FLNX, a Full function or reduced function device, a wireless actuator or any other wired or wireless device operable within the BAS **100**. Moreover, the automation components **200***a*, **200***b* may be operative within, for example, the mesh network or subnet **118***a*.

A. Request-Response (Polled) Communications

FIG. **4** illustrates a poll communication algorithm **400** or method that may be implemented, for example, between the automation components **200***a*, **200***b*. At block **402**, the automation component **200***a*, which may be a field panel or other full function device, may generate and communicate a change-of-value (COV) request message to one or more automation components **200***b* operating within the BAS **100** and/or within the individual FLNs that make up the BAS **100**. The COV request message may request or direct the automation component **200***b* to indicate whether any of the local detected values, received values, parameters, or measurements have changed or altered beyond a pre-defined reporting limit, e.g. COV limit.

At block **404**, the automation component **200***b* receives the COV request message. For example, if the automation component **200***b* has, since receipt of the last COV request message, detected or received a new value representing the change-of-value, then at block **406** the automation component **200***b* may generate a COV acknowledgment message for communication to the automation component **200***a*. Alternatively, if the automation component **200***b* hasn't detected or received the new value representing the change-of-value, then at block **408** the automation component **200***b* may generate a negative COV acknowledgment message for communication to the automation component **200***a*.

At block **410**, if the automation component **200***a* has successfully received the COV acknowledgment message provided by the automation component **200***b*, then the automation component **200***a* may generate and send an acknowledge COV request message for reply to the automation component **200***b*.

At block **412**, the automation component **200***b*, in response to the acknowledge COV request message provided by the automation component **200***a*, knows the COV was successfully transferred to the device **200***a* and clears those reported COV's, and provides a acknowledge COV request acknowledgment message. After block **412**, the communication algorithm **400** may restart and another wireless device or automation component within the BAS **100** may be polled. It will be understood that the exemplary communications algorithm **400** may be implemented in a wired or wireless BAS **100**

B. Push Communications

FIG. **5** illustrates an alternate communication algorithm **500** or method that may be implemented, for example, between the automation components **200***a*, **200***b*. The exemplary communication method **500** may be employed in a BAS **100** configured for hybrid communications utilizing both wired and wireless communications.

At block **502**, the automation component **200***b*, which may be, for example, a full function device, an FLNX and or a TEC, will check its inputs and outputs for new or changed values. If the new value has changed more than a pre-defined amount from the last reported value, then the variable is to be reported on the next COV communication.

At block **504**, the automation component **200***b* will check, at regular intervals established by an internal COV Reporting time interval or as needed by the internal algorithm, to see if Change-Of-Value (COV) are waiting to be reported. If so, the automation component **200***b* will create a Push COV message containing all queued COV values and send them to automation component **200***a*. At block **506**, the automation component **200***a* may respond to automation component **200***b* with a Push COV acknowledge response if the message is received and understood, or, at block **508**, will respond with a negative acknowledge (NAK) and an error code if the message was not understood. On receipt, at block **510**, automation component **200***b* clears the COV status. At block **512**, the automation component **200***b* may return to its normal operations until the next check for new values.

Automation component **200***a* now processes those queued COV's into the internal database of the automation component **200***a* and may optionally report those new values to other devices as defined in the drawings and description of FIG. **1**.

If automation component **200***b* was in fact a hardwired device with an external wireless network interface, such as a TEC with an FLNX configuration, then the FLNX would need to poll the TEC for COV's and hold them within the FLNX while the communication to automation component **200***a* was occurring. In addition, the FLNX would need to acknowledge the COV's from the TEC as was defined in algorithm of FIG. **4**.

If automation component **200***a* was a hardwired device with an external wireless network interface, such as a field panel with an FPX, then the FPX would need to act has the buffer for pushed COV's and queue the COV's for the field panel. The field panel would poll the FPX, in accordance with the algorithms of FIG. **4**, to accept the COV's into the database of the automation component **200***a*.

In this configuration, the communication algorithm **500** allows COV related messages to be gathered and pushed from one or more automation components **200***b* up to the **200***a* device and from the **200***a* device to other system components as defined in FIG. **1**. By pushing COV's up to automation component **200***a* as opposed to polling each automation component **200***b*, less wireless bandwidth is used and system end to end delays shortened.

If the automation component **200***b* is operating in a stable state without any COV's for extended periods of time (as defined by internal variable), the automation component **200***b* will communicate with the automation component **200***a* so that the automation component **200***a* knows that the automation component **200***b* is still operating. If the automation component **200***a* does not receive a message from the automation component **200***b* for a period longer than the internal variable defined within the automation component **200***b*, then the automation component **200***a* will report a loss of communication with the automation component **200***b*.

The communications algorithm **500** may be further configured to address and handle communications difficulties or errors between, for example, the automation components **200***a*, **200***b*. For example, if COV polling requests cannot be communicated or are not acknowledged by the intended receiving automation component, then the algorithm **500** may be configured to recover from the communications failure. Communication recovery may include repeating communication attempts a predetermined number of times (e.g., ten attempts). Similarly, if repeated communication attempts are unsuccessful, then the communication recovery may timeout and the procedure may be reattempted after a predetermined delay (e.g., every thirty minutes). Moreover, during the period when communication is not possible, the COV-related messages may still be aggregated and stored pending the reestablishment of communications.

III. Automation Component Communication and Power Saving

FIG. **6** illustrates a power saving communication algorithm **600** or method that may be implemented, for example, between the field panel **120** and the automation component **200**. Generally, the power saving communication algorithm **600** instructs the automation component **200** to provide specific or limited sensor information to, for example, the field panel **120** in response to a communication indicating the particular sensed data (from a field of all the data gathered via the multi-sensor) currently in use by the field panel **120**.

At block **602**, the exemplary multi-sensor automation component **200** scans each of the sensors operating within the sensor package **220** and/or the sensor data stored in the memory **204**. The scan time may be, for example, once every 10 msecs, once a second, or any other desirable period of time.

At block **604**, the sensor data identified during the sensor and memory scan may be compared to a COV threshold value corresponding to each individual sensor and/or sensor value. Sensor data found to exceed the COV threshold may be flagged for later transmission.

At block **606**, a receiving device such as, for example, the field panel **120** may communicate sensor usage or control information to the automation component that identifies which sensor and sensor data is currently being analyzed and/or is primary or controlling the field panel **120**. The sensor usage or control information relates to or identifies the sensor values and routines that are controlling and driving the receiving device. In other words, during any given scan cycle, one of the sensor values and/or a corresponding sensor control routine is executed by the receiving device (e.g., the field panel **120**). The communicated sensor control information provided by the receiving device identifies for the automation component **200** which sensor and/or sensor value is driving or controlling the receiving device during the scan cycle.

At block **608**, the automation component **200** may communicate the flagged sensor data corresponding to the primary sensor and/or sensor value in control of, and provided by, the field panel **120**.

At block **610**, all of the flagged sensor data, regardless of its status at the field panel **120**, may be communicated (at a regular or scheduled interval) to provide sensor data for the sensors that are not the primary focus of the field panel during a given time period or duty cycle. In this way, the overall length and frequency of communications may be reduced thereby saving battery power. Moreover, by only communicating a subset of the total sensor data reduces the overall message size thereby freeing network bandwidth for other communications.

FIG. **7** illustrates an alternate power saving communication algorithm **700** or method that may be implemented between, for example, the field panel **120** and the automation components **200**. Generally, the power saving communication algorithm **700** is configure to allow the automation component **200** to determine, in response to data provided by the field panel **120**, to determine the sensed data currently in use by the field panel **120**.

At block **702**, the exemplary multi-sensor automation component **200** scans each of the sensors operating within the sensor package **220** and/or the sensor data stored in the memory **204**. The scan time may be, for example, once every 10 msecs, once a second, or any other desirable period of time.

At block **704**, the sensor data identified during the sensor and memory scan may be compared to a COV threshold value corresponding to each individual sensor and/or sensor value. Sensor data found to exceed the COV threshold may be flagged for later transmission.

At block **706**, a receiving device such as, for example, the field panel **120** may communicate status information to the automation component **200**. The received status information provides the complete status for each of the control routines or algorithm running in connection with each of the sensor elements in the sensor package **220**. The automation component **200**, and more particularly, the processor **202**, may analyze or process to all of the received status information to determine which sensor and sensor data is currently being analyzed and/or is primary or controlling the field panel **120**.

At block **708**, the automation component **200** may communicate the flagged sensor data corresponding to the sensor and sensor data currently being analyzed and/or controlling the field panel **120**.

At block **710**, all of the flagged sensor data, regardless of its status at the field panel **120**, may be communicated (at a regular or scheduled interval) to provide sensor data for the sensors that are not the primary focus of the field panel during a given time period or duty cycle. In this way, the overall length and frequency of communications may be reduced thereby saving battery power. Moreover, by only communicating a subset of the total sensor data reduces the overall message size thereby freeing network bandwidth for other communications.

FIG. **8** illustrates another power saving communication algorithm **800** or method that may be implemented between, for example, the field panel **120** and the automation components **200**. Generally, the power saving communication algorithm **800** provides for changing the power status of the automation component **200** in response to a command from the field panel **120**.

At block **802**, the exemplary multi-sensor automation component **200** may receive a "WAKE-UP" or "ON" command from another device such as, for example, the field panel **120**. Prior to receipt of the ON command, the automation component **200** may have been in a low-power state.

At block **804**, the now-active automation component may implement the power saving communication algorithm **700** and/or **800**.

At block **806**, the exemplary multi-sensor automation component **200** may receive a "POWER DOWN" or "OFF" command from another device such as, for example, the field panel **120**. Upon receipt of the OFF command, the automation component **200** may return to a low-power state.

It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. For example, the elements of these configurations could be arranged and interchanged in any known manner depending upon the system requirements, performance requirements, and other desired capabilities. Well understood changes and modifications can be made based on the teachings and disclosure provided by the present invention and without diminishing from the intended advantages disclosed herein. It is therefore intended that such changes and modifications be covered by the appended claims.

What is claimed is:

1. An automation component configured for wireless communication within a building automation system, the automation component comprising:

a multi-sensor package configured to detect a plurality of variables and generate sensor data for each detected variable;

a wireless communications component;

a processor in communication with the wireless communications component and the sensor package;

a memory in communication with the processor, the memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor; wherein the computer readable instructions are programmed to:

receive sensor control information related to sensor data in control at a second automation component in communication with the building automation system; and

communicate a portion of the stored sensor data corresponding to the received sensor control information to the second automation component.

2. The automation component of claim **1**, wherein the sensor package includes one or more sensors selected from the group consisting of: a temperature sensor; a humidity sensor; a carbon monoxide sensor; a carbon dioxide sensor and a volatile organic compound sensor.

3. The automation component of claim **1**, wherein the computer readable instructions are further programmed to:

identify sensor values within the sensor data that exceed a corresponding change-of-value threshold.

4. The automation component of claim **1**, wherein the computer readable instructions are further programmed to:

set an identification flag for each identified sensor value.

5. The automation component of claim **1**, wherein the computer readable instructions are further programmed to:

communicate all of the stored sensor data corresponding to the received sensor control information to the second automation component.

6. The automation component of claim **1**, wherein all of the stored sensor data is communicated at a regular interval.

7. An automation component configured for wireless communication within a building automation system, the automation component comprising:

a multi-sensor package configured to generate a plurality of sensor data for each sensor within the multi-sensor package;

a wireless communications component;

a processor in communication with the wireless communications component and the sensor package;

a memory in communication with the processor, the memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor; wherein the computer readable instructions are programmed to:

receive status data related to sensor data in control at a second automation component in communication with the building automation system;

determine the sensor data in control at the second automation component based on the received status data; and

communicate the stored sensor data corresponding the sensor data in control to the second automation component.

8. The automation component of claim **7**, wherein the sensor package includes one or more sensors selected from the group consisting of: a temperature sensor; a humidity sensor; a carbon monoxide sensor; a carbon dioxide sensor and a volatile organic compound sensor.

9. The automation component of claim **7**, wherein the computer readable instructions are further programmed to:

identify sensor values within the sensor data that exceed a corresponding change-of-value threshold.

10. The automation component of claim **7**, wherein the computer readable instructions are further programmed to:

set an identification flag for each identified sensor value.

11. The automation component of claim **7**, wherein the computer readable instructions are further programmed to:

communicate all of the stored sensor data corresponding to the received status information to the second automation component.

12. The automation component of claim **7**, wherein all of the stored sensor data is communicated at a regular interval.

13. An automation component configured for wireless communication within a building automation system, the automation component comprising:

a multi-sensor package configured to detect a plurality of variables and generate sensor data for each detected variable;

a wireless communications component;

a processor in communication with the wireless communications component and the sensor package;

a memory in communication with the processor, the memory configured to store sensor data provided by the sensor package and computer readable instructions which are executable by the processor; wherein the computer readable instructions are programmed to:

receive a wake-up command from a second automation component;

communicate stored sensor data related to the sensor data in control at a second automation component; and

receive a power-down command from the second automation component.

14. The automation component of claim **13**, wherein the sensor package includes one or more sensors selected from the group consisting of: a temperature sensor; a humidity sensor; a carbon monoxide sensor; a carbon dioxide sensor and a volatile organic compound sensor.

15. The automation component of claim **13**, wherein the computer readable instructions are further programmed to:

identify sensor values within the sensor data that exceed a corresponding change-of-value threshold.

16. The automation component of claim **13**, wherein the computer readable instructions are further programmed to:

set an identification flag for each identified sensor value.

17. The automation component of claim **13**, wherein the computer readable instructions are further programmed to:

communicate all of the stored sensor data corresponding to the received status information to the second automation component.

18. The automation component of claim **17**, wherein all of the stored sensor data is communicated at a regular interval.

19. The automation component of claim **13**, wherein the computer readable instructions are further programmed to:

receive status information related to sensor data in control at a second automation component.

20. A method for providing power saving wireless communication within a building automation system, the method comprising:

scanning sensor data associated with each of a plurality of sensors contained within a multi-sensor package of a first automation component;

identifying changed sensor values within the sensor data;

receiving a first communication from a second automation component in communication with the first automation component and the building automation system; and

communicating a portion of the identified changed sensor values associated with the first communication received from the second automation component.

21. The method of claim **20**, wherein identifying changed sensor values includes identifying changed sensor values as a function of a change-of-value threshold.

22. The method of claim **20** further comprising:

determining a primary sensor routine within the second component based on the first communication.

23. The method of claim **22**, wherein the first communication includes sensor control information.

24. The method of claim **22**, wherein the first communication includes sensor status information for all of the sensor routines operating within the second automation component.

25. The method of claim **22**, wherein the first communication identifies a primary sensor routine operating within the second automation component.

* * * * *

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McFarland et al.

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(45) **Date of Patent: Sep. 11, 2012**

(54) **METHOD AND DEVICE FOR COMMUNICATING CHANGE-OF-VALUE INFORMATION IN A BUILDING AUTOMATION SYSTEM**

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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 1255 days.

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G08C 19/16 (2006.01)

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(58) **Field of Classification Search** 340/870.01; 370/473; 455/69
See application file for complete search history.

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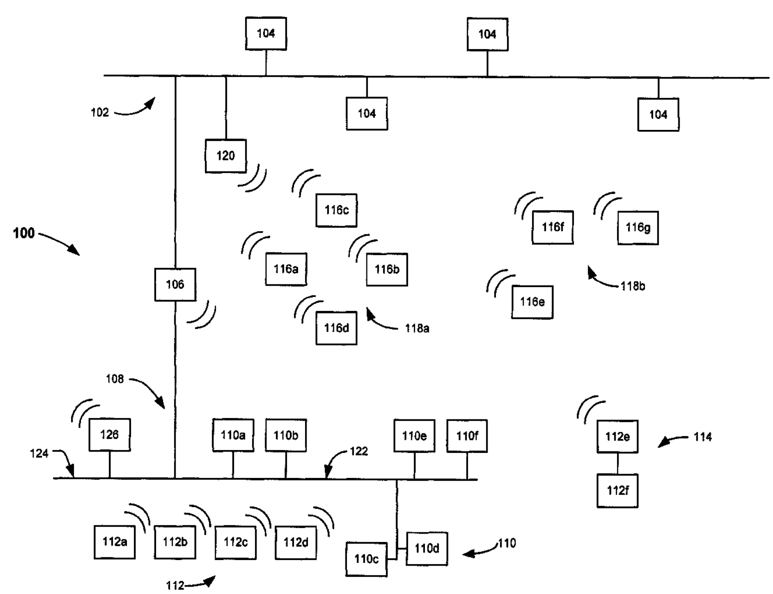
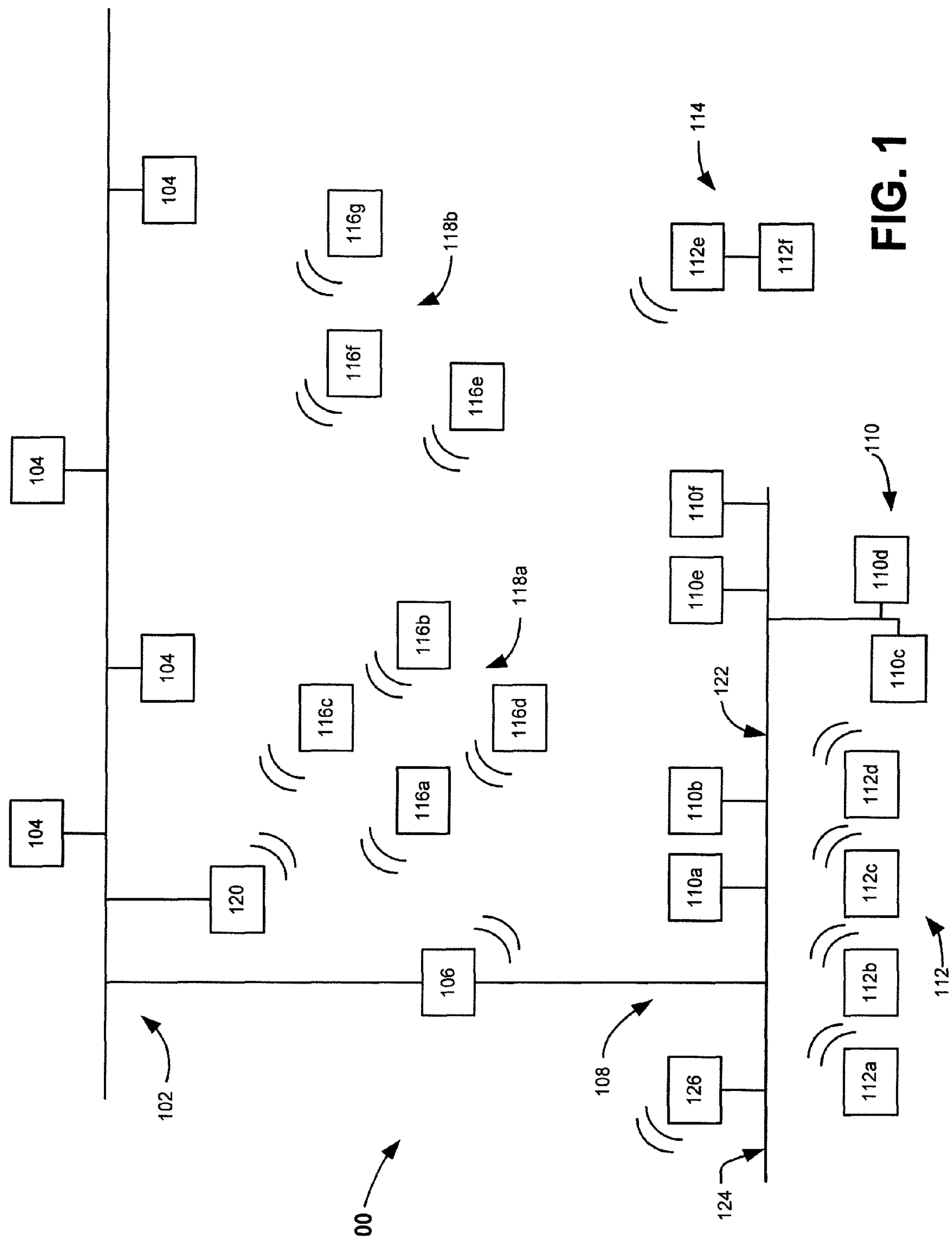
Assistant Examiner — Alfonso Perez Borroto

(57) **ABSTRACT**

An automation component configured for wireless communication within a building automation system includes a wireless communications component, a processor in communication with the wireless communications component, and a memory in communication with the processor. The memory configured to store computer readable instructions which are executable by the processor to process a change-of-value message received via the wireless communications component, generate a change-of-value update in response to the change-of-value message, and communicate the change-of-value update via the wireless communication component. This change-of-value can occur in a polled (pull) fashion, or in a pushed (when it occurs) fashions.

21 Claims, 4 Drawing Sheets





100
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112d
112e
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FIG. 1

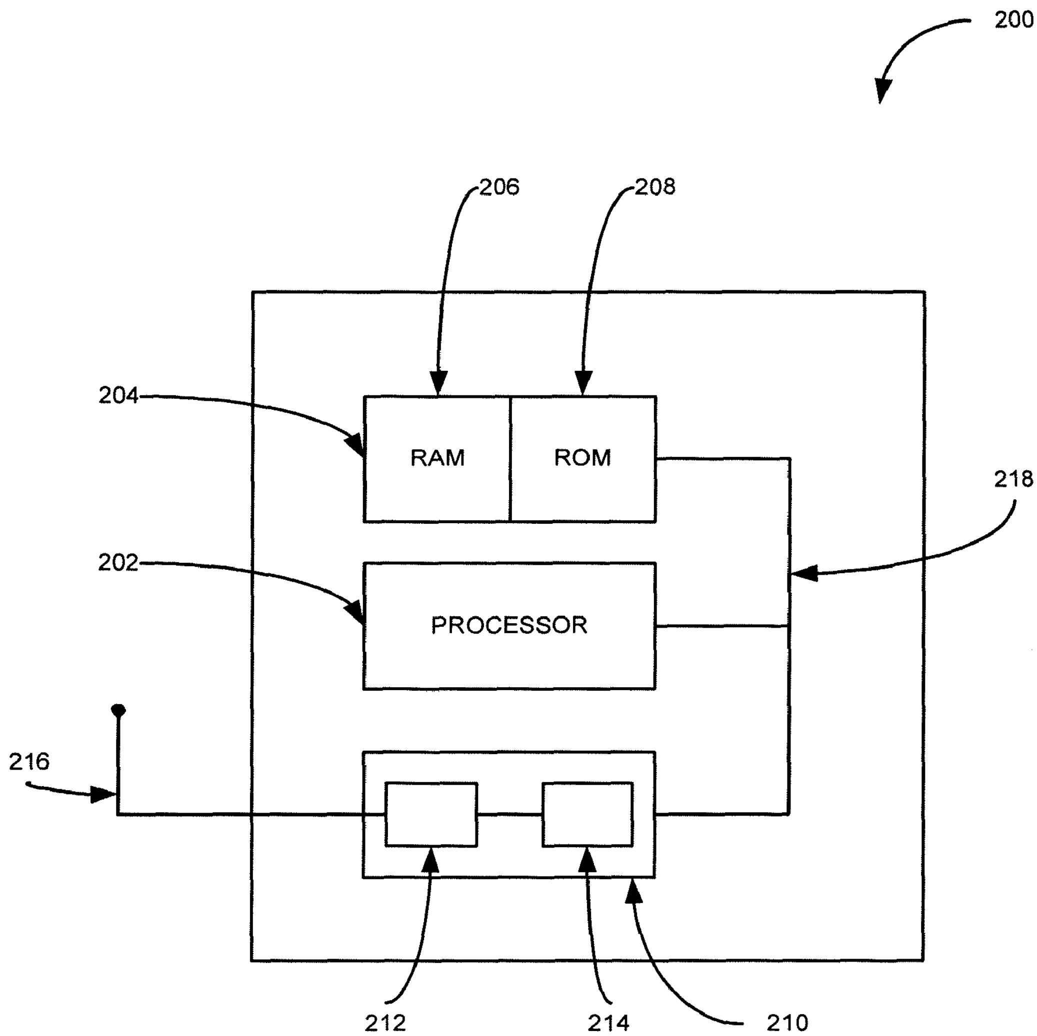

FIG. 2

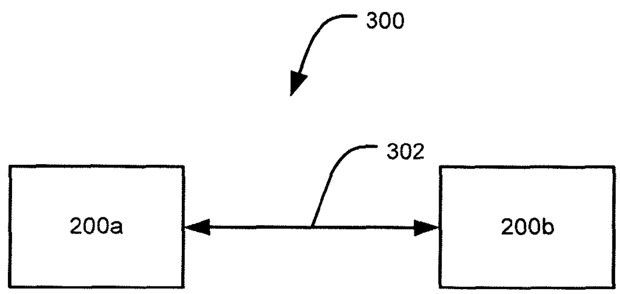
300
302
200a
200b

FIG. 3

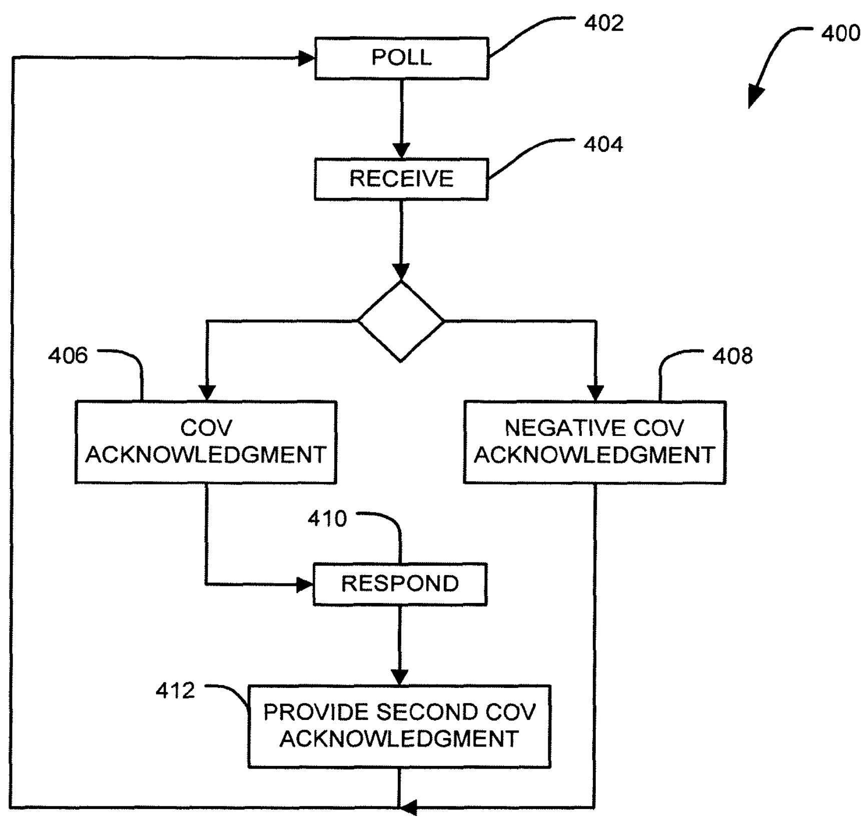
402
POLL
400
404
RECEIVE
406
408
COV ACKNOWLEDGMENT
NEGATIVE COV ACKNOWLEDGMENT
410
RESPOND
412
PROVIDE SECOND COV ACKNOWLEDGMENT

FIG. 4

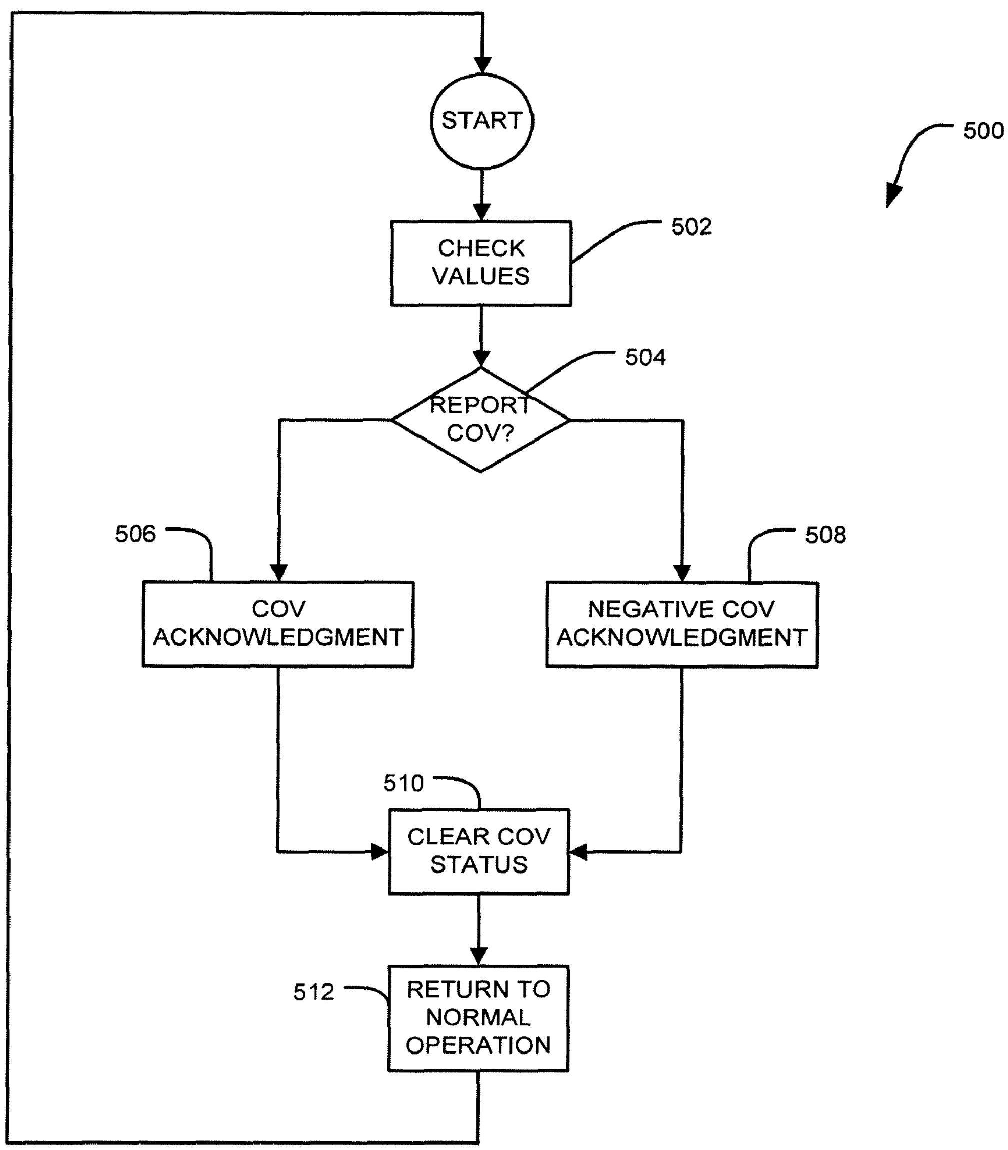
START
500
CHECK VALUES
502
REPORT COV?
504
506
COV ACKNOWLEDGMENT
508
NEGATIVE COV ACKNOWLEDGMENT
510
CLEAR COV STATUS
512
RETURN TO NORMAL OPERATION

FIG. 5

METHOD AND DEVICE FOR COMMUNICATING CHANGE-OF-VALUE INFORMATION IN A BUILDING AUTOMATION SYSTEM

BACKGROUND

The present disclosure generally relates to communications within a building automation system. In particular, the present disclosure relates to methods and devices for communicating change-of-value information within a building automation system.

A building automations system (BAS) typically integrates and controls elements and services within a structure such as the heating, ventilation and air conditioning (HVAC) system, security services, fire systems and the like. The integrated and controlled systems are arranged and organized into one or more floor level networks (FLNs) containing application or process specific controllers, sensors, actuators, or other devices distributed or wired to form a network. The floor level networks provide general control for a particular floor or region of the structure. For example, a floor level network may be an RS-485 compatible network that includes one or more controllers or application specific controllers configured to control the elements or services within floor or region. The controllers may, in turn, be configured to receive an input from a sensor or other device such as, for example, a room temperature sensor (RTS) deployed to monitor the floor or region. The input, reading or signal provided to the controller, in this example, may be a temperature indication representative of the physical temperature. The temperature indication can be utilized by a process control routine such as a proportional-integral control routine executed by the controller to drive or adjust a damper, heating element, cooling element or other actuator towards a predefined set-point.

Information such as the temperature indication, sensor readings and/or actuator positions provided to one or more controllers operating within a given floor level network may, in turn, be communicated to an automation level network (ALN) or building level network (BLN) configured to, for example, execute control applications, routines or loops, coordinate time-based activity schedules, monitor priority based overrides or alarms and provide field level information to technicians. Building level networks and the included floor level networks may, in turn, be integrated into an optional management level network (MLN) that provides a system for distributed access and processing to allow for remote supervision, remote control, statistical analysis and other higher level functionality. Examples and additional information related to BAS configuration and organization may be found in the co-pending U.S. patent application Ser. No. 11/590,157, filed on Oct. 31, 2006, and co-pending U.S. patent application Ser. No. 10/915,034, filed on Aug. 8, 2004, the contents of these applications are hereby incorporated by reference for all purposes.

Wireless devices, such as devices that comply with IEEE 802.15.4/ZigBee protocols, may be implemented within the control scheme of a building automation system without incurring additional wiring or installation costs. ZigBee-compliant devices such as full function devices (FFD) and reduced function devices (RFD) may be interconnected to provide a device net or mesh within the building automation system. For example, full function devices are designed with the processing power necessary to establish peer-to-peer connections with other full function devices and/or execute control routines specific to a floor or region of a floor level network. Each of the full function devices may, in turn, communicate with one or more of the reduced function devices in a hub and spoke arrangement. Reduced function devices such as the temperature sensor described above are designed with limited processing power necessary to perform a specific task(s) and communicate information directly to the connected full function device.

Wireless devices for use within the building automation system must be configured in order to establish communications with the different elements, components and networks that comprise the building automation system. Systems and method for configuring and establishing communications between the wireless devices and the automation components may be desirable and facilitate the setup, configuration, maintenance and operation of the building automation system.

SUMMARY

The present disclosure generally provides for communicating information between wireless devices and/or automation components operating within a building automation system (BAS). Wireless devices and/or automation components may be configured to automatically provide or otherwise push communications from one device to another upon detection of a change-of-value or change in the state of a sensed or monitored value, component and/or indicator.

In one embodiment, an automation component configured for wireless communication within a building automation system is disclosed. The automation component includes a wireless communications component, a processor in communication with the wireless communications component, a memory in communication with the processor and configured to store computer readable instructions which are executable by the processor. The computer readable instructions are programmed to process a change-of-value message received via the wireless communications component, generate a change-of-value update in response to the change-of-value message, and communicate the change-of-value update via the wireless communication component.

In another embodiment, a method for optimizing communications between automation components operating within a building automation system is further disclosed. The method includes detecting an indication representing a change-of-value, generating a change-of-value message, communicating the change-of-value message in response to the detected indication and receiving an acknowledgment of the communicated change-of-value message.

In another embodiment, an automation component configured for wireless communication within a building automation system is disclosed. The automation component includes a wireless communications component, a processor in communication with the wireless communications component, a memory in communication with the processor and configured to store computer readable instructions which are executable by the processor. The computer readable instructions are programmed to receive at least one change-of-value update via the wireless communications component, storing the at least one change-of-value update corresponding to at least one wireless device, and communicate the at least one change-of-value update in response to a polling request.

In another embodiment, a method of communicating information between automation components operating within a building automation system is disclosed. The method includes receiving a change-of-value message representing a wireless device indication, storing the received change-of-value message according to the corresponding wireless device, and communicating a change of value update that includes the change-of-value message.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description and the figures.

BRIEF DESCRIPTION OF THE FIGURES

The method, system and teaching provided relate to binding automation components within a building automation system (BAS).

FIG. **1** illustrates an embodiment of a building automation system configured in accordance with the disclosure provided herein;

FIG. **2** illustrates an embodiment of a wireless device or automation component that may be utilized in connection with the building automation system shown in FIG. **1**;

FIG. **3** illustrates an exemplary flowchart representative of a communications and updating configuration;

FIG. **4** illustrates an exemplary flowchart representative of a communications algorithm; and

FIG. **5** illustrates an exemplary flowchart representative of another communications algorithm.

DETAILED DESCRIPTION

The embodiments discussed herein include automation components, wireless devices and transceivers. The devices may be IEEE 802.15.4/ZigBee-compliant automation components such as: a personal area network (PAN) coordinator which may be implemented as a field panel transceiver (FPX); a full function device (FFD) implemented as a floor level device transceiver (FLNX); and a reduced function device (RFD) implemented as a wireless room temperature sensor (WRTS) that may be utilized in a building automation system (BAS). The devices identified herein are provided as an example of automation components, wireless devices and transceivers that may be integrated and utilized within a building automation system embodying the teachings disclosed herein and are not intended to limit the type, functionality and interoperability of the devices and teaching discussed and claimed herein. Moreover, the disclosed building automation system describes automation components that may include separate wireless devices and transceivers, however it will be understood that that the wireless device and transceiver may be integrated into a single automation component operable within the building automation system.

I. Building Automation System Overview

One exemplary building automation system that may include the devices and be configured as described above is the APOGEE® system provided by Siemens Building Technologies, Inc. The APOGEE® system may implement RS-485 wired communications, Ethernet, proprietary and standard protocols, as well as known wireless communications standards such as, for example, IEEE 802.15.4 wireless communications which are compliant with the ZigBee standards and/or ZigBee certified wireless devices or automation components. ZigBee standards, proprietary protocols or other standards are typically implemented in embedded applications that may utilize low data rates and/or require low power consumption. Moreover, ZigBee standards and protocols are suitable for establishing inexpensive, self-organizing, mesh networks which may be suitable for industrial control and sensing applications such as building automation. Thus, automation components configured in compliance with ZigBee standards or protocols may require limited amounts of power allowing individual wireless devices, to operate for extended periods of time on a finite battery charge.

The wired or wireless devices such as the IEEE 802.15.4/ZigBee-compliant automation components may include, for example, an RS-232 connection with an RJ11 or other type of connector, an RJ45 Ethernet compatible port, and/or a universal serial bus (USB) connection. These wired, wireless devices or automation components may, in turn, be configured to include or interface with a separate wireless transceiver or other communications peripheral thereby allowing the wired device to communicate with the building automation system via the above-described wireless protocols or standards. Alternatively, the separate wireless transceiver may be coupled to a wireless device such as a IEEE 802.15.4/ZigBee-compliant automation component to allow for communications via a second communications protocol such as, for example, 802.11x protocols (802.11a, 802.11b . . . 802.11n, etc.) These exemplary wired, wireless devices may further include a man-machine interface (MMI) such as a web-based interface screen that provide access to configurable properties of the device and allow the user to establish or troubleshoot communications between other devices and elements of the BAS.

FIG. **1** illustrates an exemplary building automation system or control system **100** that may incorporate the methods, systems and teaching provided herein. The control system **100** includes a first network **102** such as an automation level network (ALN) or management level network (MLN) in communication with one or more controllers such as a plurality of terminals **104** and a modular equipment controller (MEC) **106**. The modular equipment controller or controller **106** is a programmable device which may couple the first network **102** to a second network **108** such as a floor level network (FLN). The second network **108**, in this exemplary embodiment, may include a first wired network portion **122** and a second wired network portion **124** that connect to building automation components **110** (individually identified as automation components **110*a*** to **110*f***). The second wired network portion **124** may be coupled to wireless building automation components **112** via the automation component **126**. For example, the building automation components **112** may include wireless devices individually identified as automation components **112*a*** to **112*f***. In one embodiment, the automation component **112*f*** may be a wired device that may or may not include wireless functionality and connects to the automation component **112*e***. In this configuration, the automation component **112*f*** may utilize or share the wireless functionality provided by the automation component **112*e*** to define an interconnected wireless node **114**. The automation components **112*a*** to **112*f*** may, in turn, communicate or connect to the first network **102** via, for example, the controller **106** and/or an automation component **126**. The automation component **126** may be a field panel, FPX or another full function device in communication with the second wired network portion **124** which, in turn, may be in communication with the first network **102**.

The control system **100** may further include automation components generally identified by the reference numerals **116*a*** to **116*g***. The automation components **116*a*** to **116*g*** may be configured or arranged to establish one or more networks or subnets **118*a*** and **118*b***. The automation components **116*a*** to **116*g*** such as, for example, full or reduced function devices and/or a configurable terminal equipment controller (TEC), cooperate to wirelessly communicate information between the first network **102**, the control system **100** and other devices within the mesh networks or subnets **118*a*** and **118*b***. For example, the automation component **116*a*** may communicate with other automation components **116*b*** to **116*d*** within the mesh network **118*a*** by sending a message addressed to the network identifier, alias and/or media access control (MAC) address assigned to each of the interconnected automation components **116***a* to **116***g* and/or to a field panel **120**. In one configuration, the individual automation components **116***a* to **116***d* within the subnet **118***a* may communicate directly with the field panel **120** or, alternatively, the individual automation components **116***a* to **116***d* may be configured in a hierarchal manner such that only one of the components for example, automation component **116***c*, communicates with the field panel **120**. The automation components **116***e* to **116***g* of the mesh network **118***b* may, in turn, communicate with the individual automation components **116***a* to **116***d* of the mesh network **118***a* or the field panel **120**.

The automation components **112***e* and **112***f* defining the wireless node **114** may wirelessly communicate with the second network **108**, and the automation components **116***e* to **116***g* of the mesh network **118***b* to facilitate communications between different elements, section and networks within the control system **100**. Wireless communication between individual the automation components **112**, **116** and/or the subnets **118***a*, **118***b* may be conducted in a direct or point-to-point manner, or in an indirect or routed manner through the nodes or devices comprising the nodes or networks **102**, **108**, **114** and **118**. In an alternate embodiment, the first wired network portion **122** is not provided, and further wireless connections may be utilized.

FIG. **2** illustrates an exemplary automation component **200** that may be utilized within the control system **100**. The automation component **200** maybe be a full function device or a reduced function device and may be utilized interchangeably with the automation components **110**, **112** and **116** shown and discussed in connection with FIG. **1**. The automation component **200** in this exemplary embodiment may include a processor **202** such as an INTEL® PENTIUM, an AMD® ATHLON™ or other 8, 12, 16, 24, 32 or 64 bit classes of processors in communication with a memory **204** or storage medium. The memory **204** or storage medium may contain random access memory (RAM) **206**, flashable or non-flashable read only memory (ROM) **208** and/or a hard disk drive (not shown), or any other known or contemplated storage device or mechanism. The automation component may further include a communications component **210**. The communications component **210** may include, for example, the ports, hardware and software necessary to implement wired communications with the control system **100**. The communications component **210** may alternatively, or in addition to, contain a wireless transmitter **212** and a receiver **214** communicatively coupled to an antenna **216** or other broadcast hardware.

The sub-components **202**, **204** and **210** of the exemplary automation component **200** may be coupled and able to share information with each other via a communications bus **218**. In this way, computer readable instructions or code such as software or firmware may be stored on the memory **204**. The processor **202** may read and execute the computer readable instructions or code via the communications bus **218**. The resulting commands, requests and queries may be provided to the communications component **210** for transmission via the transmitter **212** and the antenna **216** to other automation components **200**, **112** and **116** operating within the first and second networks **102** and **108**. Sub-components **202-218** may be discrete components or may be integrated into one (1) or more integrated circuits, multi-chip modules, and or hybrids.

The exemplary automation component **200** may be, for example, a WRTS deployed or emplaced within the structure. In operation, the WRTS may monitor or detect the temperature within a region or area of the structure. A temperature signal or indication representative of the detected temperature may further be generated by the WRTS. In another embodiment, the automation component **200** may be, for example, an actuator coupled to a sensor or other automation component. In operation, the actuator may receive a signal or indication from another automation component **200** and adjust the position of a mechanical component in accordance with the received signal. The signal or indication may be stored or saved within the memory **204**. Moreover, the signal or indication may be stored to indicate that a change-of-value has occurred within the automation component **200**. In other words, the detection or reception of the signal or indication may operate as a change-of-value flag which denotes that the information, setting, signals and/or indications stored within the memory **204** have been altered, updated or otherwise changed. Alternatively, a separate change-of-value flag may be set and/or correspond to each detected or received signal or indication.

II. Automation Component Communication and Updating

FIG. **3** illustrates an exemplary communications and updating configuration **300** that may be implemented between automation components **200**. In this exemplary configuration, the automation components **200***a* may be configured to implement a request-response (polling) communication **302** in order to pull information from **200***b* device(s) to the polling device or for the **200***b* device to push values up to the **200***a* device. For example, the automation component **200***a* may represent a field panel, FPX or another full function device. Similarly, the automation component **200***b* may represent a TEC, FLNX, a Full function or reduced function device, a wireless actuator or any other wired or wireless device operable within the BAS **100**. Moreover, the automation components **200***a*, **200***b* may be operative within, for example, the mesh network or subnet **118***a*.

A. Request-Response (Polled) Communications

FIG. **4** illustrates a poll communication algorithm **400** or method that may be implemented, for example, between the automation components **200***a*, **200***b*. At block **402**, the automation component **200***a*, which may be a field panel or other full function device, may generate and communicate a change-of-value (COV) request message to one or more automation components **200***b* operating within the BAS **100** and/or within the individual FLNs that make up the BAS **100**. The COV request message may request or direct the automation component **200***b* to indicate whether any of the local detected values, received values, parameters, or measurements have changed or altered beyond a pre-defined reporting limit, e.g. COV limit.

At block **404**, the automation component **200***b* receives the COV request message. For example, if the automation component **200***b* has, since receipt of the last COV request message, detected or received a new value representing the change-of-value, then at block **406** the automation component **200***b* may generate a COV acknowledgment message for communication to the automation component **200***a*. Alternatively, if the automation component **200***b* hasn't detected or received the new value representing the change-of-value, then at block **408** the automation component **200***b* may generate a negative COV acknowledgment message for communication to the automation component **200***a*.

At block **410**, if the automation component **200***a* has successfully received the COV acknowledgment message provided by the automation component **200***b*, then the automation component **200***a* may generate and send an acknowledge COV request message for reply to the automation component **200***b*.

At block **412**, the automation component **200***b*, in response to the acknowledge COV request message provided by the automation component **200***a*, knows the COV was successfully transferred to the device **200***a* and clears those reported COV's, and provides a acknowledge COV request acknowledgment message. After block **412**, the communication algorithm **400** may restart and another wireless device or automation component within the BAS **100** may be polled. It will be understood that the exemplary communications algorithm **400** may be implemented in a wired or wireless BAS **100**

B. Push Communications

FIG. **5** illustrates an alternate communication algorithm **500** or method that may be implemented, for example, between the automation components **200***a*, **200***b*. The exemplary communication method **500** may be employed in a BAS **100** configured for hybrid communications utilizing both wired and wireless communications.

At block **502**, the automation component **200***b*, which may be, for example, a full function device, an FLNX and or a TEC, will check its inputs and outputs for new or changed values. If the new value has changed more than a pre-defined amount from the last reported value, then the variable is to be reported on the next COV communication.

At block **504**, the automation component **200***b* will check, at regular intervals established by an internal COV Reporting time interval or as needed by the internal algorithm, to see if Change-Of-Value (COV) are waiting to be reported. If so, the automation component **200***b* will create a Push COV message containing all queued COV values and send them to automation component **200***a*. At block **506**, the automation component **200***a* may respond to automation component **200***b* with a Push COV acknowledge response if the message is received and understood, or, at block **508**, will respond with a negative acknowledge (NAK) and an error code if the message was not understood. On receipt, at block **510**, automation component **200***b* clears the COV status. At block **512**, the automation component **200***b* may return to its normal operations until the next check for new values.

Automation component **200***a* now processes those queued COV's into the internal database of the automation component **200***a* and may optionally report those new values to other devices as defined in the drawings and description of FIG. **1**.

If automation component **200***b* was in fact a hardwired device with an external wireless network interface, such as a TEC with an FLNX configuration, then the FLNX would need to poll the TEC for COV's and hold them within the FLNX while the communication to automation component **200***a* was occurring. In addition, the FLNX would need to acknowledge the COV's from the TEC as was defined in algorithm of FIG. **4**.

If automation component **200***a* was a hardwired device with an external wireless network interface, such as a field panel with an FPX, then the FPX would need to act has the buffer for pushed COV's and queue the COV's for the field panel. The field panel would poll the FPX, in accordance with the algorithms of FIG. **4**, to accept the COV's into the database of the automation component **200***a*.

In this configuration, the communication algorithm **500** allows COV related messages to be gathered and pushed from one or more automation components **200***b* up to the **200***a* device and from the **200***a* device to other system components as defined in FIG. **1**. By pushing COV's up to automation component **200***a* as opposed to polling each automation component **200***b*, less wireless bandwidth is used and system end to end delays shortened.

If the automation component **200***b* is operating in a stable state without any COV's for extended periods of time (as defined by internal variable), the automation component **200***b* will communicate with the automation component **200***a* so that the automation component **200***a* knows that the automation component **200***b* is still operating. If the automation component **200***a* does not receive a message from the automation component **200***b* for a period longer than the internal variable defined within the automation component **200***b*, then the automation component **200***a* will report a loss of communication with the automation component **200***b*.

The communications algorithm **500** may be further configured to address and handle communications difficulties or errors between, for example, the automation components **200***a*, **200***b*. For example, if COV polling requests cannot be communicated or are not acknowledged by the intended receiving automation component, then the algorithm **500** may be configured to recover from the communications failure. Communication recovery may include repeating communication attempts a predetermined number of times (e.g., ten attempts). Similarly, if repeated communication attempts are unsuccessful, then the communication recovery may timeout and the procedure may be reattempted after a predetermined delay (e.g., every thirty minutes). Moreover, during the period when communication is not possible, the COV-related messages may still be aggregated and stored pending the reestablishment of communications.

It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. For example, the elements of these configurations could be arranged and interchanged in any known manner depending upon the system requirements, performance requirements, and other desired capabilities. Well understood changes and modifications can be made based on the teachings and disclosure provided by the present invention and without diminishing from the intended advantages disclosed herein. It is therefore intended that such changes and modifications be covered by the appended claims.

What is claimed is:

1. An automation component configured for wireless communication within a building automation system, the automation component comprising:

a wireless communications component;

a processor in communication with the wireless communications component;

a memory in communication with the processor, the memory configured to store computer readable instructions which are executable by the processor;

wherein the computer readable instructions are programmed to:

process a change-of-value request message received via the wireless communications component;

generate a change-of-value update in response to the change-of-value request message, wherein the change-of-value update includes a plurality of change-of-value messages received from a plurality of devices; and

communicate the change-of-value update via the wireless communication component at regular intervals according to a schedule or until a change-of-value acknowledgment is received.

2. The automation component of claim **1**, wherein the change-of-value request message is received from a wireless device.

3. The automation component of claim **2**, wherein the wireless device is a ZigBee-compliant device, a terminal equipment controller, a wireless room temperature sensor, a reduced function device, or a full function device.

4. The automation component of claim **1**, wherein the change-of-value update is a change-of-value response message.

5. The automation component of claim **1**, wherein the change-of-value update is automatically communicated.

6. The automation component of claim **1**, wherein the change-of-value update is pulled to a field panel transceiver in response to the reception of the change-of-value request message by the wireless communication component.

7. The automation component of claim **6**, wherein the computer readable instructions are further programmed to:

process an acknowledgment message communicated by the field panel transceiver in response to the change-of-value update.

8. A method of communicating information between automation components operating within a building automation system, the method comprising:

detecting an indication representing a change-of-value;

generating a change-of-value update that includes a plurality of change-of-value messages received from a plurality of devices;

repetitively communicating the change-of-value update in response to the detected indication;

receiving an acknowledgment of the communicated change-of-value update; and

terminating communication of the change-of-value update in response to the received acknowledgement.

9. The method of claim **8**, wherein the indication is a sensor reading, a temperature indication, or an actuator position.

10. The method of claim **8**, wherein at least one of the plurality of change-of-value messages includes the change-of-value and a device indicator.

11. The method of claim **8**, wherein communicating the change-of-value update includes automatically communicating the change-of-value update.

12. The method of claim **8**, wherein communicating the change-of-value update includes pushing the change-of-value update to a communicatively coupled wireless device.

13. An automation component configured for wireless communication within a building automation system, the automation component comprising:

a wireless communications component;

a processor in communication with the wireless communications component;

a memory in communication with the processor, the memory configured to store computer readable instructions which are executable by the processor;

wherein the computer readable instructions are programmed to:

receive at least one change-of-value update via the wireless communications component, wherein the change-of-value update includes a plurality of change-of-value messages received from a plurality of devices;

storing the at least one change-of-value update corresponding to at least one wireless device; and

communicate the at least one change-of-value update in response to a polling request and repeat the at least one change-of-value update at regular intervals according to a schedule or until a change-of value acknowledgment is received.

14. The automation component of claim **13**, wherein the change-of-value update is received from a wireless device selected from a Zig Bee-compliant device, a terminal equipment controller, a wireless room temperature sensor, a reduced function device, or a full function device.

15. The automation component of claim **13**, wherein the change-of-value update is a pushed communication.

16. The automation component of claim **13**, wherein the computer readable instructions are further programmed to:

communicate an acknowledgment in response to the received at least one change-of-value update.

17. A method of communicating information between automation components operating within a building automation system, the method comprising:

receiving a plurality of change-of-value messages from a plurality of wireless devices, each of the plurality of change-of-value messages representing a wireless device indication;

storing the received change-of-value messages according to the corresponding wireless device of the plurality of wireless devices; and

communicating a change-of-value update that includes the plurality of change-of-value messages, and repeating the change-of-value update at regular intervals according to a schedule or until a change-of-value acknowledgment is received.

18. The method of claim **17**, wherein the wireless device indication is selected from a sensor reading, a temperature indication, or an actuator position.

19. The method of claim **17**, wherein each of the plurality of the change-of-value messages includes the change-of-value and a device indicator.

20. The method of claim **17**, wherein communicating the change-of-value update includes automatically communicating the change-of-value-update.

21. The method of claim **17**, wherein communicating the change-of-value update includes pushing the change-of-value-update to a communicatively coupled wireless device.

* * * * *

CERTIFICATE OF SERVICE

I certify that today, December 17, 2024, I electronically filed the foregoing document with the Clerk of the Court for the U.S. Court of Appeals for the Federal Circuit using the appellate CM/ECF system.

/s/Brett Cooper
Brett E. Cooper
Counsel for Appellant Ollnova Technologies Ltd.

CERTIFICATE OF COMPLIANCE

This brief complies with the type-volume limitation of Federal Circuit Rule 32(b)(1), because this brief contains 4,999 words, excluding the parts of the brief exempted by Fed. R. App. P. 32(f). Fed. Cir. R. 32(b)(2).

This brief complies with the typeface requirements of Fed. R. App. P. 32(a)(5) and the type-style requirements of Fed. R. App. P. 32(a)(6) because this brief has been prepared in a proportionally spaced typeface using Microsoft Word in Times New Roman 14-point font.

/s/Brett Cooper
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