IN THE United Sates FOREIGN INTELLIGENCE SURVEILLANCE COURT and concomitantly before the Supreme Court, State of Florida, Supreme Court of the occupied Seminole Nation of Florida, and the US Court of Appeals for the Ninth and Eleventh Judicial Circuits

United States of America, ex rel Robin Hood

v. Case No. ___________

Smart Meter industry, FPL, General Lee Eng Tang (FPSC), US DOE, John and Jane Doe(s) 1-275, et al

Care of the USDOJ SEPS, Room 6217, 950 Pennsylvania Avenue, N.W, Washington, DC 20530

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VIA Rena Kim
FOIA Officer
USDOJ

Emergency ex parte Motion to enjoin General Lee Eng Tang, Bryan J. Olnick , Michael A. Dillon, John and Jane Doe(s) 1-275, US Department of Energy, Florida Public Service Commission, and Florida Power and Light from unlawful, wrongful, illegal, tortuous, and unconstitutional electronic surveillance by SmartMeters, and concomitant motion to discover such conduct and suppress all information arising therefrom

This Petition comes before the Court, submitted electronically (noting the Rules permit such, and only the supplemental Rules for 501(f) petitions require a signed original and one copy) to the Clerk, a Justice (through the Clerk at the USDC-DC), and the Security Officer through the USDOJ, pursuant to FISC RP Rule 5(a) "and such other authority, consonant with Article III of the Constitution and other statutes and laws of the United States, to the extent not inconsistent with the Act", Rule 7(b)(i) providing the Clerk shall (B) accept all documents for filing, Rule 7 (c) Electronic Filing. The Clerk, when authorized by the Court, may accept and file applications, Orders, and other filings by any reliable, and appropriately secure, electronic means, Rule 8 (c) Facsimile or Digital Signatures. With the Judge's consent, an application may be submitted by any reliable, and appropriately secure, electronic means, including facsimile, to invoke the jurisdiction of the Court under Articles One and Three of the Constitution for constitutional habeas and other writs jurisdiction, and the First through Fourth, Fifth, Sixth, Seventh, Eighth, Ninth, Tenth, Thirteenth and Fourteenth Articles of Amendment to the Constitution, as well as the statutory jurisdiction provided for in 28 USC 2241 and 28 USC 1651 (FISC RP Rule 4(a) provides that the FISC judges are all District Judges of the United States empowered under the All Writs Act by virtue of their appointment as District Judges regardless of which special courts they may serve on from time to time, FISC is a Court established by an Act of Congress and the Judges thereof this have All Writs authority), 28 USC 2201(a) (the FISC is a court of the United States) seeking a declaration of Petitioner's rights to be free from surveillance which could be authorized by the Court under Title 50 of the US Code or otherwise, 50 USC 1810 (the Act does not specify that Petitioner's aggrieved person cause of action will not lie before the FISC), 50 USC 1806 (c), (d),(f)" whenever any motion or request is made by an aggrieved person pursuant to any other statute or rule of the United States or any State before any court or other authority of the United States or any State to discover or obtain applications or orders or other materials relating to electronic surveillance or to discover, obtain, or suppress evidence or information obtained or derived from electronic surveillance under this chapter ", 50 USC 1806(i) (violates the Fourth amendment on its face), 50 USC 1825(g), 50 USC 1822(3)(B), 50 USC 1842(f), 50 USC 1861(e), 50 USC 1861(a)(1) and(2)(B) "provided that such investigation of a United States person is not conducted solely upon the basis of activities protected by the first amendment to the Constitution."

Such remote energy consumption surveillance exposes spouses to unlawful surveillance contrary the privacy rights secured under Loving v Virginia, etc., and places vulnerable persons at special risk, such as the elderly, infirm or differently abled, or persons subject to budgets controlled by Trustees or other fiduciaries. Smart Meters also violate the constitutional right to contract by impairing the inherent right of privacy essential to contracts for services affecting core household privacy issues (such as when occupants bathe, shave, shower), and the Third amendment rights of householders to keep the martial authorities of the US from quartering in their homes, even remotely. For Orthodox Jewish residents in the occupied Indian nations constituted and self-styled as the State of Florida, use of Smart Meters poses very problematic first amendment issues under the specific laws of the Jewish Shabbat commanded from Mount Sinai to the Jewish people as explained to them in each generation by the wisdom of the Princes of Israel, the Holy Torah teachers. Smart meters could well adversely affect reliance on Shabbat compliant devices in condominiums and nursing homes, or private homes, of Orthodox Jews and elderly survivors of the Holocaust. Smart meter use may thus violate the federal civil rights acts and federal religious civil rights acts, or Indian Civil Rights Acts.

"FPL is also partnering with Miami Dade College to develop a program through the Florida community college system that will help customers create personal energy plans using face-to-face training and hands-on participation - with a special focus on low-income communities, non-English-speaking communities, senior citizens and small business owners with activated smart meters. Training will be delivered at various locations, including college campuses, community centers, senior centers and civic and business association meetings, and will be tailored to meet the specific needs of the audience. This program is funded by a federal American Recovery and Reinvestment Act ("ARRA") grant from the U.S. Department of Energy. It will be offered free of charge and is scheduled to roll-out in the second quarter of 201 1."

www.**fpl**.com/energysmart/**pdf**/esf3.**pdf**

www.**fpl**.com/energysmart/**pdf**/esf1.**pdf** "Smart meters enable remote two-way communication".

http://www.fpl.com/energysmart/pdf/esf3.pdf Florida Power & Light smart meters – by the numbers: 4.5 million – total number of smart meter installations smartgridview.com/node/197

Bryan J. Olnick is the Vice President of Customer Service Smart Grid Solutions and Meter Operations at Florida Power & Light Company. In his current role, Mr. Olnick is responsible for the strategic development and deployment of FPL's Advanced Smart Metering Initiative (AMI) program which will affect over 4.5 million customers. Additionally, Mr. Olnick leads the development of FPL's key Smart Grid strategies and initiatives, including the $800 million dollar Energy Smart Florida (ESF) project, which will be partially funded through a $200 million dollar grant from the U.S. Department of Energy.

He is also involved in the development of national standards for the Smart Grid industry. Other previous major initiatives he has managed for FPL include: Distribution Automation, Remote Capacitor and VAR control, and Outage Management System implementations. Additionally, Mr. Olnick leads a workforce of 275 field technicians and professionals responsible for all meter related activities including engineering, purchasing, product testing and evaluation, and daily meter connect requests throughout FPL's state-wide service territory.

Prior to joining FPL, Mr. Olnick held a variety of positions ranging from a correspondent for the New York Times, Sales Director for Tech Electronics, Inc., and Division Manager for Sound Marketing, Inc., located in Frankfurt, Germany. He proudly served five years in the United States Air Force in the US, Europe, and Middle East. He is a member of IEEE, Florida Engineering Society, EEI, and Utilimetrics.
http://www.collinscenter.org/resource/resmgr/sustainable_fl_docs/olnick_bio.pdf

Pursuant to Order No. PSC-10-0153-FOF-E1, issued March 17, 2010 in Docket Nos. 080677-E1 and 090130-E1 ("Order 0153"), Florida Power & Light Company ("FPL") Provided an annual progress report on its implementation of smart meters.

As of March 1, 201 1, FPL has installed approximately 1.7 million
smart meters in its service area, approximately 800,000 of which have been activated,
allowing these meters to be read remotely.

FPL continues to anticipate it will achieve full
deployment of residential smart meters throughout its service area by the fourth quarter
of2013.

Customers will benefit from reliability improvements, including outage identification and
prevention and faster restoration, even if they choose not to change their behavior as a
result of having the smart meter and access to usage information.

Instead of having to wait until the end of the month to see how much energy they used, customers whose smart meters have been activated have access to an online energy portal, where they can see how much energy they are using by the hour, day, and month, as well as what they are spending for electricity during those time intervals, and make informed choices. The average temperature for each day is also available so that customers can correlate the impact weather has on their energy use. Customers can also compare their past energy use information to see trends or patterns in their energy use.

FPL's proposed pilot is part
of our In-Home-Technology Project, which is designed to test emerging in-home technologies and to assess whether a new pricing incentive is effective in helping customers change their energy habits. Participants in the voluntary project will provide
valuable feedback as FPL continues to explore new products and services to help our customers gain more control over their energy use and save them money. This pilot is a
component of our Energy Smart Florida initiative and is funded by the A R M grant.
www.gc.energy.gov/.../**FloridaPowerLight**_Comments_CommsReqs.**pdf**

FPL strongly supports the Department of Energy Smart Grid vision that enables energy **....** Outage notification / power loss notification at the meter **....** training and video surveillance will demand additional bandwidth to the plants

www.nistep.go.jp/achiev/ftx/eng/stfc/stt038e/qr38**pdf**/STTqr3802.**pdf** setting, automation, surveillance, and network management.

Wireless communications is a key enabler of the emerging smart grid. While the smart grid is far from

complete, utilities have successfully deployed millions of smart meters and are leveraging two-way wireless

communications to relay usage data accurately, implement energy awareness and demand response

programs, and run other smart grid applications.

Smart meter connectivity and other Neighborhood Area Network (NAN) communications can take place over privately licensed spectrum or license-free 900 MHz spectrum.

Silver Spring Networks is a leading smart grid solution provider

whose communications platform, based on unlicensed 900 MHz spectrum, has been selected to power

more than 17 million smart meters in the United States and abroad.

Devices shifting to higher frequencies - In recent years, many household devices and new technologies

that do not need to transmit long distances have moved to the larger unlicensed spectrum bands at 2.4

GHz and 5 GHz, including wireless in-home networks.

» Prevalence of low power devices - Many of the devices that do operate at 900 MHz, such as some

cordless phones, operate at very low power levels to conserve battery life. Lower-power devices

generate less noise within the band.

When noise is present, a well-designed unlicensed system can still provide robust communications. Utilities

considering solutions that operate in unlicensed spectrum should look for systems that offer the following

capabilities:

» Rapid frequency hopping across many channels to sidestep interference from other sources

» Communications protocols that reduce the probability of collisions when transmitting

» A self-forming mesh network architecture to route around noisy RF areas

Since the early 1990s, utility commissions across the country have approved billions of dollars of rate-

recoverable utility assets based on unlicensed spectrum. Historically, unlicensed spectrum has been used for

one-way automated meter reading (AMR) and for SCADA systems that need to communicate with power

control devices deployed across a utility's distribution network. Today, many of the largest AMI deployments

in the world use unlicensed spectrum, including:

United States

» Pacific Gas and Electric

» Florida Power & Light

» Pepco Holdings

» Southern California Edison

» San Diego Gas & Electric

» Oncor

» CenterPoint Energy

Fact #3: Unlicensed spectrum is used for other critical communications.

In addition to serving the needs of utilities, major cities across the United States such as New Orleans, Las

Vegas, and Spokane, Wash. use unlicensed spectrum for public safety communications, video surveillance

and emergency disaster response.

Canada

» Toronto Hydro

» Hydro One

Australia

» Jemena

» CitiPower & Powercor

Protection against rF attacks and eavesdropping. The use of
FHSS provides inherent protection against jamming and eavesdropping. Each Silver Spring radio has a
different hopping sequence, and radios hop to different channels anywhere from 50 to 100 times per
second, making it extremely difficult for outsiders to track and lock onto the signal.
www.silverspringnet.com/**pdf**s/SilverSpring-Whitepaper

www.ntia.doc.gov/comments/100402174.../CDT_smartgrid_comment.**pdf** www.oe.energy.gov/DocumentsandMedia/SGSRMain_090707_lowres.pdf. ... Google PowerMeter to collect smart meter data directly from utilities.21 ... 19 For example, in Florida Power and Light Company's Residential On Call program, ... and surveillance by law enforcement, as discussed further below. ...

Prayer for Relief

1. The FISC Court and US Court of Appeals for the Eleventh Circuit shall enjoin FPL and PGE, SCEdison, US DOE, FPSC, CPSC, and all or any utilities in the US (including the allied American Formosa trust territory island of Taiwan), from use of Smart Meters without lawful authority therefor.
2. The Courts shall impose punitive damages of US$100 billion dollars on the Smart Meter deployed utilities, Cisco, and Silver Spring Networks, or other stakeholders in the ongoing civil rights conspiracy to deprive and impair consumers of the right to contract for use of energy as they see fit.
3. The Courts shall impose additional damages for the violations of Orthodox Jewish rights to be free from Sabbath surveillance through Smart Meters affecting Sabbath mode reliance in electronic appliances, elevators, and otherwise affecting Sabbath quality of life and observance.
4. The FISC Court shall enjoin any use of electronic surveillance obtained by Smart Meters contrary the Constitution, treaties and laws.
5. All other proper relief.

Respectfully submitted,

Dr. Paul Maas Risenhoover, Petitioner/Appellant Pro Se as Relator for the USA
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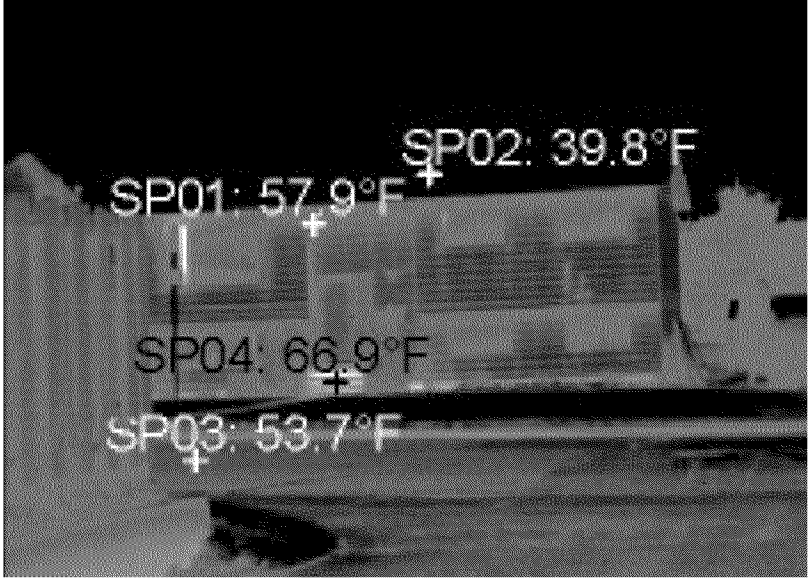
Appendices



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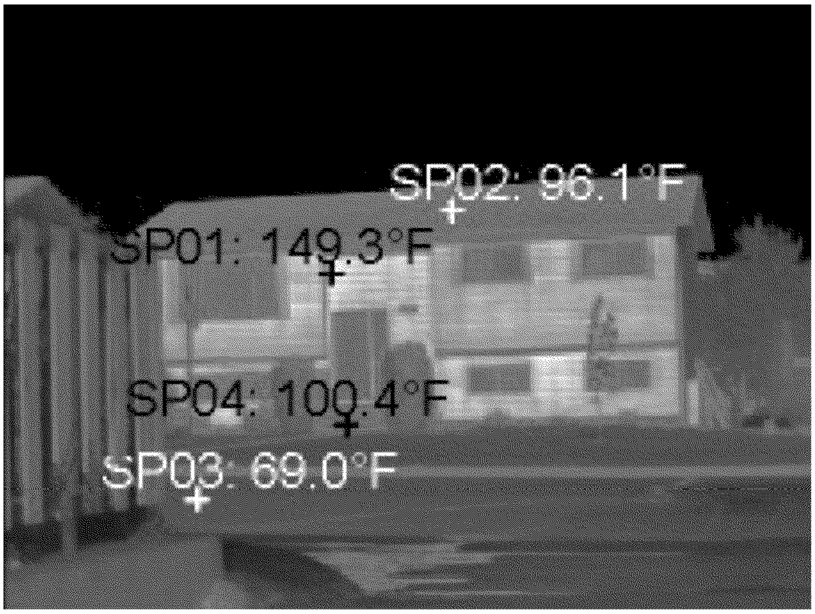

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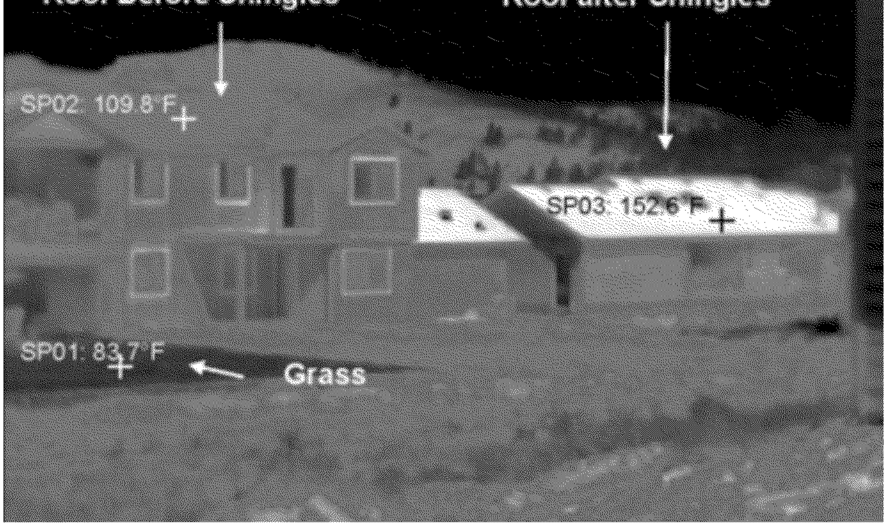
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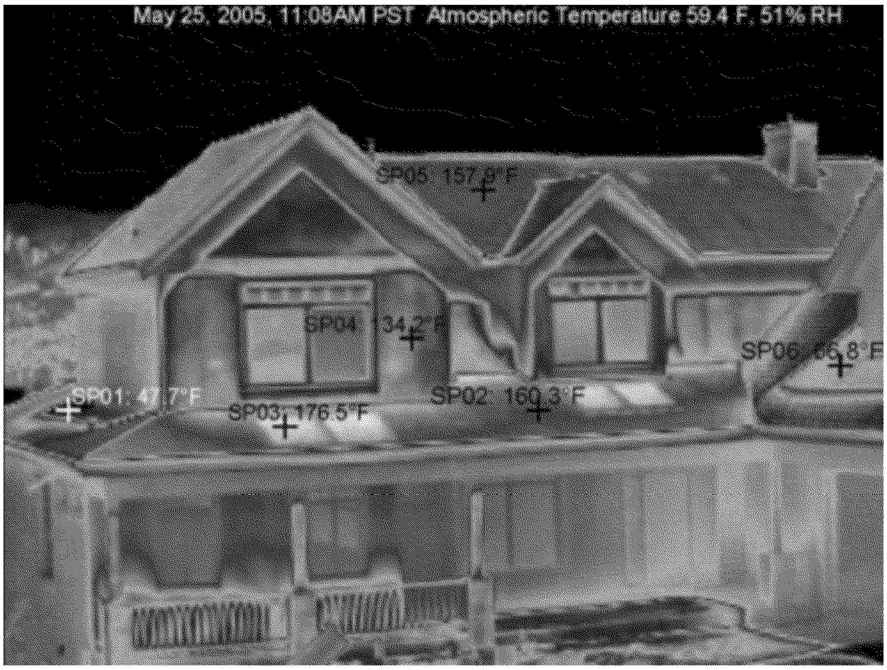
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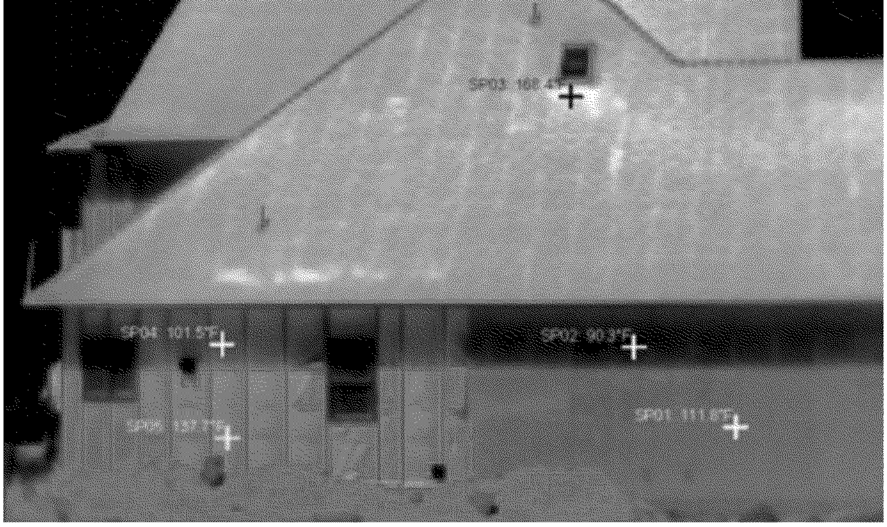
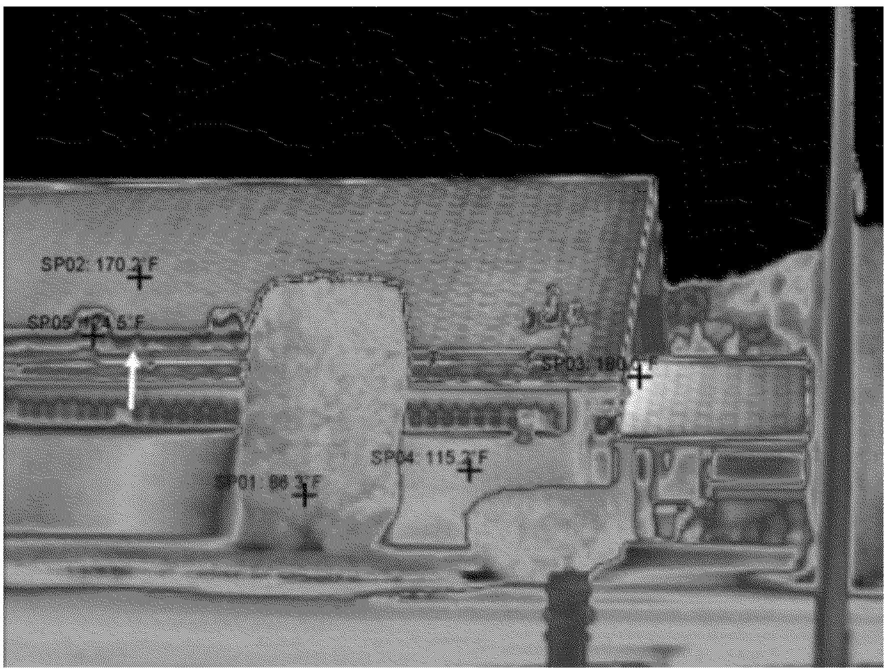
SP03: 176.5°F
SP02: 160.3°F





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Appendix electronic surveillance is the very purpose of smart meter technology

United States Patent **7,884,727**
Tran **February 8, 2011**

Wireless occupancy and day-light sensing

Abstract

A system to control energy consumption in a room uses a wireless mesh network that allows for continuous connections and reconfiguration around blocked paths by hopping from node to node until a connection can be established, the mesh network including one or more wireless area network transceivers adapted to communicate data with the wireless mesh network, the transceiver detecting motion by analyzing reflected wireless signal strength.

Inventors: **Tran; Bao** (San Jose, CA)
Appl. No.: **11/832,697**
Filed: **August 2, 2007**

Related U.S. Patent Documents

Application Number	Filing Date	Patent Number	Issue Date<TD< TD>
60939856	May., 2007		<TD< TD>

Current U.S. Class: **340/573.1** ; 307/117; 340/500; 342/28; 700/278
Current International Class: G08B 23/00 (20060101)
Field of Search: 340/573.1,500 342/18 307/117 700/278

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Other References

Dietz, et al "Very Low Cost Sensing and Communication Using Bidirectional LEDs", MERL 2003. cited by other.

Primary Examiner: Bugg; George A

Assistant Examiner: Nwugo; Ojiako

Attorney, Agent or Firm: Tran & Associates

Parent Case Text

This invention claims priority from Provisional Application Ser. No. 60/939,856, filed May 24, 2007 and 11/768,381, filed Jun. 26, 2007, the contents of which are incorporated by reference.

Claims

What is claimed is:

1. A system to control energy consumption in a room, comprising: a wireless data transceiver, said transceiver detecting motion by analyzing reflected radio frequency wireless signal strength; and an appliance coupled to the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength, wherein the transceiver comprises a Multiple Input Multiple Output (MIMO) transceiver coupled to a plurality of MIMO antennas, wherein the MIMO transceiver comprises a Doppler radar.

2. The system of claim 1, comprising a recognizer coupled to the transceiver including one of: a Hidden Markov Model (HMM) recognizer, a dynamic time warp (DTW) recognizer, a neural network, a fuzzy logic engine, a Bayesian network.

3. The system of claim 1, comprising a sound transducer coupled to the wireless transceiver to communicate audio over a telephone network through the mesh network.

4. The system of claim 3, comprising a call center coupled to the transceiver to provide a human response.

5. The system of claim 1, comprising an in-door positioning system coupled to one or more mesh network appliances to provide location information.

6. The system of claim 1, comprising a ***smart meter*** coupled to the appliance, wherein the ***smart meter*** includes bi-directional communication, power measurement and management capability, software-controllable disconnect switch, and communication over low voltage power line.

7. The system of claim 1, wherein the appliance minimizes operating cost by shifting energy use to an off-peak period in response to utility pricing that varies energy cost by time of day.

8. The system of claim 1, comprising a rechargeable energy reservoir coupled to the appliance, wherein the reservoir is charged during a utility off-peak period and used

during a utility peak pricing period.

9. A system to control energy consumption in a room, comprising: a wireless data transceiver, said transceiver detecting motion by analyzing reflected radio frequency wireless signal strength; and an appliance coupled to the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength; and a remote processor that can remotely turn power on or off for the appliance, read usage information from a meter, detect a service outage, detect the unauthorized use of electricity, change the maximum amount of electricity that the appliance can demand, and remotely change the meters billing plan from credit to prepay as well as from flat-rate to multi-tariff.

10. A system to control energy consumption in a room, comprising: a wireless data transceiver, said transceiver detecting motion by analyzing reflected radio frequency wireless signal strength; and an appliance coupled to the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength; and a light emitting diode (LED) coupled to the wireless transceiver, the LED having a first mode to generate light and a second mode to generate a voltage based on ambient light.

11. The system of claim 10, comprising an analog to digital (ADC) converter reading an output from the LED corresponding to ambient light in the area.

12. A system to control energy consumption in a room, comprising: a wireless data transceiver, said transceiver detecting motion by analyzing reflected radio frequency wireless signal strength; and an appliance coupled to the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength; and a mesh network that communicates lighting profiles that incorporate time-based control with occupancy, daylighting, and manual control and an analyzer that integrates time-based lighting control with occupancy sensing control.

13. A system to control energy consumption in a room, comprising: a wireless data transceiver, said transceiver detecting motion by analyzing reflected radio frequency wireless signal strength; and an appliance coupled to the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength; and a light emitting diode (LED), the LED generating light in a first mode and sensing room light in a second mode.

14. The system of claim 13, comprising a flexible membrane coupled to the LED to pick up sound vibration, wherein the LED senses sound in a third mode.

15. The system of claim 13, comprising an energy scavenger coupled to the processor and transceiver and LED to provide power.

16. The system of claim 13, wherein the LED is operated under a reverse bias condition to optically induce a photocurrent and wherein the photocurrent is measured to determine incident light in a room, wherein the appliance is turned on or off based on daylight and occupancy determination while the wireless data transceiver tranceives data to provide automatic appliance control with minimal incremental cost by sharing the LED and wireless data transceiver.

17. A system to control energy consumption in a room, comprising: a wireless data transceiver, said transceiver detecting motion by analyzing reflected radio frequency wireless signal strength; and an appliance coupled to the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength; and a processor that integrates time-based lighting control, sound detection control and occupancy sensing control.

Description

BACKGROUND

This invention relates generally to methods and systems for sensing occupancy.

Many building owners, including the owners of apartments, offices and hotels, continue to seek methods to decrease their heating, ventilating and cooling ("HVAC") expenses. One method to do so is to select minimum and maximum setback temperatures for a room when the room is not occupied. Motion detection devices have been used to determine if the room is occupied and thus being used. Motion detectors have also been used as intrusion detection devices, or ***surveillance*** systems, have been developed to monitor an area or space, to protect against the entry of unauthorized personnel into that area or space, and to provide an alarm signal when such entry occurs.

Motion sensors can be based on sonic or ultrasonic/acoustical detectors, photoelectric break-beam devices, passive infrared detectors, video systems, and radar or microwave-based systems. The sonic, ultrasonic or acoustical devices are illustrated in U.S. Pat. Nos. 4,499,564, 4,382,291, 4,229,811 and 4,639,902. In the devices disclosed in these patents the intrusion detection systems utilize an acoustical signal, either sonic or ultrasonic, which is transmitted into the space to be protected. The acoustical signal is reflected off of objects in the space or the walls forming the perimeter of the space and is collected by an acoustical receiver. The return signal represents the total reflected energy pattern for that space. A change in the signal received indicates some change in the space protected; however, these systems do not provide any means of identifying where, either directionally or distance-wise, in the protected space that the change has occurred. Thus, the only information derivable from such systems is whether or not such a change has occurred which then requires some form of follow-up by the security force. An additional limitation of systems of this type is that they are generally unacceptable in anything but a closed environment since they are subject to false alarms from naturally occurring sound changes such as generated by wind, thunder, or other naturally occurring sounds in an open environment.

The photoelectric break-beam devices are illustrated in U.S. Pat. Nos. 3,875,403, 4,239,961, 4,310,756, 4,384,280 and 4,514,625. In the devices disclosed, the intrusion detection system uses an active photo-beam projected into the area under ***surveillance***. A detector sees the continuous beam at the opposite end of the detection zone. If the photo-beam is broken by an intruder, then an alarm is sounded. This type of system does not give any information above the distance of the intruder from the detector device. This system also requires two head units with the protection zone between them. This leads to a more complex installation than if only one unit is required.

Passive infrared detection technology is illustrated in U.S. Pat. Nos. 3,476,946, 3,476,947, 3,476,948 and 3,475,608. With systems such as these, changes in the infrared content of the light received by the device from the area under control is monitored and an alarm signal is generated if the infrared content changes. This is based on the presumption that the infrared content of the light will be affected by intruders, particularly individuals, entering into the controlled space. However, it has been found that such infrared detectors are falsely triggered by normal changes in the infrared content of the light in a space due to ordinary changes in the sun as well as the effects of clouds passing over the sun. Still further, such systems do not provide distance or direction information and thus require follow-up by security staff to determine the true nature of the cause that triggered the alarm.

The video based intrusion detection systems utilize a video camera to view an area under protection and are illustrated in U.S. Pat. Nos. 3,823,261; 3,932,703 and 4,408,224. Typically, the video signal is digitized and stored in a memory. Thereafter, the video signal is compared with a reference signal stored in the memory and, when a difference is detected, an alarm is sounded. These systems use changes in scene illumination to determine an alarm condition rather than changes in object distances and therefore, unless the space to be observed and protected is carefully controlled and isolated from changes in environmental illumination, such changes will result in false alarms. As a result, such a system is less than satisfactory for exterior spaces. Furthermore, the amount of data that is necessarily stored to obtain reasonable resolution of the image of the space being protected requires a significant quantity of expensive computer memory.

Systems employing radar or other microwave technology are illustrated in U.S. Pat. No. 4,197,537. In this particular system a single microwave signal source is used to bathe the space with microwave energy. A receiver detects the return signal reflected from the space being protected which can be compared with a reference signal to detect an intrusion thereinto. This particular system is unable to identify the precise location of the intruder.

While other radar/microwave-based systems can provide such information, their cost can be significant. U.S. Pat. No. 4,952,911 discloses a scanning intrusion detection device that is capable of monitoring a large volume of either interior or exterior space from a single relatively inexpensive unit. This intrusion detection device has a radiation emitter arranged to scan a beam of infrared radiation about a field of view and means for receiving the radiation of the beam reflected from the field of view. The receiver is arranged to generate a signal indicative of the distance from the device at which the beam has been reflected for each of a plurality of azimuthal sectors of the field of view during a selected time period. The device stores a plurality of reference signals which are indicative of the distance of reflection of the beam from each azimuthal sector of the field of view during a reference time period. The signals from a selected time period are compared with the reference signals and an output signal is generated if one of the signals is different from the respective reference signal.

SUMMARY

In one aspect, a system to control energy consumption in a room uses a wireless mesh network that allows for continuous connections and reconfiguration around blocked paths by hopping from node to node until a connection can be established, the mesh network including one or more wireless area network transceivers adapted to communicate data with the wireless mesh network, the transceiver detecting motion by analyzing reflected wireless signal strength.

In another aspect, an occupancy sensing system for an area includes one or more wireless nodes forming a wireless mesh network; and wireless transceiver adapted to communicate with the one or more wireless nodes, the wireless transceiver generating a received signal strength indication (RSSI) signal, wireless transceiver including an analyzer to process the RSSI signal to detect occupancy in the area.

In yet another aspect, a system includes a processor; a transceiver coupled to the processor and communicating an RSSI signal to indicate the presence of one or more persons in a room; and a light emitting diode (LED) coupled to the processor, the LED generating light in a first mode and sensing room light in a second mode.

Implementations of the above system may include one or more of the following. An appliance can be controlled by the transceiver, the appliance being activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength. A recognizer can be embedded in the transceiver including one of: a Hidden Markov Model (HMM) recognizer, a dynamic time warp (DTW) recognizer, a neural network, a fuzzy logic engine, a Bayesian network. The recognizer monitors one or more personally identifiable signatures. The transceiver identifies one person from another based on a Doppler heart rate signature. A sound transducer can be connected with the wireless transceiver to communicate audio over a telephone network through the mesh network. A call center or a receptionist or a person in a company's facility department can be connected to the transceiver to provide a human response such as a voice response to a question, or the call center can remotely turn off the appliance if appropriate. An in-door positioning system can be connected to one or more mesh network appliances to provide location information. The transceiver can be a Doppler radar. A wireless router can be connected to the mesh network and wherein the wireless router comprises one of: 802.11 router, 802.16 router, WiFi router, WiMAX router, Bluetooth router, X10 router. The transceiver can be a Multiple Input Multiple Output (MIMO) transceiver coupled to a plurality of MIMO antennas. The MIMO transceiver can operate as a Doppler radar. The transceiver transmits a pattern of predetermined varying burst widths and determines motion based on the received pattern of predetermined varied burst widths. A ***smart meter*** can control or communicate with the appliance. The ***smart meter*** includes bi-directional communication, power measurement and management capability, software-controllable disconnect switch, and communication over low voltage power line. A remote processor such as a processor in a different room or a different building can remotely turn power on or off for the appliance, read usage information from the meter, detect a service outage, detect the unauthorized use of electricity, change the maximum amount of electricity that the appliance can demand, and remotely change the meters billing plan from credit to prepay as well as from flat-rate to multi-tariff. The appliance minimizes operating cost by shifting energy use to an off-peak period in response to utility pricing that varies energy cost by time of day. A rechargeable energy reservoir can provide power to the appliance, wherein the reservoir is charged during a utility off-peak period and used during a utility peak pricing period. The appliance's operation is customized to each individual's preference. The appliance's operation can be customized to a plurality of individuals in a room by clusterizing all preferences and determining a best fit preference from all preferences. The mesh network can store and analyze personal information including one of: heart rate, respiration rate, medicine taking habits, eating and drinking habits, sleeping habits, excise habits. In a Doppler radar embodiment, the frequency of a radio signal is altered when the signal reflects off of a moving object. In one embodiment, the movement of people is detected. In another embodiment, the periodic movement of the chest and internal organs of the person modulates an incident or transmitted radio signal from one of the wireless transceivers, and the resulting reflection is interpreted to deduce, for example, heart and breathing activity. Transceivers that operate at high frequencies can be used to provide higher resolution and improved antenna patterns could be used for more detailed observations of arterial motion.

In other implementations, a light emitting diode (LED) can be connected to the wireless transceiver, the LED having a first mode to generate light and a second mode to generate a voltage based on ambient light. An analog to digital (ADC) converter such as a sigma delta converter can read an output from the LED corresponding to ambient light in the area. The analyzer identifies one occupant from another based on a Doppler signature. The mesh network communicates lighting profiles that incorporate time-based control with occupancy, daylighting, and manual control and wherein the analyzer integrates time-based lighting control with occupancy sensing control. The LED can sense sound in a third mode. The processor integrates time-based lighting control, sound detection control and occupancy sensing control.

Advantages of the system may include one or more of the following. The system provides motion sensing practically for free by simply adding software to each wireless transceiver. In contrast, conventional system requires extra hardware such as PIRs or photocells to detect people in a room, among others. The same wireless transceiver for controlling the appliance is used to sense motion and thus the cost is virtually free. The system provides links between information technologies and electricity delivery that give industrial, commercial and residential consumers greater control over when and how their energy is delivered and used. The system provides wireless metering capability measurable to each device or appliance. Additionally, real-time electricity pricing information is used to optimize cost. The system links devices starting with the utility meter and reaches thermostats, household appliances, HVAC, pool pumps, water heaters, lighting systems and other household or building systems that are part of the home area network (HAN). The system provides a standards based approach to energy efficiency programs such as demand response, time-of-use pricing programs, energy monitoring, pay-as-you-use and net metering programs, enabling home owners use of distributed generation products like solar panels. These new energy management capabilities directly impact consumers and businesses as utilities grapple with meeting growing power demand while reducing the threat of rolling blackouts during peak usage periods. With the system, users can: view and react to energy consumption every day; track and adjust energy consumption; plan, budget and pre-pay their utilities bills; save energy and money based on price fluctuations; enhance conservation by using less energy during peak demands; and help the environment by helping consumers reduce greenhouse gas emissions through less energy usage.

Lighting commercial buildings in the United States currently consumes about 3.7 quadrillion Btus (British thermal units) of primary energy a year, equivalent to the output of over 175 modern power plants. Lighting accounts for 30 to 50% of a building's energy use, or about 17% of total annual US electricity consumption. Simply turning off unneeded lights can reduce direct lighting energy consumption up to 45%. Reducing lighting electricity usage reduces energy cost and lessens the environmental impacts associated with electricity generation. The system enables buildings to automatically dim electric lights in daylit spaces, and building occupants could manually dim local lighting according to preference, the U.S. energy savings could amount to more than half a quadrillion Btus per year--about 14 percent of annual energy use for lighting in commercial buildings.

Other advantages of RF wireless control include reduced capital and operating expenses. Wireless control can save as much as 30 to 40 percent on installation and material costs compared to a wired control system, making this option potentially attractive for retrofit as well as new construction. Maintenance expenses can be reduced because devices can be replaced one to one without control wiring being involved. As another potential benefit, RF wireless control offers flexibility centered on the mobility of devices, which can be moved and grouped based on evolving application needs without changing wiring. Wireless control systems are scalable, as devices can be added and removed easily. Based on adoption of open protocols, lighting control systems can be more easily integrated with other building systems such as HVAC and security. Intelligence can be both centralized and decentralized, with devices receiving commands from a central computer (and sending information back in a two-way stream), while also interacting with each other independently and allowing occupant control of local systems without location restraints. With wireless components, the system can grow over time and be reconfigured if needed at a much lower cost for a hard-wired system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a wireless area network (WAN) that provides occupancy or motion sensing.

FIG. 2 shows an exemplary process for sensing occupancy or motion using a WAN transceiver.

FIG. 3 shows an exemplary transceiver circuit.

FIG. 4 shows an exemplary transceiver operating as a Doppler radar.

FIG. 5 shows a MIMO transceiver operating as a Doppler radar.

FIG. 6 shows an exemplary LED ambient light sensor.

FIG. 7 shows an exemplary LED based microphone to detect sound in the room.

FIG. 8 shows an exemplary mesh network in communication with the occupancy sensing system.

FIG. 9 shows an exemplary mesh network.

DESCRIPTION

Reference will now be made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the preferred embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be obvious to one of ordinary skill in the art that the present invention may be practiced without these specific details. In other instances, well known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the present invention.

FIG. 1 shows a wireless area network that provides motion sensing. A wireless communication transceiver 10 is mounted in a room such as near an entrance. The transceiver 10 includes a sensor to determine whether the room is empty or being used by at least one person 12. The sensor can be implemented in software to provide the motion sensing at a very low cost. A plurality of transceivers 10 form a mesh network 22, which is a communications network having two or more paths to any node. Mesh networking is a way to route data, voice and instructions between nodes. It allows for continuous connections and reconfiguration around blocked paths by "hopping" from node to node until a connection can be established. The transceiver 10 can be an 802.15 (ZigBee) transceiver, but can also be 802.11 (WiFi) transceiver, 802.16 (WiMAX) transceiver, Bluetooth transceiver, cellular transceiver, or cordless telephone transceiver, among others. The transceiver 10 wirelessly communicates with one or more appliances 20 using the mesh network 22. The transceiver 10 controls one or more appliances 20 directly, or alternatively, can send a message to a host device that controls the appliances 20.

In this embodiment, a wireless device such as transceiver 10 transmits a radio frequency (RF) signal and listens for RF signal bouncing back from the walls and other paths. The RF signal is measured as a Received Signal Strength Indicator or Indication (RSSI). The RSSI signal or circuit indicates the strength of the incoming (received) signal in a receiver. RSSI is often done in the IF stage before the IF amplifier. In zero-IF systems, it is done in the baseband signal chain, before the baseband amplifier. RSSI output is often a DC analog level. It can also be sampled by an internal ADC and the resulting codes available directly or via peripheral or internal processor bus.

Signal strength across the RF link varies because of the indoor multi-path environment. A mixture of direct and reflected signal paths results in a time-varying fading characteristic. The RSSI measurements therefore vary in time and follow a statistical model depending on the proportion of direct and indirect rays in the environment. Since up-fades vary less than downfades, a peak-holding algorithm provides a reasonable estimate of average RSSI (FIG. 4) for two static nodes measuring a mobile node crossing at a cell boundary. Due to fading variations there is a 5 dB variability in peak-signal strength, which can be controlled by filtering and hysteresis thresholds.

Based on the RSSI signal, the transceiver detects whether the room is occupied. This is done using only the wireless transceiver circuitry without dedicated sensors such as PIR sensors. The transceiver can then perform time-based control as well as sensor based control. In time-based control, lighting circuits are all routed through a control circuit that switches power on/off based upon preset time schedules or astronomical clocks. In sensor-based control, the control circuit or relays that are integrated into sensors or stand-alone relay (power) packs control the power to individual lights or circuits based upon occupancy and/or daylight.

FIG. 2 shows a process executed by the transceiver 10 to determine motion. In one embodiment, the motion sensing is based on an average Receive Signal Strength Indication (RSSI) signal. In this embodiment, the transceiver 10 is positioned near the entrance and monitors the RSSI signal. When a person is in the room or otherwise is positioned near the antenna of the transceiver 10, the RSSI signal changes in value and the transceiver 10 can detect motion using the RSSI strength as follows:

TABLE-US-00001 Measure a base RSSI level for an empty room base configuration and calibrate system for different parts of the day (40) Optionally power down transceiver to save energy (42) Loop Periodically wake up transceiver (44) Measure

RSSI signal and compare against base RSSI level (46) If RSSI differs from base RSSI level, then set motion detected flag to true and turn on appliance for a predetermined period in response to the detected motion (48) Process other operations (50) Optionally power down transceiver (52) End Loop

The processor for sensing the RSSI can be turned on all the time, or alternatively, can be powered down and periodically be woken up to sense motion. One embodiment measures base RSSI level at different times of the day to improve the accuracy of the motion detection. The RSSI level can change during the day due to periodic fades occurring during hours of the day when the transceivers are affected by solar radiation or other issues. The base RSSI level can be used to handle transmitter variability. Different transmitters behave differently even when they are configured exactly in the same way. When a transmitter is configured to send packets at a power level then the transmitter will send these packets at a power level that is close to that power level but not necessarily equal and this can alter the received signal strength indication and thus it can lead to inaccuracies. The system also accounts for receiver variability: The sensitivity of the receivers across different radio chips is different. In practice, this means that the RSSI value recorded at different receivers can be different even when all the other parameters that affect the received signal strength are kept constant. The base RSSI level takes into consideration the antenna orientation: Each antenna has its own radiation pattern that is not uniform. In practice, this means that the RSSI value recorded at the receiver for a given pair of communicating nodes and for a given distance between them varies as the pair wise antenna orientations of the transmitter and the receiver are changed. Multi-path fading and shadowing in the RF channel are also accounted for. In indoor environments the transmitted signals get reflected after hitting on the walls and/or on other objects in the room such as furniture. Both the original signal and the reflected signal reach the receiver almost at the same time since they both travel at the speed of light. As a result of this, the receiver is not able to distinguish the two signals and it measures the received signal strength for both.

The system can use a plurality of transceivers in a room that coordinates with each other to detect motion more accurately by covering specific areas. For example, as shown in FIG. 1, a transceiver 10 mounted near the room entrance and share information with a transceiver 10 mounted on the opposite side of the room can cooperate to improve the motion sensing process. Since the transceiver 10 performs the motion sensing in software by examining its received signal strength, the motion sensing is implemented at a cost that is nearly zero since only code is loaded into the transceiver 10 in contrast to conventional solutions that require additional costly hardware such as a trip sensor using LED and photosensors or alternatively a Passive Infrared Receivers (PIRs) to detect motion. For the multi-transceiver embodiment, each transceiver 10 can detect motion, and the collective intelligence from all transceivers in the network can be applied to optimize power consumption of the appliances. In the multiple transceiver configuration, each transceiver is already provided in wireless enabled appliance, so the enhanced accuracy of the multi-transceiver embodiment is achieved without additional hardware cost.

For higher accuracy, other schemes can be used such as time-of-flight; angle-of-arrival techniques. The transmitter sends pulses of known duration and intensity. This is accomplished by synchronizing the clocks of the transmitter and receiver. If the transmitter sends data at a known clock cycle, and the receiver gets it at another clock cycle, a distance calculation can be made. The transmitter works continuously at low power, and at 2.4 GHz a 2.5 foot distance resolution can be obtained. To capture the angle of arrival information, the receiver has multiple patch antennas with a plurality of rake fingers which integrate the signal from different sources using a modified CDMA detection process. Prompt, late, early entries received by the rake fingers are correlated to determine arrival angles, not only different multipath conditions.

In one embodiment, the system can be set to provide Occupancy Sensor Time Delays, Switch Operation (Manual/Automatic On), Enable/Disable Microphone Occupancy Sensor/Door Sensor/Other Sensor, Custom Device Names, Photocell Setup & Control, 2-Pole Device Settings, Dimming Limits, Remote Firmware Upgrades. The system can also Override Lights ON/OFF, Scheduled ON/OFF, Auto-ON/OFF with Occupancy, Manual ON/OFF via Local Switch, Auto-Dim via LED Sensing, Auto-ON/OFF via LED Sensing, Auto-ON/OFF with Astronomical Clock, Increase Dim Level Decrease Dim Level. The system can also schedule (date/hour/minute) changes to any setting or control mode with convenient recurrence patterns: daily, weekly, weekdays, weekends, etc. Preset and Custom Device Groups selection enable quick programming of zones. The system also provides automatic Daylight Savings Adjustment.

Lobby

Auto-ON with first occupant Permanent ON (no OFFs due to Vacancy) during working hours Photocell overrides lights OFF during peak daylight Return to occupancy-based control during non-working hours Private Office Custom time delays based on occupant requirements Lumen maintenance through ceiling dimming photosensor User-selected dim levels Open Office Requires first morning occupant to initiate Lights ON Permanent ON status during working hours Standard occupancy control during evening non-working hours Short time delays during late night guard walk through Restroom 2-Pole sensor controls light and fan separately Light turns OFF shortly after vacancy; fan runs for extended time Varying time delay periods for working vs. non-working hours in order to maintain lamp life while maximizing energy savings Retail Floor Occupancy control during early morning stocking hours Lights are on Time-of-Day/Day-of-Week schedule during store hours Occupancy control during evening cleaning hours Occupancy sensors automatically accommodate special late night sales without reprogramming system Classroom System accommodates inboard/outboard switching (A/B) Stepped dimming or continuous dimming with local set-point control Dual Technology (PDT) during class hours, single technology (PIR) and shortened time delays during cleaning periods Parking Garage/Lot Astronomical dawn and dusk times available Photocell override during daylight hours All lights extinguished during times when garage is closed

In one embodiment, each person's heartbeat is a virtual fingerprint that can be used to identify one person from another person in the house. As discussed above, suitable statistical recognizers such as Hidden Markov Model (HMM) recognizers, neural network, fuzzy recognizer, dynamic time warp (DTW) recognizer, a Bayesian network, or a Real Analytical Constant Modulus Algorithm (RACMA) recognizer, among others can be used to distinguish one person's heartbeat from another. This technique allows the system to track multiple people in a residence at once. Additionally, three or more transceivers can be positioned in the residence so that their position can be determined through triangulation. The positional data, heart rate, and breathing rate/respiration rate, as well as change delta for each, can be data mined to determine the user's daily activity patterns. A Hidden Markov Model (HMM) recognizer, a dynamic time warp (DTW) recognizer, a neural network, a fuzzy logic engine, or a Bayesian network can be applied to the actual or the difference/change for a particular signal, for example the heart rate or breathing rate, to determine the likelihood of a stroke attack in one embodiment.

Substantially any type of learning system or process may be employed to determine the user's ambulatory and living patterns so that unusual events can be flagged.

In one embodiment, clustering operations are performed to detect patterns in the data. In another embodiment, a neural network is used to recognize each pattern as the neural network is quite robust at recognizing user habits or patterns. Once the treatment features have been characterized, the neural network then compares the input user information with stored templates of treatment vocabulary known by the neural network recognizer, among others. The recognition models can include a Hidden Markov Model (HMM), a dynamic programming model, a neural network, a fuzzy logic, or a template matcher, among others. These models may be used singly or in combination.

Dynamic programming considers all possible points within the permitted domain for each value of i. Because the best path from the current point to the next point is independent of what happens beyond that point. Thus, the total cost of [i(k), j(k)] is the cost of the point itself plus the cost of the minimum path to it. Preferably, the values of the predecessors can be kept in an M.times.N array, and the accumulated cost kept in a 2.times.N array to contain the accumulated costs of the immediately preceding column and the current column. However, this method requires significant computing resources. For the recognizer to find the optimal time alignment between a sequence of frames and a sequence of node models, it must compare most frames against a plurality of node models. One method of reducing the amount of computation required for dynamic programming is to use pruning. Pruning terminates the dynamic programming of a given portion of user habit information against a given treatment model if the partial probability score for that comparison drops below a given threshold. This greatly reduces computation.

Considered to be a generalization of dynamic programming, a hidden Markov model is used in the preferred embodiment to evaluate the probability of occurrence of a sequence of observations O(1), O(2), O(t), . . . , O(T), where each observation O(t) may be either a discrete symbol under the VQ approach or a continuous vector. The sequence of observations may be modeled as a probabilistic function of an underlying Markov chain having state transitions that are not directly observable. In one embodiment, the Markov network is used to model a number of user habits and activities. The transitions between states are represented by a transition matrix A=[a(i,j)]. Each a(i,j) term of the transition matrix is the probability of making a transition to state j given that the model is in state i. The output symbol probability of the model is represented by a set of functions B=[b(j) (O(t)], where the b(j) (O(t) term of the output symbol matrix is the probability of outputting observation O(t), given that the model is in state j. The first state is always constrained to be the initial state for the first time frame of the utterance, as only a prescribed set of left to right state transitions are possible. A predetermined final state is defined from which transitions to other states cannot occur. Transitions are restricted to reentry of a state or entry to one of the next two states. Such transitions are defined in the model as transition probabilities. Although the preferred embodiment restricts the flow graphs to the present state or to the next two states, one skilled in the art can build an HMM model without any transition restrictions, although the sum of all the probabilities of transitioning from any state must still add up to one. In each state of the model, the current feature frame may be identified with one of a set of predefined output symbols or may be labeled probabilistically. In this case, the output symbol probability b(j) O(t) corresponds to the probability assigned by the model that the feature frame symbol is O(t). The model arrangement is a matrix A=[a(i,j)] of transition probabilities and a technique of computing B=b(j) O(t), the feature frame symbol probability in state j. The Markov model is formed for a reference pattern from a plurality of sequences of training patterns and the output symbol probabilities are multivariate Gaussian function probability densities. The patient habit information is processed by a feature extractor. During learning, the resulting feature vector series is processed by a parameter estimator, whose output is provided to the hidden Markov model. The hidden Markov model is used to derive a set of reference pattern templates, each template representative of an identified pattern in a vocabulary set of reference treatment patterns. The Markov model reference templates are next utilized to classify a sequence of observations into one of the reference patterns based on the probability of generating the observations from each Markov model reference pattern template. During recognition, the unknown pattern can then be identified as the reference pattern with the highest probability in the likelihood calculator. The HMM template has a number of states, each having a discrete value. However, because treatment pattern features may have a dynamic pattern in contrast to a single value. The addition of a neural network at the front end of the HMM in an embodiment provides the capability of representing states with dynamic values. The input layer of the neural network comprises input neurons. The outputs of the input layer are distributed to all neurons in the middle layer. Similarly, the outputs of the middle layer are distributed to all output states, which normally would be the output layer of the neuron. However, each output has transition probabilities to itself or to the next outputs, thus forming a modified HMM. Each state of the thus formed HMM is capable of responding to a particular dynamic signal, resulting in a more robust HMM. Alternatively, the neural network can be used alone without resorting to the transition probabilities of the HMM architecture.

In one embodiment, the system can operate in a home, a nursing home, or a hospital. In this system, one or more mesh network appliances 8 are provided to enable wireless communication in the home monitoring system. Appliances 8 in the mesh network can include home security monitoring devices, door alarm, window alarm, home temperature control devices, fire alarm devices, among others. Appliances 8 in the mesh network can be one of multiple portable physiological transducer, such as a blood pressure monitor, heart rate monitor, weight scale, thermometer, spirometer, single or multiple lead electrocardiograph (ECG), a pulse oxymeter, a body fat monitor, a cholesterol monitor, a signal from a medicine cabinet, a signal from a drug container, a signal from a commonly used appliance such as a refrigerator/stove/oven/washer, or a signal from an exercise machine, such as a heart rate. For example, within a house, a user may have mesh network appliances that detect window and door contacts, smoke detectors and motion sensors, video cameras, key chain control, temperature monitors, CO and other gas detectors, vibration sensors, and others. A user may have flood sensors and other detectors on a boat. An individual, such as an ill or elderly grandparent, may have access to a panic transmitter or other alarm transmitter. Other sensors and/or detectors may also be included. The user may register these appliances on a central security network by entering the identification code for each registered appliance/device and/or system. The mesh network can be Zigbee network or 802.15 network.

FIG. 3 shows an exemplary ZigBee version of the transceiver 10. In the block diagram of a typical ZigBee communication transceiver, a wireless communication transceiver has a BaseBand (BB) modem 100 that performs modulation and demodulation using modulation and demodulation schemes defined by the physical layer specifications of each standard, a Radio Frequency (RF) front-end block (or RF/analog block) 105 that converts a digital modulated signal, output from the modem, into an RF modulated signal and converts an RF modulated signal, received from an antenna 110, into a digital modulated signal, and the antenna 110 that wirelessly transmits and receives the RF modulated signal.

In the transmission operation of the RF front-end block 105, a Digital-Analog Converter (DAC) 115 converts a signal, digitally modulated by the modem 100, into an analog modulated signal according to bit resolution corresponding to a selected standard, and a Direct Current (DC) component correction and Low-Pass Filter (LPF) unit 120 removes a DC offset from the analog modulated signal output from the DAC 115, and low-pass-filters the analog modulated signal to a bandwidth corresponding to a selected transmission standard. Frequency up-converters 125 and 130 up-convert the In-phase (I) component of the BB analog modulated signal, output from the DC component correction and LPF unit 120, and the Quadrature (Q) component thereof into an RF band corresponding to the selected transmission standard, and output I and Q RF modulated signal components, respectively. The I and Q RF modulated signal components are combined together by an adder 135, and the output of the adder 135 is amplified by a power amplifier 140. The RF modulated signal is output to the antenna 110 at transmission periods based on TDD through a transmission/reception switch 145. In this case, the RF modulated signal passes through a Band-Pass Filter (BPF) 150 to allow out-of-band spurious signals to be removed therefrom.

In the reception operation of the RF front-end block 105, the RF modulated signal, input from the antenna 110, is freed from out-of-band spurious signals by the BPF 150, and is input to the transmission/reception switch 145.

The transmission/reception switch 145 outputs the RF modulated signal, output from the power amplifier 140 of a transmission side, toward the antenna 110 through the BPF 150 at the intervals of transmission and reception, or inputs the RF modulated signal, received from the antenna 110 and passed through the BPF 150, to the Low Noise Amplifier 170 of a reception side.

The LNA 170 low-noise-amplifies an analog modulated signal (RF modulated signal) in an RF frequency band. The low-noise-amplified analog modulated signal is down-converted into BB modulated signals by frequency down-conversion mixers 175 and 180 with respect to the I and Q components thereof. A low-pass filter and programmable gain amplifier 185 low-pass-filters the down-converted BB band modulated signal to channel bandwidth corresponding to the transmission standard and performs BB amplification with respect to the I and Q components.

An Analog-Digital Converter (ADC) 190 converts the above-described BB signal into a digital modulated signal according to a bit resolution corresponding to the selected transmission standard, and outputs the digital modulated signal to the BB modem 100.

In regard to the generation of a carrier, a programmable divider 160 diminishes a local oscillation frequency generated by an oscillator 155, and a frequency synthesizer 165 generates a carrier frequency using a frequency output from the programmable divider 160.

FIG. 4 shows a block diagram of a wireless communication transceiver capable of performing radar sensing of people using Doppler techniques. Although the system is shown for ZigBee transceiver to minimize cost, systems based on WiMAX transceiver or WiFi transceiver can be implemented as well. The embodiment of FIG. 4 is similar to the embodiment of FIG. 1, but with separate transmit antenna 110 and receive antenna 111 and separate bandpass filters 150 and 151, respectively. The separate transmit and receive circuitry allows Doppler detection of the reflected signals. In the Doppler radar phenomenon, the frequency of a radio signal is altered when the signal reflects off of a moving object. In one embodiment, the movement of people is detected. In another embodiment, the periodic movement of the chest and internal organs of the person modulates an incident or transmitted radio signal from one of the wireless transceivers, and the resulting reflection is interpreted to deduce the presence of a person. The reflection can capture fine resolution information about the person who is in range of the transceiver 10. The information can include, for example, heart and breathing activity. Transceivers that operate at high frequencies can be used to provide higher resolution and improved antenna patterns could be used for more detailed observations of arterial motion. The improved arterial motion pattern can be used to distinguish one person from another person using Hidden Markov Model recognizers in one embodiment.

In another embodiment, two separate wireless conventional ZigBee devices are used: one as a transmitter and the other one as a receiver. Separate transmit and receive antennas perform transmission and reception simultaneously. Each wireless adapter can be an 802.15 (ZigBee) adapter that can be wall mounted or placed on suitable furniture. The local oscillators of the adapters are synchronized by providing a common crystal reference to the LO synthesizers in both chip sets. The baseband output of the receiver adapter is prefiltered with a low-pass RC filter with a cut-off frequency of about 100 Hz in one embodiment to remove out of band noise and avoid aliasing error. The pre-filtered signal is digitized and used to calculate heart rate. The digitized signal is the additionally filtered in the digital domain to separate the heart and breathing signals. To determine heart rate, an autocorrelation function was calculated for the heart signal. The periodicity of the autocorrelation function is used to determine the heart rate. A filter can also be applied to extract breathing rate from the digitized signal.

Another embodiment shown in FIG. 5 uses a multiple input, multiple output (MIMO) wireless adapter chip set. The inventor contemplates that the adapter can be ZigBee adapter, but also be 802.11 (WiFi), 802.16 (WiMAX), Bluetooth adapters, cell phones, or cordless telephones.

FIG. 5 is a schematic block diagram illustrating a wireless communication device that uses a MIMO radio 60 as a Doppler radar to detect people and/or organ movement such as heart beat detection. Radio 60 includes a host interface 62, a baseband processing module 64, memory 66, a plurality of radio frequency (RF) transmitters 68-72, a transmit/receive (T/R) module 74, a plurality of antennas 82-86, a plurality of RF receivers 76-80, and a local oscillation module 100. The baseband processing module 64, in combination with operational instructions stored in memory 66, execute digital receiver functions and digital transmitter functions, respectively. The digital receiver functions include, but are not limited to, digital intermediate frequency to baseband conversion, demodulation, constellation demapping, decoding, de-interleaving, fast Fourier transform, cyclic prefix removal, space and time decoding, and/or descrambling. The digital transmitter functions include, but are not limited to, scrambling, encoding, interleaving, constellation mapping, modulation, inverse fast Fourier transform, cyclic prefix addition, space and time encoding, and/or digital baseband to IF conversion. The baseband processing modules 64 may be implemented using one or more processing devices. Such a processing device may be a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions. The memory 66 may be a single memory device or a plurality of memory devices. Such a memory device may be a read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, and/or any device that stores digital information. Note that when the processing module 64 implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions is embedded with the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry. A number of the RF transmitters 68-72 will be enabled to convert the outbound symbol streams 90 into outbound RF signals 92. The transmit/receive module 74 receives the outbound RF signals 92 and provides each outbound RF signal to a corresponding antenna 82-86. When the radio 60 is in the receive mode, the transmit/receive module 74 receives one or more inbound RF signals via the antennas 82-86. The T/R module 74 provides the inbound RF signals 94 to one or more RF receivers 76-80. The RF receiver 76-80 converts the inbound RF signals 94 into a corresponding number of inbound symbol streams 96. The baseband processing module 60 receives the inbound symbol streams 90 and converts them into inbound data 98.

In one embodiment, the MIMO transceiver can also be a spread-spectrum microwave motion sensor that can be co-located with other spectrum users without having to set a specific operating frequency.

The non-invasive measuring techniques can be enhanced by the attachment of wireless sensors to critical locations on the body. The body sensor technique allows the return or reflected signal to be more easily isolated from radar clutter effects, and provides a means for sensing additional data not easily derived from a radar signal, such as skin temperature. The body sensors can be as simple as conductive patches that attach to the back of badges and enhance the reflection of the incident radio signal at a particular location. Alternatively, the body sensors are more complex frequency resonant structures, or even oscillating or multiplying semiconductor circuits. Such circuits can alter the reflected radio signal in time and/or frequency, and can impose additional modulated data, which is generated by, for example, skin temperature, bio-electric effects, re-radiated radar effects, and physical acceleration.

A conducting surface will then reflect most of the energy from an incident radio wave. Placing such a surface or patch on a target area of the body, such as the chest or the skin over an artery, will enhance the return of the radar signal from that target area. As one skilled in the art will appreciate, if the physical dimensions of the conducting surface are properly chosen, the path can act as an electrically resonant antenna that provides an enhanced radar return.

In one embodiment, each person's personal information such as hearbeat is a virtual fingerprint that can be used to identify one person from another person in the house. As discussed above, suitable statistical recognizers such as Hidden Markov Model (HMM) recognizers, neural network, fuzzy recognizer, dynamic time warp (DTW) recognizer, a Bayesian network, or a Real Analytical Constant Modulus Algorithm (RACMA) recognizer, among others can be used to distinguish one person's heartbeat from another. This technique allows the system to track multiple people in a residence at once. Additionally, three or more transceivers can be positioned in the residence so that their position can be determined through triangulation.

In one embodiment, a differential pulse Doppler motion sensor provides a range-invariant Doppler response within a range limited region, and no response outside the region. The transmitter transmits a sequence of transmitted bursts of electromagnetic energy to produce a sensor field, the transmitted bursts having burst widths which vary according to a pattern which cause responses to disturbance in the sensor field which also vary according to the pattern. For one example pattern, the transmitted bursts are switched between a first burst width and a second burst width at a pattern frequency. The receiver receives a combination of the transmitted bursts and reflections of the transmitted bursts and produces a combined output. Thus, the combined output indicates a mixing of the transmitted burst with its own reflection. The width of the burst defines the range limit because any reflection which returns after the burst has ended, results in zero mixing.

In another implementation, the transmitter transmits the sequence of transmitted bursts at a transmitter frequency with a burst repetition rate. The transmitter frequency is on the order of gigaHertz, such as between 900 megaHertz and 24 gigaHertz, or for example between about 5 and 6 gigaHertz. The burst repetition rate is on the order of megaHertz, such as for example 1-5 megaHertz, and more preferably 1-3 megaHertz. A burst width control circuit controls the pattern of varying burst widths by switching a burst widths of the transmitted bursts in the sequence between or among a plurality of burst widths according to a pattern. The pattern has for example a characteristic pattern frequency on the order of 10 kiloHertz to 100 kiloHertz. The pattern at which the burst widths are varied can take on a variety of characteristics. In one system, the burst widths are switched between two different burst widths. In other embodiments, the pattern may vary according to a sine wave, a triangle wave, a ramp signal, or a noise modulated signal for example.

Another embodiment is based upon the reflection of sound waves. Sound waves are defined as longitudinal pressure waves in the medium in which they are travelling. Subjects whose dimensions are larger than the wavelength of the impinging sound waves reflect them; the reflected waves are called the echo. If the speed of sound in the medium is known and the time taken for the sound waves to travel the distance from the source to the subject and back to the source is measured, the distance from the source to the subject can be computed accurately. This is the measurement principle of this embodiment. Here the medium for the sound waves is air, and the sound waves used are ultrasonic, since it is inaudible to humans. Assuming that the speed of sound in air is 1100 feet/second at room temperature and that the measured time taken for the sound waves to travel the distance from the source to the subject and back to the source is t seconds, the distance d is computed by the formula d=1100.times.12.times.t inches. Since the sound waves travel twice the distance between the source and the subject, the actual distance between the source and the subject will be d/2. The devices used to transmit and receive the ultrasonic sound waves in this application are 40-kHz ceramic ultrasonic transducers. The processor drives the transmitter transducer with a 12-cycle burst of 40-kHz square-wave signal derived from the crystal oscillator, and the receiver transducer receives the echo. A timer is configured to count the 40-kHz crystal frequency such that the time measurement resolution is 25 .mu.s. The echo received by the receiver transducer is amplified by an operational amplifier and the amplified output is fed to a comparator input. The comparator senses the presence of the echo signal at its input and triggers a capture of the timer count value to capture a compare register. The capture is done exactly at the instant the echo arrives at the system. The captured count is the measure of the time taken for the ultrasonic burst to travel the distance from the system to the subject and back to the system. The distance in inches from the system to the subject is computed using this measured time and displayed on a two-digit static LCD. Immediately after updating the display, the processor goes to sleep mode to save power and is periodically woken by another time every 205 milliseconds to repeat the measurement cycle and update the display.

FIG. 6 shows an exemplary LED ambient light sensor. The LED is a photodiode that is sensitive to light at and above the wavelength that which it emits (barring any filtering effects of a colored plastic package). Under reverse bias conditions, a simple model for the LED is a capacitor in parallel with a current source which models the optically induced photocurrent. The system measures the photocurrent. One way to make a photodetector out of an LED is to tie the anode to ground and connect the cathode to a CMOS I/O pin driven high. This reverse biases the diode, and charges the capacitance. Next switch the I/O pin to input mode, which allows the photocurrent to discharge the capacitance down to the digital input threshold. By timing how long this takes, the photocurrent can be measure to determine the amount of incident light. The microprocessor interface technique uses one additional digital I/O pin, but no other additional components compared to those need to simply light the LED. Since the circuit draws only microwatts of power, it has a minimal impact on battery life.

In one embodiment, the LED blinks very fast, and then ambient light is detected when the LED is off. The LED is connected to general IO port GP0 with a resistor between the LED and GP1. When GP0 is high, and GP1 is low, will it conduct, and emit light. When the GP0 is low, and GP1 is high, then the LED is off. The LED is charged to -5V across it, and when the GP1 turns into tri-state and goes low, and the time depends on capacity and on current in LED. A 16-bit Sigma Delta ADC is used to detect the voltage output of the LED when it is off. The voltage output is proportional to the amount of light in the room and can be used to turn on/off room lighting or other peripherals.

FIG. 6A shows the "Emitting" mode where current is driven in the forward direction, lighting the LED. FIG. 6B shows "Reverse Bias" mode, which charges the capacitance and prepares the system for measurement. The actual measurement is made in "Discharge" mode shown in FIG. 6c. Since the current flowing into a CMOS input is extremely small, the low value current limiting resistor has little impact on the voltage seen at the input pin. The system times how long it takes for the photocurrent to discharge the capacitance to the pin's digital input threshold. The result is a simple circuit that can switch between emitting and receiving light. Because the circuit changes required to provide this bidirectional communication feature consist of only one additional I/O pin, adding the light sensor is essentially free.

In one embodiment, a TI MSP430F20x3 microcontroller is used to drive an LED. The LED is used both as an indicator or night light and an ambient room light sensor. The voltage generated by the LED is measured using a built-in 16 bit sigma delta converter. A LED voltage reading is obtained every 200 ms. Based on predefined "Min" and "Max" reference values, the active duty cycle for lighting ballasts is adjusted according to the current light conditions. The darker the ambient light is, the more the ballasts will be set so that room will be illuminated. The microcontroller/LED is exposed to darkness for a short moment in order to calibrate the LED's offset voltage. A very low frequency oscillator (VLO) is used to clock a timer which is used for both PWM generation to adjust LED brightness but also to derive the timings. A calibration process can be implemented to accommodate for variations in VLO frequency.

FIG. 7 shows an exemplary LED based microphone to detect sound or noise in the room. In this embodiment, a base surface 710 supports a cylinder that protrudes from the base surface using legs or posts 720. At one end, a flexible membrane 730 is positioned to pick up sound and to vibrate according to noise or sound in the room. A piece of light-reflecting metal foil 740 is positioned on one end. Speech or sound vibrates the foil 740. An LED 750 is directed at the foil 740 and the vibration is reflected off the foil on to the same LED 750 acting as a photocell. Sound is thus captured by the LED 750 and processed by low power a microcontroller 760. The microcontroller 760 is Zigbee transceiver connected to an antenna 780. Radio reflections from occupants in the room cause changes in the RSSI signal which is captured and processed by the controller 780 for occupancy sensing. To aid the LED receiver in detecting the signal, the light source should be pulsed at the highest possible power level. To produce the highest possible light pulse intensity without burning up the LED, a low duty cycle drive must be employed. This can be accomplished by driving the LED with high peak currents with the shortest possible pulse widths and with the lowest practical pulse repetition rate. For standard voice systems, the transmitter circuit can be pulsed at the rate of about 10,000 pulses per second as long as the LED pulse width is less than about 1 microsecond. Such a driving scheme yields a duty cycle (pulse width vs. time between pulses) of less than 1%. However, if the optical transmitter is to be used to deliver only an on/off control signal, then a much lower pulse rate frequency can be used. If a pulse repetition rate of only 50 pps were used, it would be possible to transmit the control message with duty cycle of only 0.005%. Thus, with a 0.005% duty cycle, even if the LED is pulsed to 7 amps the average current would only be about 300 ua. Even lower average current levels are possible with simple on/off control transmitters, if short multi-pulse bursts are used. To obtain the maximum efficiency, the LED should be driven with low loss transistors. Power field effect transistors (FET) can be used to efficiently switch the required high current pulses.

In one embodiment, the LED microphone can be used with the occupancy sensor or detector, providing an ideal solution for areas with obstructions like bathrooms with stalls or open office cubicle areas. This embodiment first detects motion using the wireless radar system and then engages the LED microphone to listen for continued occupancy. The system can tune the sound detection to sudden noise changes only and filters out the background "white" noise.

In another embodiment, the LED microphone can be used with the LED ambient light detector or sunlight sensor/detector. This embodiment first detects ambient room light condition using the LED light sensor and then engages the LED microphone to listen for continued occupancy. The system can tune the sound detection to sudden noise changes only and filters out the background "white" noise.

In another embodiment, the LED microphone can be used with the LED light detector and the LED occupancy sensor or detector. This embodiment first detects if sufficient light exists, then detects people's motion using the wireless radar system and then engages the LED microphone to listen for continued occupancy. The system can tune the sound detection to sudden noise changes only and filters out the background "white" noise.

In yet other embodiments, the clock kept by the microcontroller can be used to supplement the turn on or off of lighting or power other devices in the room. The microcontroller can communicate with a ballast. The ballast is the unit in a fluorescent lighting system that provides power to the fluorescent tube at the proper frequency. Located in the lamp's housing, it is a featureless metal box containing electronic circuitry. Dimmable ballasts are an advanced design that allow lights to be tuned continuously from full brightness to a very low level (usually about five percent of total brightness), to save electricity when less light is needed or to reduce lighting glare.

The system can detect light, sound and people present to provide an accurate determination of occupancy and such determination can be used to effectively provide environmental comforts for the occupants. One exemplary process for room environmental control is as follows: Check clock to see user specified appliance on-off period is met and if so, turn appliance on or off Check room light to see if room light is below threshold and if so Check room microphone to see if people are present and if so Check occupancy sensing radar to sense motion in the room, and if so, turn on one or more appliances such as lighting and display terminals in the room. Check room temperature and turn on AC if needed.

A user override button is provided so that the user can manually force the room to turn on appliances as desired.

FIGS. 8-9 show exemplary mesh networks. Data collected and communicated on the display 1382 of the watch as well as voice is transmitted to a base station 1390 for communicating over a network to an authorized party 1394. The watch and the base station is part of a mesh network that may communicate with a medicine cabinet to detect opening or to each medicine container 1391 to detect medication compliance. Other devices include mesh network thermometers, scales, or exercise devices. The mesh network also includes a plurality of home/room appliances 1392-

1399. The ability to transmit voice is useful in the case the patient has fallen down and cannot walk to the base station 1390 to request help. Hence, in one embodiment, the watch captures voice from the user and transmits the voice over the Zigbee mesh network to the base station 1390. The base station 1390 in turn dials out to an authorized third party to allow voice communication and at the same time transmits the collected patient vital parameter data and identifying information so that help can be dispatched quickly, efficiently and error-free. In one embodiment, the base station 1390 is a POTS telephone base station connected to the wired phone network. In a second embodiment, the base station 1390 can be a cellular telephone connected to a cellular network for voice and data transmission. In a third embodiment, the base station 1390 can be a ZigBee, WiMAX or 802.16 standard base station that can communicate VOIP and data over a wide area network. In one implementation, Zigbee or 802.15 appliances communicate locally and then transmits to the wide area network (WAN) such as the Internet over WiFi or WiMAX. Alternatively, the base station can communicate with the WAN over POTS and a wireless network such as cellular or WiMAX or both.

The above described systems can be used to energy efficient control of appliances such as lighting or cooling/heating devices that use energy consumption in a room. The wireless mesh network 22 allows for continuous connections and reconfiguration around blocked paths by hopping from node to node until a connection can be established, the mesh network 22 including one or more wireless area network transceivers 10 adapted to communicate data with the wireless mesh network, the transceiver detecting motion by analyzing reflected wireless signal strength. The appliance 20 is coupled to the transceiver 10 and the appliance is activated or deactivated in response to sensed motion in the room based on the reflected wireless signal strength. For example, if the sensor 12 senses no motion over a period of time, the system turns off non-essential appliances such as the lights and the fan in the room and changes the temperate setting to the lowest cost configuration.

Because each individual emits patterns that are unique to the user, the system can automatically recognize the individuals based on his or her emitted pattern. A recognizer can receive user identifiable characteristics from the transceiver. The recognizer can be a Hidden Markov Model (HMM) recognizer, a dynamic time warp (DTW) recognizer, a neural network, a fuzzy logic engine, or a Bayesian network recognizer, among others.

The recognizer can monitor one or more personally identifiable signatures. For example, the transceiver identifies one person from another based on a heart rate signature as measured by a Doppler radar. A sound transducer such as a microphone and/or a speaker can be connected to the wireless transceiver to communicate audio over a telephone network through the mesh network. A call center or a remote receptionist can be linked to the transceiver to provide a human response. An in-door positioning using triangulation or RSSI-based pattern matching can communicate with one or more mesh network appliances to provide location information. A web server can communicate over the mesh network and to a telephone network to provide information to an authorized remote user. A wireless router can be coupled to the mesh network and wherein the wireless router comprises one of: 802.11 router, 802.16 router, WiFi router, WiMAX router, Bluetooth router, X10 router.

A mesh network appliance can be connected to a power line to communicate data to and from the mesh network. A ***smart meter*** can relay data to a utility over the power line and the mesh network to the appliance. The ***smart meter*** includes bi-directional communication, power measurement and management capability, software-controllable disconnect switch, and communication over low voltage power line. A remote processor that can remotely turn power on or off to a customer, read usage information from a meter, detect a service outage, detect the unauthorized use of electricity, change the maximum amount of electricity that a customer can demand at any time; and remotely change the meters billing plan from credit to prepay as well as from flat-rate to multi-tariff. The appliance minimizes operating cost by shifting energy use to an off-peak period in response to utility pricing that varies energy cost by time of day. A rechargeable energy reservoir such as a fuel cell or a battery can supply energy to the appliance, and the reservoir is charged during a utility off-peak period and used during a utility peak pricing period. Solar panels, wind mill, or other sources of renewable energy can be provided outside the premises to generate local energy that recharges the reservoir or store energy in the utility grid.

The appliance's operation is customized to each individual's preference since the system can identify each individual through his or her heart rate signature, among others. Each user can set his or her preferences and the system can detect the user's entry into a room and automatically customizes the room to the user. For example, upon entry into a room, the network can stream the user's preferred music into a music player in the room or alternatively can stream his or her favorite TV shows and display on a screen for the user. Also, lighting level and temperature can be customized to the user's preferences. The bed setting can be customized to reflect the user's preference for a soft or hard mattress setting. The chair height, tilt/reclination and firmness can be adjusted to the user's preference. The window transparency or tint can be automatically set to the user's preferred room brightness. Phone calls can automatically be routed to the user's current position. If there are many people in the room, the appliance's operation is customized to a plurality of individuals in a room by clusterizing all preferences and determining a best fit preference from all preferences.

Since the system can track user position quite accurately, the system can store and analyze personal information including medicine taking habits, eating and drinking habits, sleeping habits, or excise habits. The information can be used to track the user's general health.

For users that are at risk of stroke, the positional data, heart rate, and breathing rate/respiration rate, as well as change delta for each, can be data mined to determine the user's daily activity patterns. A Hidden Markov Model (HMM) recognizer, a dynamic time warp (DTW) recognizer, a neural network, a fuzzy logic engine, or a Bayesian network can be applied to the actual or the difference/change for a particular signal, for example the heart rate or breathing rate, to determine the likelihood of a stroke attack in one embodiment.

In another embodiment, a Doppler radar positioned near the heart can pick up the heart beat corresponding to as the S1-S4 heart sounds and determine the likelihood of a stroke from the heart movements that generate the sound patterns for S1-S4. The progression of heart failure (HF) is typically accompanied by changes in heart sounds over time. First, an S4 heart sound may develop while the heart is still relatively healthy. Second, the S4 heart sound becomes more pronounced. Third, as deterioration of the left ventricle continues, S3 heart sounds become more pronounced. Sometimes, this is accompanied by a decrease in S1 heart sounds due to a decrease in the heart's ability to contract. Thus, ongoing or continuous monitoring of heart sounds would greatly assist caregivers in monitoring heart disease. However, individual patients may exhibit unique heart sounds that complicate a generalized approach to heart sound monitoring. For example, the mere presence of an S4 heart sound is not necessarily indicative of heart disease because normal patients may have an S4 heart sound. Another complication develops if a patient experiences atrial fibrillation when an ischemia occurs. In this case a strong atrial contraction, and the associated S4 heart sound, is likely to be absent due to the atrial fibrillation. This results in an increase in the S3 heart sound without an associated S4 heart sound or without an increase in an S4 heart sound. Therefore, the progression of heart disease, such as HF and an ischemic event, is typically better monitored by establishing a patient-specific control baseline heart sound measurement and then monitoring for changes from that baseline. The baseline could be established in one or several different criteria, such as at particular physiologic or pathophysiologic state, at a specific posture, at a particular time of day, etc.

Changes due to acute myocardial infarction (AMI) are immediate and result in a heart sound change within seconds or minutes. In contrast, heart sound changes due to worsening HF are gradual and occur over hours or days. Therefore, not just the change but the timeframe of the occurrence of the change in heart sounds can be used to detect overall progression of heart disease. Additionally, relationships between heart sounds can be used to determine the likelihood of an ischemic event. For example, the dynamics between the S3 and S4 heart sounds with respect to the HF progression can be used to determine the likelihood that a patient experienced an ischemic event. An appearance of the S3 and S4 heart sounds is more likely to indicate a recent occurrence of an ischemic event if the S4/S3 ratio is high than if the S4/S3 ratio is low, which would instead indicate that a patient is in a more advanced stage of HF. More details on the relationship of S1-S4 to ischemia are disclosed in published Application 20060282000 entitled "Ischemia detection using a heart sound sensor" as well as application Ser. No. 10/900,570 entitled "DETERMINING A PATIENT'S POSTURE FROM MECHANICAL VIBRATIONS OF THE HEART," filed on Jul. 28, 2004, Ser. No. 10/703,175, entitled "A DUAL USE SENSOR FOR RATE RESPONSIVE PACING AND HEART SOUND MONITORING," filed on Nov. 6, 2003, Ser. No. 10/334,694 entitled "METHOD AND APPARATUS FOR MONITORING OF DIASTOLIC HEMODYNAMICS," filed on Dec. 30, 2002, Ser. No. 10/746,874 entitled "A THIRD HEART SOUND ACTIVITY INDEX FOR HEART FAILURE MONITORING," filed on Dec. 24, 2003, Ser. No. 11/037,275, entitled "METHOD FOR CORRECTION OF POSTURE DEPENDENCE ON HEART SOUNDS," filed on Jan. 18, 2005, Ser. No. 60/631,742 entitled "CARDIAC ACTIVATION SEQUENCE MONITORING FOR ISCHEMIA DETECTION," filed on Nov. 30, 2004, and Ser. No. 11/129,050, entitled "METHOD AND APPARATUS FOR CARDIAC PROTECTION PACING," filed on May 16, 2005, each of which is hereby incorporated by reference.

The mesh network comprises code to store and analyze personal information including heart rate, respiration rate, medicine taking habits, eating and drinking habits, sleeping habits, or excise habits, among others.

In one embodiment for home monitoring, the user's habits and movements can be determined by the system for fall or stroke detection. This is done by tracking location, ambulatory travel vectors and time in a database. If the user typically sleeps between 10 pm to 6 pm, the location would reflect that the user's location maps to the bedroom between 10 pm and 6 pm. In one exemplary system, the system builds a schedule of the user's activity as follows:

TABLE-US-00002 Location Time Start Time End Heart Rate Bed room 10 pm 6 am 60-80 Gym room 6 am 7 am 90-120 Bath room 7 am 7:30 am 85-120 Dining room 7:30 am 8:45 am 80-90 Home Office 8:45 am 11:30 am 85-100 . . . . . .

The habit tracking is adaptive in that it gradually adjusts to the user's new habits. If there are sudden changes, the system flags these sudden changes for follow up. For instance, if the user spends three hours in the bathroom, the system prompts the third party (such as a call center) to follow up with the patient to make sure he or she does not need help.

In one embodiment, data driven analyzers may be used to track the patient's habits. These data driven analyzers may incorporate a number of models such as parametric statistical models, non-parametric statistical models, clustering models, nearest neighbor models, regression methods, and engineered (artificial) neural networks. Prior to operation, data driven analyzers or models of the patient's habits or ambulation patterns are built using one or more training sessions. The data used to build the analyzer or model in these sessions are typically referred to as training data. As data driven analyzers are developed by examining only training examples, the selection of the training data can significantly affect the accuracy and the learning speed of the data driven analyzer. One approach used heretofore generates a separate data set referred to as a test set for training purposes. The test set is used to avoid overfitting the model or analyzer to the training data. Overfitting refers to the situation where the analyzer has memorized the training data so well that it fails to fit or categorize unseen data. Typically, during the construction of the analyzer or model, the analyzer's performance is tested against the test set. The selection of the analyzer or model parameters is performed iteratively until the performance of the analyzer in classifying the test set reaches an optimal point. At this point, the training process is completed. An alternative to using an independent training and test set is to use a methodology called cross-validation. Cross-validation can be used to determine parameter values for a parametric analyzer or model for a non-parametric analyzer. In cross-validation, a single training data set is selected. Next, a number of different analyzers or models are built by presenting different parts of the training data as test sets to the analyzers in an iterative process. The parameter or model structure is then determined on the basis of the combined performance of all models or analyzers. Under the cross-validation approach, the analyzer or model is typically retrained with data using the determined optimal model structure.

In general, multiple dimensions of a user's daily activities such as start and stop times of interactions of different interactions are encoded as distinct dimensions in a database. A predictive model, including time series models such as those employing autoregression analysis and other standard time series methods, dynamic Bayesian networks and Continuous Time Bayesian Networks, or temporal Bayesian-network representation and reasoning methodology, is built, and then the model, in conjunction with a specific query makes target inferences.

Bayesian networks provide not only a graphical, easily interpretable alternative language for expressing background knowledge, but they also provide an inference mechanism; that is, the probability of arbitrary events can be calculated from the model. Intuitively, given a Bayesian network, the task of mining interesting unexpected patterns can be rephrased as discovering item sets in the data which are much more--or much less--frequent than the background knowledge suggests. These cases are provided to a learning and inference subsystem, which constructs a Bayesian network that is tailored for a target prediction. The Bayesian network is used to build a cumulative distribution over events of interest.

In another embodiment, a genetic algorithm (GA) search technique can be used to find approximate solutions to identifying the user's habits. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, natural selection, and recombination (or crossover). Genetic algorithms are typically implemented as a computer simulation in which a population of abstract representations (called chromosomes) of candidate solutions (called individuals) to an optimization problem evolves toward better solutions. Traditionally, solutions are represented in binary as strings of 0s and 1s, but different encodings are also possible. The evolution starts from a population of completely random individuals and happens in generations. In each generation, the fitness of the whole population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), modified (mutated or recombined) to form a new population, which becomes current in the next iteration of the algorithm.

The system allows patients to conduct a low-cost, comprehensive, real-time monitoring of their parameters such as ambulation and falls. Information can be viewed using an Internet-based website, a personal computer, or simply by viewing a display on the monitor. Data measured several times each day provide a relatively comprehensive data set compared to that measured during medical appointments separated by several weeks or even months. This allows both the patient and medical professional to observe trends in the data, such as a gradual increase or decrease in blood pressure, which may indicate a medical condition. The invention also minimizes effects of white coat syndrome since the monitor automatically makes measurements with basically no discomfort; measurements are made at the patient's home or work, rather than in a medical office. The user may give permission to others as needed to read or edit their personal data or receive alerts. The user or clinician could have a list of people that they want to monitor and have it show on their "My Account" page, which serves as a local central monitoring station in one embodiment. Each person may be assigned different access rights which may be more or less than the access rights that the patient has. For example, a doctor or clinician could be allowed to edit data for example to annotate it, while the patient would have read-only privileges for certain pages. An authorized person could set the reminders and alerts parameters with limited access to others.

The server may communicate with a business process outsourcing (BPO) company or a call center to provide central monitoring in an environment where a small number of monitoring agents can cost effectively monitor multiple people 24 hours a day. A call center agent, a clinician or a nursing home manager may monitor a group or a number of users via a summary "dashboard" of their readings data, with ability to drill-down into details for the collected data. A clinician administrator may monitor the data for and otherwise administer a number of users of the system. A summary "dashboard" of readings from all Patients assigned to the Administrator is displayed upon log in to the Portal by the Administrator. Readings may be color coded to visually distinguish normal vs. readings that have generated an alert, along with description of the alert generated. The Administrator may drill down into the details for each Patient to further examine the readings data, view charts etc. in a manner similar to the Patient's own use of the system. The Administrator may also view a summary of all the appliances registered to all assigned Patients, including but not limited to all appliance identification information. The Administrator has access only to information about Patients that have been assigned to the Administrator by a Super Administrator. This allows for segmenting the entire population of monitored Patients amongst multiple Administrators. The Super Administrator may assign, remove and/or reassign Patients amongst a number of Administrators.

In one embodiment, the server provides a web services that communicate with third party software through an interface. In one implementation, telephones and switching systems in call centers are integrated with the home mesh network to provide for, among other things, better routing of telephone calls, faster delivery of telephone calls and associated information, and improved service with regard to client satisfaction through computer-telephony integration (CTI). CTI implementations of various design and purpose are implemented both within individual call-centers and, in some cases, at the telephone network level. For example, processors running CTI software applications may be linked to telephone switches, service control points (SCPs), and network entry points within a public or private telephone network. At the call-center level, CTI-enhanced processors, data servers, transaction servers, and the like, are linked to telephone switches and, in some cases, to similar CTI hardware at the network level, often by a dedicated digital link. CTI processors and other hardware within a call-center is commonly referred to as customer premises equipment (CPE). It is the CTI processor and application software is such centers that provides computer enhancement to a call center. In a CTI-enhanced call center, telephones at agent stations are connected to a central telephony switching apparatus, such as an automatic call distributor (ACD) switch or a private branch exchange (PBX). The agent stations may also be equipped with computer terminals such as personal computer/video display unit's (PC/VDU's) so that agents manning such stations may have access to stored data as well as being linked to incoming callers by telephone equipment. Such stations may be interconnected through the PC/VDUs by a local area network (LAN). One or more data or transaction servers may also be connected to the LAN that interconnects agent stations. The LAN is, in turn, typically connected to the CTI processor, which is connected to the call switching apparatus of the call center.

When a call from a patient arrives at a call center, whether or not the call has been pre-processed at an SCP, the telephone number of the calling line and the medical record are made available to the receiving switch at the call center by the network provider. This service is available by most networks as caller-ID information in one of several formats such as Automatic Number Identification (ANI). Typically the number called is also available through a service such as Dialed Number Identification Service (DNIS). If the call center is computer-enhanced (CTI), the phone number of the calling party may be used as a key to access additional medical and/or historical information from a customer information system (CIS) database at a server on the network that connects the agent workstations. In this manner information pertinent to a call may be provided to an agent, often as a screen pop on the agent's PC/VDU.

The call center enables any of a first plurality of physician or health care practitioner terminals to be in audio communication over the network with any of a second plurality of patient wearable appliances. The call center will route the call to a physician or other health care practitioner at a physician or health care practitioner terminal and information related to the patient (such as an electronic medical record) will be received at the physician or health care practitioner terminal via the network. The information may be forwarded via a computer or database in the practicing physician's office or by a computer or database associated with the practicing physician, a health care management system or other health care facility or an insurance provider. The physician or health care practitioner is then permitted to assess the patient, to treat the patient accordingly, and to forward updated information related to the patient (such as examination, treatment and prescription details related to the patient's visit to the patient terminal) to the practicing physician via the network 200.

In one embodiment, the system informs a patient of a practicing physician of the availability of the web services and referring the patient to the web site upon agreement of the patient. A call from the patient is received at a call center. The call center enables physicians to be in audio communication over the network with any patient wearable appliances, and the call is routed to an available physician at one of the physician so that the available physician may carry on a two-way conversation with the patient. The available physician is permitted to make an assessment of the patient and to treat the patient. The system can forward information related to the patient to a health care management system associated with the physician. The health care management system may be a healthcare management organization, a point of service health care system, or a preferred provider organization. The health care practitioner may be a nurse practitioner or an internist.

The available health care practitioner can make an assessment of the patient and to conduct an examination of the patient over the network, including optionally by a visual study of the patient. The system can make an assessment in accordance with a protocol. The assessment can be made in accordance with a protocol stored in a database and/or making an assessment in accordance with the protocol may include displaying in real time a relevant segment of the protocol to the available physician.

In one embodiment, the wireless nodes convert freely available energy inherent in most operating environments into conditioned electrical power. Energy harvesting is defined as the conversion of ambient energy into usable electrical energy. When compared with the energy stored in common storage elements, like batteries and the like, the environment represents a relatively inexhaustible source of energy. Energy harvesters can be based on piezoelectric devices, solar cells or electromagnetic devices that convert mechanical vibrations.

Power generation with piezoelectrics can be done with body vibrations or by physical compression (impacting the material and using a rapid deceleration using foot action, for example). The vibration energy harvester consists of three main parts. A piezoelectric transducer (PZT) serves as the energy conversion device, a specialized power converter rectifies the resulting voltage, and a capacitor or battery stores the power. The PZT takes the form of an aluminum cantilever with a piezoelectric patch. The vibration-induced strain in the PZT produces an ac voltage. The system repeatedly charges a battery or capacitor, which then operates the EKG/EMG sensors or other sensors at a relatively low duty cycle. In one embodiment, a vest made of piezoelectric materials can be wrapped around a person's chest to generate power when strained through breathing as breathing increases the circumference of the chest for an average human by about 2.5 to 5 cm. Energy can be constantly harvested because breathing is a constant activity, even when a person is sedate. In another embodiment, piezoelectric materials are placed in between the sole and the insole; therefore as the shoe bends from walking, the materials bend along with it. When the stave is bent, the piezoelectric sheets on the outside surface are pulled into expansion, while those on the inside surface are pushed into contraction due to their differing radii of curvature, producing voltages across the electrodes. In another embodiment, PZT materials from Advanced Cerametrics, Inc., Lambertville, N.J. can be incorporated into flexible, motion sensitive (vibration, compression or flexure), active fiber composite shapes that can be placed in shoes, boots, and clothing or any location where there is a source of waste energy or mechanical force. These flexible composites generate power from the scavenged energy and harness it using microprocessor controls developed specifically for this purpose. Advanced Cerametric's viscose suspension spinning process (VSSP) can produce fibers ranging in diameter from 10 .mu.m (1/50 of a human hair) to 250 .mu.m and mechanical to electrical transduction efficiency can reach 70 percent compared with the 16-18 percent common to solar energy conversion. The composite fibers can be molded into user-defined shapes and is flexible and motion-sensitive. In one implementation, energy is harvested by the body motion such as the foot action or vibration of the PZT composites. The energy is converted and stored in a low-leakage charge circuit until a predetermined threshold voltage is reached. Once the threshold is reached, the regulated power is allowed to flow for a sufficient period to power the wireless node such as the Zigbee CPU/transceiver. The transmission is detected by nearby wireless nodes that are AC-powered and forwarded to the base station for signal processing. Power comes from the vibration of the system being monitored and the unit requires no maintenance, thus reducing life-cycle costs. In one embodiment, the housing of the unit can be PZT composite, thus reducing the weight.

In another embodiment, body energy generation systems include electro active polymers (EAPs) and dielectric elastomers. EAPs are a class of active materials that have a mechanical response to electrical stimulation and produce an electric potential in response to mechanical stimulation. EAPs are divided into two categories, electronic, driven by electric field, and ionic, driven by diffusion of ions. In one embodiment, ionic polymers are used as biological actuators that assist muscles for organs such as the heart and eyes. Since the ionic polymers require a solvent, the hydrated human body provides a natural environment. Polymers are actuated to contract, assisting the heart to pump, or correcting the shape of the eye to improve vision. Another use is as miniature surgical tools that can be inserted inside the body. EAPs can also be used as artificial smooth muscles, one of the original ideas for EAPs. These muscles could be placed in exoskeletal suits for soldiers or prosthetic devices for disabled persons. Along with the energy generation device, ionic polymers can be the energy storage vessel for harvesting energy. The capacitive characteristics of the EAP allow the polymers to be used in place of a standard capacitor bank. With EAP based jacket, when a person moves his/her arms, it will put the electro active material around the elbow in tension to generate power. Dielectric elastomers can support 50-100% area strain and generate power when compressed. Although the material could again be used in a bending arm type application, a shoe type electric generator can be deployed by placing the dielectric elastomers in the sole of a shoe. The constant compressive force provided by the feet while walking would ensure adequate power generation.

For wireless nodes that require more power, electromagnetics, including coils, magnets, and a resonant beam, and micro-generators can be used to produce electricity from readily available foot movement. Typically, a transmitter needs about 30 mW, but the device transmits for only tens of milliseconds, and a capacitor in the circuit can be charged using harvested energy and the capacitor energy drives the wireless transmission, which is the heaviest power requirement. Electromagnetic energy harvesting uses a magnetic field to convert mechanical energy to electrical. A coil attached to the oscillating mass traverses through a magnetic field that is established by a stationary magnet. The coil travels through a varying amount of magnetic flux, inducing a voltage according to Faraday's law. The induced voltage is inherently small and must therefore be increased to viably source energy. Methods to increase the induced voltage include using a transformer, increasing the number of turns of the coil, and/or increasing the permanent magnetic field. Electromagnetic devices use the motion of a magnet relative to a wire coil to generate an electric voltage. A permanent magnet is placed inside a wound coil. As the magnet is moved through the coil it causes a changing magnetic flux. This flux is responsible for generating the voltage which collects on the coil terminals. This voltage can then be supplied to an electrical load. Because an electromagnetic device needs a magnet to be sliding through the coil to produce voltage, energy harvesting through vibrations is an ideal application. In one embodiment, electromagnetic devices are placed inside the heel of a shoe. One implementation uses a sliding magnet-coil design, the other, opposing magnets with one fixed and one free to move inside the coil. If the length of the coil is increased, which increases the turns, the device is able to produce more power.

In an electrostatic (capacitive) embodiment, energy harvesting relies on the changing capacitance of vibration-dependant varactors. A varactor, or variable capacitor, is initially charged and, as its plates separate because of vibrations, mechanical energy is transformed into electrical energy. MEMS variable capacitors are fabricated through relatively mature silicon micro-machining techniques.

In another embodiment, the wireless node can be powered from thermal and/or kinetic energy. Temperature differentials between opposite segments of a conducting material result in heat flow and consequently charge flow, since mobile, high-energy carriers diffuse from high to low concentration regions. Thermopiles consisting of n-and p-type materials electrically joined at the high-temperature junction are therefore constructed, allowing heat flow to carry the dominant charge carriers of each material to the low temperature end, establishing in the process a voltage difference across the base electrodes. The generated voltage and power is proportional to the temperature differential and the Seebeck coefficient of the thermoelectric materials. Body heat from a user's wrist is captured by a thermoelectric element whose output is boosted and used to charge the a lithium ion rechargeable battery. The unit utilizes the Seeback Effect which describes the voltage created when a temperature difference exists across two different metals. The thermoelectric generator takes body heat and dissipates it to the ambient air, creating electricity in the process.

In another embodiment, the kinetic energy of a person's movement is converted into energy. As a person moves their weight, a small weight inside the wireless node moves like a pendulum and turns a magnet to produce electricity which can be stored in a super-capacitor or a rechargeable lithium battery. Similarly, in a vibration energy embodiment, energy extraction from vibrations is based on the movement of a "spring-mounted" mass relative to its support frame. Mechanical acceleration is produced by vibrations that in turn cause the mass component to move and oscillate (kinetic energy). This relative displacement causes opposing frictional and damping forces to be exerted against the mass, thereby reducing and eventually extinguishing the oscillations. The damping forces literally absorb the kinetic energy of the initial vibration. This energy can be converted into electrical energy via an electric field (electrostatic), magnetic field (electromagnetic), or strain on a piezoelectric material.

Another embodiment extracts energy from the surrounding environment using a small rectenna (microwave-power receivers or ultrasound power receivers) placed in patches or membranes on the skin or alternatively injected underneath the skin. The rectanna converts the received emitted power back to usable low frequency/dc power. A basic rectanna consists of an antenna, a low pass filter, an ac/dc converter and a dc bypass filter. The rectanna can capture renewable electromagnetic energy available in the radio frequency (RF) bands such as AM radio, FM radio, TV, very high frequency (VHF), ultra high frequency (UHF), global system for mobile communications (GSM), digital cellular systems (DCS) and especially the personal communication system (PCS) bands, and unlicensed ISM bands such as 2.4 GHz and 5.8 GHz bands, among others. The system captures the ubiquitous electromagnetic energy (ambient RF noise and signals) opportunistically present in the environment and transforming that energy into useful electrical power. The energy-harvesting antenna is preferably designed to be a wideband, omnidirectional antenna or antenna array that has maximum efficiency at selected bands of frequencies containing the highest energy levels. In a system with an array of antennas, each antenna in the array can be designed to have maximum efficiency at the same or different bands of frequency from one another. The collected RF energy is then converted into usable DC power using a diode-type or other suitable rectifier. This power may be used to drive, for example, an amplifier/filter module connected to a second antenna system that is optimized for a particular frequency and application. One antenna system can act as an energy harvester while the other antenna acts as a signal transmitter/receiver. The antenna circuit elements are formed using standard wafer manufacturing techniques. The antenna output is stepped up and rectified before presented to a trickle charger. The charger can recharge a complete battery by providing a larger potential difference between terminals and more power for charging during a period of time. If battery includes individual micro-battery cells, the trickle charger provides smaller amounts of power to each individual battery cell, with the charging proceeding on a cell by cell basis. Charging of the battery cells continues whenever ambient power is available. As the load depletes cells, depleted cells are switched out with charged cells. The rotation of depleted cells and charged cells continues as required. Energy is banked and managed on a micro-cell basis.

In a solar cell embodiment, photovoltaic cells convert incident light into electrical energy. Each cell consists of a reverse biased pn+junction, where light interfaces with the heavily doped and narrow n+ region. Photons are absorbed within the depletion region, generating electron-hole pairs. The built-in electric field of the junction immediately separates each pair, accumulating electrons and holes in the n+ and p-regions, respectively, and establishing in the process an open circuit voltage. With a load connected, accumulated electrons travel through the load and recombine with holes at the p-side, generating a photocurrent that is directly proportional to light intensity and independent of cell voltage.

As the energy-harvesting sources supply energy in irregular, random "bursts," an intermittent charger waits until sufficient energy is accumulated in a specially designed transitional storage such as a capacitor before attempting to transfer it to the storage device, lithium-ion battery, in this case. Moreover, the system must partition its functions into time slices (time-division multiplex), ensuring enough energy is harvested and stored in the battery before engaging in power-sensitive tasks. Energy can be stored using a secondary (rechargeable) battery and/or a supercapacitor. The different characteristics of batteries and supercapacitors make them suitable for different functions of energy storage. Supercapacitors provide the most volumetrically efficient approach to meeting high power pulsed loads. If the energy must be stored for a long time, and released slowly, for example as back up, a battery would be the preferred energy storage device. If the energy must be delivered quickly, as in a pulse for RF communications, but long term storage is not critical, a supercapacitor would be sufficient. The system can employ i) a battery (or several batteries), ii) a supercapacitor (or supercapacitors), or iii) a combination of batteries and supercapacitors appropriate for the application of interest. In one embodiment, a microbattery and a microsupercapacitor can be used to store energy. Like batteries, supercapacitors are electrochemical devices; however, rather than generating a voltage from a chemical reaction, supercapacitors store energy by separating charged species in an electrolyte. In one embodiment, a flexible, thin-film, rechargeable battery from Cymbet Corp. of Elk River, Minn. provides 3.6V and can be recharged by a reader. The battery cells can be from 5 to 25 microns thick. The batteries can be recharged with solar energy, or can be recharged by inductive coupling. The tag is put within range of a coil attached to an energy source. The coil "couples" with the antenna on the RFID tag, enabling the tag to draw energy from the magnetic field created by the two coils.

As one of average skill in the art will appreciate, the wireless communication devices described above may be implemented using one or more integrated circuits. For example, a host device may be implemented on one integrated circuit, the baseband processing module may be implemented on a second integrated circuit, and the remaining components of the radio, less the antennas, may be implemented on a third integrated circuit. As an alternate example, the radio may be implemented on a single integrated circuit. As yet another example, the processing module of the host device and the baseband processing module may be a common processing device implemented on a single integrated circuit.

"Computer readable media" can be any available media that can be accessed by client/server devices. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media includes volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by client/server devices. Communication media typically embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media.

All references including patent applications and publications cited herein are incorporated herein by reference in their entirety and for all purposes to the same extent as if each individual publication or patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety for all purposes. Many modifications and variations of this invention can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. The specific embodiments described herein are offered by way of example only. The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

United States Patent **7,253,732**
Osann, Jr. **August 7, 2007**

Home intrusion confrontation avoidance system

Abstract

A system is described that enables the user to deal with an intrusion into their home without having to personally confront the intruder. Given the night-time nature of many intruder events, a display and control unit is disclosed that is suitable for residing on a bedside table, typically in the Master Bedroom, performing a remote viewing and control function. Various locations within the particular home are represented by buttons such that the user can easily choose the location(s) to be viewed and can verify, among other things, the presence of an intruder. Motion detection is various rooms may be included and viewing can be enhanced by lights controlled from this unit. User interface features are included that are simple to operate when the user is half-awake. *Surveillance* and control features may be combined with common bedside appliance functions including a clock-radio, a television, or a telephone.

Inventors: **Osann, Jr.; Robert** (Cupertino, CA)
Appl. No.: **11/006,263**
Filed: **December 7, 2004**

Related U.S. Patent Documents

Application Number	Filing Date	Patent Number	Issue Date<TD< TD>
09949551	Sep., 2001	6993417	<TD< TD>

Current U.S. Class:	**340/541** ; 340/539.16; 340/539.25; 348/143; 348/152; 348/153
Current International Class:	G08B 13/00 (20060101)
Field of Search:	340/539.25,539.16,539.18,539.14,541 348/143,152,153,154,155

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Primary Examiner: Hofsass; Jeffery
Assistant Examiner: Labbees; Edny

Parent Case Text

CROSS REFERENCE TO RELATED APPLICATIONS AND DOCUMENTS

This application is a Continuation-In-Part of U.S. Utility patent application Ser. No. 09/949,551 filed Sep. 10, 2001 now U.S. Pat. No. 6,993,417, and originally entitled "Energy Smart Home System", commonly assigned with the present invention and incorporated herein by reference.

This application is also based on Disclosure Document Ser. No. 533894 filed on Dec. 10, 2002 under the USPTO Disclosure Document Program, entitled "Video Security and Power Control System", incorporated by reference herein. A separate transmittal letter requesting that this Disclosure Document be retained has been filed with this application.

Claims

What is claimed is:

1. A compact display and control console suitable for use on a bedside table in a bedroom including: a display for displaying video images sent from video cameras located in a plurality of rooms in a home, where said video cameras are capable of capturing said video images under both low lighting and bright lighting conditions; and split screen capability for viewing one or more images from multiple rooms at the same time in different portions of the display area, and where the choice of which images to display is automatically made according to motion detectors located

in the rooms; buttons for remotely controlling lights in corresponding rooms such that said lights may initially be off and then may be remotely turned on by the user in order to frighten an intruder or obtain a better view of an intruder; and motion indicators for informing the user which rooms in the home contain a potential intruder; and at least one direct access button enabling the user to signal the police or a security company that an intruder has been detected.

2. The display and control console of claim 1, also including a alarm clock function that when displayed, occupies either the full screen or one of the portions of the split screen.

3. The display and control console of claim 1, also including a radio function.

4. The display and control console of claim 1, also including a TV function.

5. A compact display and control console suitable for use on a bedside table in a bedroom including: a display for displaying video images sent from video cameras located in a plurality of rooms in a home where said video cameras are capable of capturing said video images under both low lighting and bright lighting conditions; and split screen capability for viewing one or more images from multiple rooms at the same time in different portions of the display area, and where the choice of which images to display is automatically made according to motion detectors located in the rooms; and buttons for remotely controlling lights in corresponding rooms such that said lights may initially be off and then may be remotely turned on by the user in order to frighten an intruder or obtain a better view of an intruder; and motion indicators for informing the user which rooms in the home contain a potential intruder; and at least one direct access button enabling the user to signal the police or a security company that an intruder has been detected; and an alarm clock function that when displayed, occupies either the full screen or one of the portions of the split screen; and a radio function.

6. The display and control console of claim 5, also including a TV function.

7. A compact display and control console suitable for use on a bedside table in a bedroom including: a display for displaying video images sent from video cameras located in a plurality of rooms in a home, where said video cameras are capable of capturing said video images under both low lighting and bright lighting conditions, and where the choice of which images to display may optionally be automatically

made according to motion detectors located in the rooms; buttons for remotely controlling lights in corresponding rooms such that said lights may initially be off and then may be remotely turned on by the user in order to frighten an intruder or obtain a better view of an intruder; and at least one direct access button enabling the user to signal the police or a security company that an intruder has been detected; an alarm clock function; and a radio function.

8. The display and control console of claim 7, also including a TV function.

9. The display and control console of claim 7, also including optional split screen capability for viewing one or more images from multiple rooms at the same time in different portions of the display area.

10. A video ***surveillance,*** communications, and control system for the home comprising: A plurality of video cameras located in a plurality of rooms in a home, where said video cameras are capable of capturing video images under both low lighting and bright lighting conditions; and A plurality of motion detectors in different rooms in a home for sensing which rooms contain a potential intruder; and A plurality of lights in different rooms in a home, said lights being remotely controllable; and A compact display and control console suitable for use on a bedside table in a bedroom wherein said console displays video images sent from said video cameras and where said console includes: split screen capability for viewing one or more images from multiple rooms at the same time in different portions of the display area, and where the choice of which images to display may optionally be automatically made according to motion detectors located in the rooms; buttons for remotely controlling lights in corresponding rooms such that said lights may initially be off and then may be remotely turned on by the user in order to frighten an intruder or obtain a better view of an intruder; and motion indicators for informing the user which rooms in the home contain a potential intruder; and at least one direct access button enabling the user to silently signal the police or security company that an intruder has been detected.

11. The display and control console of claim 10, also including an alarm clock function that when displayed, occupies either the full screen or one of the portions of the split screen.

12. The display and control console of claim 10, also including a radio function.

13. A method for interacting with a home intruder, a security service, and law enforcement officials comprising the steps of: observing the presence and behavior of a potential home intruder on a compact display and control console suitable for use on a bedside table in a home bedroom, said console including a display for displaying video images sent from video cameras located in a plurality of rooms in a home, where said video cameras are capable of capturing said video images under both low lighting and bright lighting conditions; and passively discerning, by the user, the presence of an intruder in low lighting conditions; and generating a silent alarm message by pressing at least one direct access button on said console, by the user, said alarm message being sent to a security service or law enforcement officials; and pressing at least one of a plurality of buttons on said console, by the user, for remotely controlling lights in corresponding rooms such that said lights may initially be off and then may be remotely turned on by the user in order to frighten an intruder or obtain a better view of an intruder.

14. The method of claim 13, wherein said console also includes optional split screen capability for viewing one or more images from multiple rooms at the same time in different portions of the display area.

15. The method of claim 13, wherein said console also includes motion indicators for informing the user which rooms in the home contain a potential intruder.

16. The method of claim 14, wherein motion detectors in the rooms are used to determine which rooms are viewed on the split screen in the different portions of the display area on said console.

17. The method of claim 14, wherein said console also includes an alarm clock function that when displayed, occupies either the full screen or one of the portions of the split screen.

Description

FIELD OF THE INVENTION

This invention generally relates to the field of electronic systems for homes and buildings, including systems for home networking, home energy and appliance controls, and home security***/surveillance*** systems, with special emphasis on energy monitoring, feedback and profiling, and in particular, the use of electrical junction boxes for purposes they do not normally perform. Although many of the features of this invention will be described in relation to a residential home environment, it is understood that they are generally applicable to many office and industrial building applications as well.

BACKGROUND

Many products have been introduced over the last 25 years for controlling electrical and electronic devices and appliances within homes and buildings. It is well known to use a variety of communications mediums to enable this control (power lines, phone lines, and purpose built network connectivity such as cabled Ethernet or wireless networks).

More recently, it is known to extend this control to connection via the Internet allowing a further degree of remote control and communication. In addition, ***surveillance*** capabilities have been added by using video cameras that can transmit images to monitors in other parts of the home/building as well as supplying these images to remote locations via the Internet. Also, there is discussion that future home and building appliances (washing machines, refrigerators, etc.) will connect to the Internet such that they can communicate over the Internet directly. Among other possible remote interactions, they can communicate their condition and signal the need for service before breakdowns occur, as well as enable diagnostics to be performed remotely via the Internet.

The move toward home and building automation has not necessarily been prioritized according to how the general public accepts new things--especially in light of the fact that old habits are hard to break regarding how one deals with power consuming devices in homes and buildings. While most people may not be ready to have their lights and appliances controlled automatically, there are other motivations that may move them toward installing a home/building monitoring and control system: Saving money given increasing energy costs Security***/Surveillance***/Remote Care The pervasive nature of home networking and Internet connectivity Expansion of home entertainment capabilities Interaction of Monitoring/Feedback with Automated and Manual Control

The psychological element is extremely critical in the adoption rate of any system involving monitoring and/or control. Letting a computer control one's home/building appliances that in the past were controlled manually, is a sensitive issue. A monitoring and feedback system is much less disturbing or threatening, but for users who wish to add some amount of automatic control, there must be a carefully planned interaction between the two. It is not uncommon for some lights in homes, and especially in office buildings, to be controlled by circuits containing motion detectors. Invariably, there are occurrences where the motion detector causes the lights to be shut off at the wrong time. This can easily get annoying since, as is commonly known, it takes a multitude of positive interactions to overcome the emotional effect of a single negative interaction.

Alternately, let's say that there exists a local PC (Personal Computer) running software for home automation and control, and a centrally controlled light switch that is programmed to shut off at 1:00 AM regardless of switch position to ensure that it is not left on all night accidentally.

Now, let's say the user has stayed up late and is in the room with this switch. At the programmed time, the automatic control system will shut off the power at the switch. (It may signal the user some time prior to shutting off by flashing the lights). To prevent the switch in question from causing the user great aggravation, it must have the ability to override the auto shutoff event. If the switch has a transmit capability such as that described below for EMAC (Energy Monitoring And Control) points, the user could, for instance, toggle the switch or push a mode button after the flashing warning (or if the light has turned off already), and that action would be transmitted back to the central controlling PC to allow a revised scenario to occur. Even if the override can be performed locally without interaction with the central PC, it is useful to transmit back to the central PC that the event has happened to aid in avoiding similar user aggravation in the future. For instance, the central control system could "learn" and, in this case, delay the auto shutoff of that particular light switch until 1:00 AM or later, or switch to a motion detector-controlled mode after 1:00.

The most common mechanism today for controlling lights is based on motion detectors incorporated into the controlling switch assembly or alternately incorporated into the light socket assembly. These work fairly well in some circumstances--especially in spaces where people seldom go such as attics and closets. However, in primary living areas, they can often cause a negative interaction with the user. For instance, the inventor installed a light switch with motion detector at the entry to his living room. Unfortunately, the detector's range does not cover the entire room, thus occasionally leaving the inventor "in the dark". Were there a multitude of motion detectors scattered around this same room--communicating through a data communications link such that the light control circuit was guided in a more informed manner (as described later in this invention)--the inventor would be more positively illuminated.

Interaction of Monitoring/Feedback with Audio/Video Functionality

Although this invention deals primarily with energy use, monitoring, feedback, and control, the overall system in a given home or building may also deal with the distribution and control of multi-media information including audio and video. Over time, the communications link between the EMAC points of this invention and the central controlling device (usually a PC or Residential Gateway), will have more and more bandwidth capability, such that this link also becomes the primary means for distributing digital multimedia information throughout the home or building. Thus, there will be a coexistence, if not a functional link, between the elements of this invention focused on energy monitoring, feedback, and control, and elements focused on audio/video integration and control. This transmission of audio/video information can be for communications, security, or entertainment purposes.

No Feedback on Energy Consumption

At the time of this writing, energy costs have risen substantially and are likely to continue to do so. One of the first, and most important problems consumers are faced with is knowing exactly where, and how much power is being consumed in specific areas/appliances in their homes and buildings. Today's home and building automation systems are much more focused on controlling than on providing energy usage feedback. Meanwhile, the typical occupant may have little or no idea of where the energy is actually being consumed.

Simplistic Control of Heating and Cooling Systems based on Limited Information

Today's typical control system for heating and cooling, the traditional thermostat, does not take advantage of networked connectivity and the information gathering that it affords, thereby missing the opportunity to provide a much more comfortable and energy efficient thermal environment. Even today's "programmable" thermostat observes only the temperature at it's own location. It is therefore very common for rooms or offices not containing the thermostat to be overheated or overcooled. Such rooms or offices waste energy if they are not occupied, or make the occupants uncomfortable if they are occupied.

Security Systems

The International Association of Chiefs of Police estimates that between 95% and 98% of all home-alarm calls are false, costing police departments nationwide about $600 million a year. If a Security Company, or the Police, could remotely view the interior of the home or building where the alarm has just been activated, most of this money could be saved. Security companies offer video ***surveillance,*** but the systems are complex and expensive and not easily adapted to existing homes without extensive additional wiring and adding provisions for mounting and powering the video cameras.

Intruder Confrontation Avoidance

Hundreds of innocent people are killed every year because they confronted an intruder in their home. The occupant may have owned a gun--the intruder may have carried one--either way, the result was the same. Hundreds more are killed accidentally by friends and relatives because they are assumed to be intruders. Most of these instances could have been avoided if the "Security QuickView" technology described herein had been available that was easy to use, given the occupant is probably in bed and only half-awake.

Conventional security systems don't avoid confrontation. When a conventional alarm is set off, the occupant needs to decide whether the alarm is false or not. If false, they need to call their security service provider to prevent police dispatch and possible false alarm fees. The result is that they walk about the house checking for an intruder. So much for safety.

Some security systems have integrated the security control panel into a "smart home" control center, typically centrally located in the home (usually in a hallway near a primary entrance or in the kitchen), and sometimes including video ***surveillance*** capability. Unfortunately, these systems don't help when the occupant is awakened in the middle of the night.

Most confrontations happen at night. Either the alarm goes off or the occupant is awakened by a noise. Either way, the occupant is in their bed in the master bedroom and is groggy and barely awake. Even the brightest persons don't think clearly at moments like these. Absolute "push-button" simplicity is required to enable a quick and accurate decision to be made. If there is a suspected intruder, there should be a direct way to call 911 and also confirm the intrusion with the security service provider. It may be also desirable that an intercom is available to broadcast a message to the intruder that the police have been informed and that they should leave immediately.

SUMMARY

Overall, the home system described in this invention relates to the energy distribution systems in a home or building. Much of the uniqueness in this invention deals with the combining of diverse functionalities that heretofore have not been combined in similar ways. Although the digital communications networks or links described in this invention are typically based on communication by sending signals through existing electrical power wiring (hence the term "powerline communications"), not all embodiments are restricted to this form of communications. However, when powerline communication is utilized herein, the result is a system that uses electrical wiring for energy distribution, monitoring, and control as well as security, audio/video communications and entertainment, and general network communications such as file transfers and Internet connectivity.

Energy consumption in most homes/buildings today is made up of both electrical power and some form of oil/gas based power. Some homes and buildings use electrical power only. This invention deals with both, although many of the features described can be optionally used in different combinations as desired by the customer.

A primary aspect of this invention is to provide a form of "biofeedback" for home and building energy consumption. By providing easy to understand information to consumers, they can adjust their usage of energy and still have normal control of their power-consuming devices--over time transitioning to automated control as they desire. Also, some specific capabilities of this invention enhance the effectiveness of automated energy controls.

Electrical energy is typically consumed by devices attached to electrical junction boxes. These junction boxes are typically proliferated throughout a home or building.

As a result, they become not only convenient locations to measure and display electrical power consumption--they also provide a convenient means to proliferate temperature sensors, motion detectors, and video cameras. The same communications mechanism used for transmitting power-related data is typically used for these additional functionalities which aid in the enhancement of energy control (both thermal and electrical) while enhancing security at the same time.

This invention has the following primary goals regarding energy feedback: 1) Provide "instant feedback" at the point of usage. 2) Provide electrical energy usage profiling with multi-dimensional graphics on a centrally located PC, or Residential Gateway. Include both spatial usage and usage over time. Transfer related information via the Internet as necessary and desired. 3) Provide thermal profiling on a centrally located PC, Residential Gateway, or Smart Thermostat. Use multi-dimensional graphics as useful or appropriate. Include both spatial profiling and profiling over time. 4) Provide more intelligent and efficient thermal energy usage by combining a multi dimensional thermal profile with an enhanced and more intelligent (thermostat) control system for heating and cooling.

Another object of this invention is to allow easy retrofit of all components into existing homes/buildings with minimal or no modification to the home/building or special skills required on the part of the installer. This goal is greatly facilitated by attachment to and communications through existing electrical junction boxes.

Another object of this invention is to provide integration of the energy feedback and profiling mechanisms with various known and/or new types of control mechanisms.

A home/building system according to this invention provides a unique solution for energy profiling and feedback, while including network connectivity, energy control, ***surveillance,*** communications, and entertainment functionality as deemed necessary, useful, or desired. This invention essentially creates a "bio-feedback" mechanism for energy use, covering both electrical and thermal energy, through a system architecture that enables a more thorough and broad-based gathering of energy related information. This information is used by the occupant to allow manual control of power consumption in a more informed and effective manner, and also to allow either partial or fully automatic control of energy consumption to be more effectively performed as well.

For the most part, this invention takes advantage of the pervasiveness of electrical junction boxes, typically implementing power plug outlets and the wall switches, within any home or building. These become convenient locations for installing what are called EMAC (Energy Monitoring And Control) points. As explained later, an EMAC point will typically contain one or more forms of energy sensor, often containing both electrical current sensors and a temperature sensor. Since EMAC points typically reside at locations having convenient access to electrical power, they are normally powered directly by this available source, and also typically contain a digital communications circuit that communicates with the central computer, Residential Gateway, or other data gathering and/or controlling device via power line communications, although other forms of data communications--such as wireless--can be used under the right circumstances. This communication link then affords a basic backbone infrastructure for network connections in general. EMAC points may also communicate with other EMAC points as appropriate.

Thus, in an environment where network connectivity has not yet been made readily available (typically referring to the home environment), the installation of EMAC points creates a local network infrastructure that can be built upon before adding other capabilities in addition to normal computer connectivity. These include facilities for enabling home ***surveillance,*** security, and entertainment. Not all EMAC points contain a "control" capability. In some cases it is not appropriate due to the type of energy consuming device that is connected, either because it must be "on" all the time, or because it is already controlled by some other mechanism (for instance a thermostat and/or relay), or because the level of power consumption is high enough to cause a control capability to be too expensive or inappropriate.

Wall switches for controlling lights are also convenient and effective locations for mounting video security cameras. There is usually a wall switch at the entrance to a room and usually it has a relatively commanding view. The easy proliferation of video cameras throughout a home or building, by way of installation at existing junction boxes, has considerable security benefit. In particular, such a system could allow a Security Company or even the Police to view inside and around the home or building in the case of an alarm being set off, so that a "false alarm" condition can be determined without having to visit the location.

A variation on the system enables the user to deal with an intrusion into their home without having to personally confront the intruder. Given the night-time nature of many intruder events, a Display and Control console is disclosed that is suitable for residing on a bedside table, typically in the Master Bedroom, performing a remote viewing and control function. Video cameras are placed around the house, commonly residing at junction box locations as described above. Various locations within the particular home are represented by buttons such that the user can easily choose the location(s) to be viewed and can verify, among other things, the presence of an intruder. Motion detection in various rooms may be included (again, commonly installed at junction boxes) which may alternately control which rooms are viewed, and viewing can be enhanced by lights controlled from the Display and Control unit, the power control circuits for these lights actually residing at the junction boxes that power the lights. Wireless or powerline communications are used between junction boxes and the Display and Control console. User interface features are included that are simple to operate when the user is half-awake. ***Surveillance*** and control features may be combined with common bedside appliance functions including a clock-radio, a television, or a telephone.

Wall switches are also convenient locations for incorporating intercom functionality. Wall mounted power plug receptacles typically have a high degree of proliferation within any room as a result of convention and also building codes. Power plug receptacles are therefore especially useful for gathering temperature information since their proliferation allows gathering a thorough profile of the temperature distribution within any room. Power plug receptacles are also very convenient locations to offer network connection jacks where any computer or network compatible device or appliance may be attached. They are also convenient locations for adding motion detectors in order to provide a proliferation of detectors in order to enable thorough coverage of rooms not easily covered from a single vantage point.

EMAC points dealing specifically with electrical power consumption may also be added to the electrical breaker box by: 1) Retrofitting EMAC capability into an existing breaker box. 2) Adding smart (EMAC enabled) breakers to an existing box, or 3) Having a replacement breaker box that has EMAC points added in series with conventional breakers.

To effectively provide the aforementioned "biofeedback capability" for energy consumption, this invention offers two forms of feedback--local/instant feedback at the point of use, and general profiling over both time and space provided to the user by software which typically runs on a central PC or Residential Gateway. To assist in creating an overall multi dimensional model for a home or building, capabilities are also described that enable either automatic or semiautomatic identification of EMAC points and their location within the home or building.

To allow a more effective, efficient, and intelligent control of thermal energy utilization, the concept of collecting temperature information in a highly distributed manner is also utilized to enhance the capabilities of the traditional thermostat transforming it into a "smart", network enabled thermostat.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described with respect to particular exemplary embodiments thereof and reference is accordingly made to the drawings in which:

FIG. 1 shows an overall system view including power distribution, communications circuits and connectivity, central controlling elements (local PC or Residential Gateway, smart thermostat) and various forms of EMAC points;

FIG. 2 shows a typical wall switch assembly including an EMAC point;

FIG. 3 shows a wall switch assembly including an EMAC point with a variety of display formats for direct visual communication of energy consumption;

FIG. 4 shows a wall switch assembly including an EMAC point with an alternative display format for direct visual communication of energy consumption and local temperature, including a data read out and a suite of enunciators;

FIG. 5 shows a wall-mounted power-outlet assembly including an EMAC point;

FIG. 6 shows a wall-mounted power-outlet assembly with alternate functionality;

FIG. 7 shows an overall system view with emphasis on connectivity through the Internet between the local system and utility companies, security companies, and a data service company supplying information to specifically support the configuration of the particular local system;

FIG. 8 shows one form of connectivity for video ***surveillance*** where video information is transferred from EMAC points to a central location in the analog format, and are digitized and compressed at that central location before being supplied to the local PC;

FIG. 9 shows a network hub capability allowing EMAC points having different data rate transmission capabilities to all talk to the local PC;

FIG. 10 shows a smart breaker box where a form of EMAC point is used in conjunction with conventional breakers to determine the amount of electrical current being consumed by all devices that are wired to a particular breaker;

FIG. 11 shows how an EMAC point can be retrofitted in a standard, conventional breaker box, providing sensing of all incoming and outgoing electrical current;

FIG. 12 shows how smart breakers incorporating EMAC points can be retrofitted in a standard, conventional breaker box;

FIG. 13 shows how an EMAC point is used in conjunction with a conventional light bulb socket of the type typically found in attics and garages;

FIG. 14 shows how an assembly including an EMAC point is incorporated into a multi-outlet power strip;

FIG. 15 shows how an assembly including an EMAC point can be connected to flow meters monitoring natural gas or heating oil consumption to allow communication of this information to a local PC;

FIG. 16 shows a two dimensional layout drawing for a typical home that has been fully instrumented with EMAC points at wall switch and power plug locations as well as some dedicated locations for directly wired devices;

FIG. 17 shows a two dimensional layout drawing for a typical home including a detailed blow-up showing a possible visual representation for an electrical energy utilization profile;

FIG. 18 shows a two dimensional layout drawing for a typical home including a possible visual representation for a temperature profile;

FIG. 19 shows a two dimensional layout drawing for an office environment with distributed temperature sensors communicating through network connections with smart thermostats;

FIG. 20 shows an EMAC-enabled wall-outlet having a closure detection provision allowing the unit to determine when a nearby window is open;

FIG. 21 shows an EMAC-enabled wall-outlet having a closure detection provision allowing the unit to determine when a nearby window is open, including wireless communication between the EMAC point and the closure detection sensor;

FIG. 22 shows a portable or add-on EMAC wall outlet assembly that can easily be plugged into an existing conventional wall outlet and can also be easily moved to other locations within a home or building;

FIG. 23 shows a portable EMAC identification unit that is used in proximity to, or attached to, an EMAC point. When operating in conjunction with appropriate position locating apparatus, this device will assist the user in creating a two dimensional layout map of a home or building while automatically identifying the location of EMAC points;

FIG. 24 shows how a portable EMAC identification unit might be used with multiple wireless transmitting beacons to determine its position in a manner similar to that used in the GPS (Global Positioning System) system;

FIG. 25 shows how audio information can be transmitted to an EMAC point over the data connection and then be converted to audible sound by circuitry which is powered by the same power line that carried the data;

FIG. 26 shows how a full motion video panel display can be incorporated into an EMAC point allowing a multi-media intercom/teleconferencing capability as well as viewing of other areas of the home for ***surveillance*** purposes, in addition to displaying energy consumption and temperature data;

FIG. 27 shows how assemblies including EMAC points can be serialized by use of a scanned, programmable wiring matrix implemented on a PCB (Printed Circuit Board).

FIG. 28 shows an EMAC point that functions as an extension to an electrical junction box, providing a re-creation of the junction box interface, and including a video camera and motion detector.

FIG. 29 shows a concealed pinhole video camera that is incorporated into a conventional junction box face plate.

FIG. 30 shows security QuikView functionality incorporated into a wall switch.

FIG. 31 shows security QuikView functionality incorporated into a bedside display and control console.

FIG. 32 shows security QuikView functionality incorporated into a bedside display and control console with split screen capability.

FIG. 33 shows security QuikView functionality incorporated into a bedside display and control console with a clock/radio function added.

FIG. 34 shows security QuikView functionality incorporated into a bedside display and control console with split screen capability and a clock/radio function added.

FIG. 35 shows security QuikView functionality incorporated into a bedside display and control console with a TV function added.

DETAILED DESCRIPTION OF THE INVENTION

The diagram of FIG. 1 shows an architectural overview of how the present invention might be implemented in a typical home or building. The incoming AC power line passes through the Utility Company meter 1 on its way to one more breaker boxes 2 before being generally distributed throughout the home or building through conventional power wiring 3. Throughout the home/building there are user-accessible, electrical junction box power access locations such as wall switch assembly 4 and power plug receptacle assembly 5. In addition, there are power-consuming devices 6 that are directly connected by way of interface module 7. Some, most, or all of these power connection locations can be implemented, within the scope of this invention, incorporating Energy Monitoring And Control (EMAC) points. Each EMAC point contains at a minimum an energy sensing capability (electrical, thermal, or both) and a digital communications circuit enabling communication with a central intelligence such as a local PC 9 (personal computer) or Residential Gateway residing in the same home/building. Note that throughout this document, "local PC" is considered to be synonymous with "central PC" and "Residential Gateway" in that they all represent a form of centrally located intelligence that may perform analysis, control, and communications functions. In today's vernacular, a Residential Gateway is considered to be always in the "ON" condition and provides a constantly available connection to the Internet 24/7 (24 hours a day and 7 days a week). Depending on the particular installation, a local PC can be "ON" for 24/7 and also perform this function. Alternately, there may be an additional device that specifically performs the Residential Gateway function shown as local PC 9. Note that a "smart" thermostat can also be a form of "centrally located intelligence" that communicates with EMAC points.

Note that from the perspective of an EMAC point, a local PC, a Residential Gateway, a Smart Thermostat, or a device located somewhere on the Internet, as well as other EMAC points, are all considered "remote devices". Also, much of the functionality attributed to local PC 9 can also be performed by an intelligent device located at a different physical location and connected via the Internet by way of local PC 9 or some form of Residential Gateway.

In addition to these basic capabilities, EMAC points can incorporate a number of other additional functionalities, all of which will be described herein. Also, although most figures describing the capabilities of EMAC points show current sensing as the means to measure electrical power consumption, it is understood that to compute the true power consumption, the voltage must also be known. If it is desired to measure power consumption in an accurate manner that correlates with the Utility Company power bill, then the voltage measurement used for computing power consumption should be made as close (from an electrical resistivity standpoint) to the Utility Company power meter as possible. Where any EMAC capability is included at the primary breaker box location, a voltage measurement on the input side would be a good location.

Although not strictly limited to power lines, communication between EMAC points will typically be carried out by signals sent over power lines since this medium is obviously convenient at any junction box power connection location. Where electrical devices are directly wired (not plugged-in or switched), interface modules 7 may be inserted to allow the EMAC function to be performed. Other possible locations to insert EMAC functions include light bulb sockets, circuit breaker boxes, and circuit breakers themselves, just to mention a few). Although power line communication is a focal point of this invention, depending upon the evolution of data communication technology for the home or building environment, it may become suitable to utilize other forms such as Wireless Communications in the future. It may also be that some forms of information, such as video in its analog form, may be better suited to a wireless transmission. Also, for systems implemented in office buildings, it may be convenient to communicate by way of pre-existing network connections such as Ethernet.

Another interface module 8 is used to connect between the power lines and a local PC 9 to enable the communication function to be performed. Other intelligent devices may also connect to this power line-based networking capability. In addition to the smart thermostat 10 shown in FIG. 1, this networking infrastructure backbone for the home/building can also be used to implement capabilities in the area of home ***surveillance,*** home entertainment, or simply connecting computers so that they may exchange data or connect to the Internet 11. Although throughout the description of this invention, reference will often be made to communication between EMAC points and a local PC 9, it is understood that with the necessary functionality incorporated into an EMAC point, this communication could instead transfer information directly between an EMAC point and a website or other entity via the Internet. EMAC points can also be capable of transferring information among themselves, without having to communicate with any central form of intelligence such as local PC 9, a Residential Gateway, or the Internet 11.

EMAC Points

Energy monitoring, local feedback, data transmission/reception and control, along with other functions (such as video ***surveillance*** and/or motion detection, and general-purpose network connections), can be included at a variety of locations within the home/building. A few examples include conventional electrical junction boxes where wall switches, power plug receptacles, light bulb sockets, and other power consuming and/or power-controlling devices may be installed. Other possible locations for installing EMAC functionality include circuit breaker boxes, or circuit breakers themselves.

FIG. 2 shows how a replacement light switch assembly 12 attached to an electrical junction box might be implemented to include EMAC functionality. A current sensor 13 measures the power to the load. These sensors can use any of a number of known technologies including inductive or resistive (current shunt). An optional control unit (if present) can optionally turn the power on/off or dim (for lights) in response to a remote command, or can effect various forms of local control for dimming (for lights). Such control modes and others, as well as their implementations--(often relying on SCR (Silicon Controlled Rectifier) devices--are well known in the art. Also, various interactions that may take place between a remote device (local PC 9, a smart thermostat, or some remote device communicating via the Internet 11) and a wall switch EMAC point will be discussed later. The implementation of any EMAC point that includes a switch should always include a means for sensing the switch position (open or closed), regardless of whether or not current is flowing through it. There may be circumstances where a control element in the EMAC point has blocked electrical current from passing through the switch, however it is necessary for the position of the switch to be communicated back to local PC 9 or to some other networked device.

Where a power control function is included in an EMAC point, it is important that the EMAC point operate consistently and predictably, even when the power to the home or building fluctuates or goes off and on, or when a problem arises with a remote device that may issue control commands to the particular EMAC point. A "power-on-reset" circuit should be included to insure the EMAC point never gets "confused" by power fluctuations. Also, when the EMAC point is operating in a mode where its function is being controlled by local PC 9 or some other remote device, the EMAC point may, from time to time, poll the remote device to ensure that the communications link (and the remote device) are still functioning properly. If the remote device did not respond, indicating a possible problem, the EMAC point should switch to its default mode--for instance, if there is a light switch, the power should be applied according to the position of the switch.

The multi-digit display 14 shown in FIG. 2, as well as the displays shown in the many other figures included herein, may be used for many different purposes. A few examples are listed below: 1) Identify to the user the particular switch or outlet assembly and the individual switches/outlets/devices within the assembly 2) Display the current or power (KW/time) being used by the load at a switch, outlet, device, or breaker. 3) Display the cost per time of operating the load attached to a switch, outlet, device, or breaker. 4) Display any mode-related information in response to the optional mode button(s), in response to voice commands, and/or in response to the central PC. 5) Display the temperature recorded by the temperature sensor. 6) Provide feedback for calibration of the temperature sensor, the optional video camera, or the optional motion detector.

FIG. 2 also shows an optional video camera 15 as well as temperature sensor 16, motion detector 17 and intercom capability 18 comprising microphone 18a, and speaker 18b. Some implementations may allow a single transducer to be used for both the microphone and speaker. Circuit 13a shown in FIG. 2 includes a digital communications circuit containing all functionality necessary for data transmission and reception. Circuit 13a also contains the power supply necessary to power any circuitry within the assembly from the available AC power located within the particular junction box, as well as any power control circuitry for an electrical load connected to the assembly. In addition, 13a contains all display driver functionality as well as any circuit functionality necessary to interface with the optional video camera--including video digitization and compression functionality. Various functionalities for video digitization and compression are well known in the art.

FIG. 3 and FIG. 4 both show possible implementations of this local display. In the case of electrical energy consumption, the purpose of these displays is to provide instant visual feedback to the user on energy consumption at the point of use. When displaying temperature, these displays are a guide to thermal energy efficiency by showing the user instantly where certain areas of the home/building have been made overly hot or overly cool beyond what is desired or necessary thereby consuming excess and therefore wasted energy.

These local displays may have any number of digits, depending on the specific requirement. The multi-digit display need not only be of the seven-segment variety as shown in enlarged view 14a. One or more of the digits could be alphanumeric (either with additional segments, or a full matrix as indicated by 14b and 14c [e.g. 5.times.7, 7.times.12, etc.]). Utilizing more than a simple seven-segment capability may provide a more informative and intuitive user interface. This may be especially useful in displaying symbols like "$" or " " in the scenario described below.

A key element of this invention is related to display purpose number (3) listed above ("Display the cost per time of operating the load attached to the switch, outlet, device, or breaker."). The local PC 9 (or Internet 11 directly) can supply the current cost per unit of energy (kW, Therm, etc.) for the consumer's home/building which, in turn, is used to convert the energy consumption level to a cost-per-time parameter, for instance $/month. Energy cost parameters can be automatically accessed from time to time over the Internet. (Energy cost parameters could also be accessed directly over the Internet by an EMAC function, if this EMAC function was designed to incorporate enough intelligence to directly access the Internet.) The energy consumption value at the point of use is then displayed on the switch panel thereby providing instant feedback to the consumer. The conversion calculation from "current consumption" to "cost per time" can be performed in the local controller at the switch or at local PC 9. FIG. 3 shows how another alternate form of the local display can be implemented.

In addition to the forms of display shown in FIGS. 3 and 4, it is also possible to utilize a generalized LCD matrix display (discussed later with reference to FIG. 26) similar to those now found in small wireless communication devices and/or hand-held video games. Incorporation of an LCD matrix display would allow a full motion video image to be shown, further enhancing the overall system capability by allowing the user to view images being recorded at cameras elsewhere in the home from any room having an EMAC point with such an LCD matrix display. Since it is possible according to this invention to also add ***surveillance*** cameras which observe activity around the exteriors of the home, this capability to add video-capable LCD displays to EMAC points is also useful to enhance the security***/surveillance*** capabilities of the overall system.

Both FIGS. 2 and 3 show optional control buttons 118 that can be used to determine the form of the information displayed, and/or affect the operation of an EMAC function. An alternative to using any control buttons on an EMAC point and a way of adding additional functionality is to incorporate a voice recognition technology into the system. This recognition function can be performed by hardware and software contained within the EMAC point. Alternately, it can be performed without adding additional hardware cost to the EMAC point itself by utilizing the microphone, such as that required to implement intercom 18 in FIG. 2. This microphone will receive voice information that in turn can be digitized and sent to local PC 9 for analysis. Voice recognition software is well known and can be trained to respond well to the voices of the home's primary occupants. This incorporation of voice recognition software can be used for a variety of purposes in conjunction with EMAC points including remote control of functionality at the particular EMAC point receiving the voice command or alternately controlling other EMAC points within the home. Control of any Home Systems functionality by a user interfacing with a particular EMAC point can alternately be accomplished by some form of remote control receiver--either IR (Infrared) or wireless--that is incorporated into an EMAC point.

The display incorporated into an EMAC point can also be used for displaying the temperature or other parameters. Where more parameters are to be displayed than there are digits or space available, the display can alternately display different parameters in multiplexed intervals. This is also the methodology shown in FIG. 4 for displaying the power consumption for each of multiple receptacles. Enunciator LEDs could be used or, if necessary, an additional digit can be added to indicate the position of a particular receptacle whose parameter is being displayed at the moment. To indicate what type of information is being displayed and/or what units of measurement are being displayed, other forms of display means can be used. For instance, enlarged view 14d of display 14 in FIG. 4 shows that multiple enunciator icons 19 representing parameters or identifying power consuming loads (switches, outlets, etc.) can exist on the display. The appropriate one(s) of these enunciator icons are then illuminated/highlighted depending on what energy or temperature information is being displayed at the moment. The display technology can be LED, LCD, gas discharge, or any other available and appropriate technology. Depending upon the display technology chosen, an additional display driver chip may need to be incorporated into the EMAC function.

Also shown in FIG. 4, are a number of optional functions including temperature sensor 16, video camera 15, and motion detector 17. If motion detection is desired, it can be done through a standard sensor (usually IR), or could alternately be performed by image analysis performed on the video image either locally or remotely. Each method has advantages and disadvantages.

The easy proliferation of video cameras throughout a home or building, by way of installation at existing junction boxes, has considerable security benefit. Since video camera 15 is connected to local PC 9 through a communications link, it can be viewed remotely via the Internet after the video information has been digitized and compressed. The video camera can be statically mounted and include a wide-angle lens and manually operated gimbal capability. Optionally, the video camera could include a motorized gimbal to allow remotely controlled movement (even via the Internet). In many instances, it may be desirable to include On/Off switch 15a to control video camera 15 such that the camera may be turned off when privacy is desired. Information regarding the position of this switch may also be made available through the communications link to local PC 9 and/or a remote device on the Internet.

Regardless of how the video camera is controlled, images that have been transferred to the central PC can also be automatically moved to an off-site web/domain server for storage. Thus, if the ***surveillance*** camera detects and captures images of an intruder or some important event, the images will be preserved even if the PC in the home/building is damaged, destroyed or stolen. A buffer of the video ***surveillance*** information storing video information for some fixed period of time into the past, can be stored at an off site location, via the Internet. In a mode where the system is armed for intruder detection, or alternately tied into a conventional security system for intruder detection, and an intruder is detected, this historical buffer of the information can be preserved to aid in the identification of the intruder and the recreation of the event. Any video information moved offsite is probably encrypted to ensure the privacy of the occupant.

The detection of a possible intruder can be performed by the elements of this invention, by a separate conventional security system, or both working together. Given the inconvenience and expense of false alarms, the distributed video capability of this invention, made easier to implement due to its installation and communications through existing junction boxes, could allow a Security Company or even the Police to view inside and around the home or building in the case of an alarm being set off, so that a "false alarm" condition can be determined without having to visit the location. To make such a capability acceptable to the occupant, especially in the case of a residence, it would be imperative that there exist a privacy mechanism (in software) such that the local PC or Residential Gateway does not allow any viewing by the Police or Security Company unless an intruder detection alert is in progress.

In general, transmission and storage of video information can be based on motion information derived from the motion detectors in each room. If no motion is occurring, storing a static snapshot taken at regular intervals may be completely adequate. When motion is detected, the video information from that area of the home or building can be recorded completely and buffered. A remote interface via the Internet coupling into this Home System can show a plan of the home or building, wherein the user can see a two dimensional map of where motion has been detected and also see the most recent snapshots (in small "thumbnail" pictures) allowing the user to click on a room or camera location and immediately see the live action video from that location.

Depending on the available bandwidth of the connection in the home/building between the video camera and local PC 9, it may not be necessary to have full speed/live action video to serve a useful purpose. Even a "jerky" picture or one with reduced resolution may still constitute a very useful function if it is available at a significantly lower price and if the low price allows a much more prolific deployment throughout the home/building. Also, regardless of the bandwidth available to transfer digitized video images to local PC 9 or directly to the Internet, the cost of the video camera may be significantly reduced (with a corresponding reduction in image quality) by using a newly available video sensor technology. Here, video sensor arrays can be constructed on a standard CMOS semiconductor process and potentially integrated onto the same chip with other functions required to implement the various features of an EMAC function. It may also be acceptable to use black & white video if it is available at a much lower price than color.

An alternative mechanism for sending video information from an EMAC point to local PC 9 and the Internet may include analog video transmission from the EMAC point to a device, located near local PC 9, which receives, digitizes and optionally compresses the video as will be shown in FIG. 8.

FIG. 5 shows an EMAC configuration similar to FIG. 2 except that it describes a power plug receptacle assembly, containing at least one receptacle location 20, instead of a switch. FIG. 5 also includes an optional video camera 15. Note that according to this invention, any electrical junction box is a possible location for installing a video camera, and that when installed, the camera can be powered by the source of AC power available at the junction box, and the video signal, after being digitized and compressed, may be transmitted digitally by way of the available power connection to local PC 9 or some other remote device.

FIG. 6 shows a power receptacle assembly similar to FIG. 5 except that optional network connection jack 21 is included. This network connection jack can offer standard Ethernet compatibility. If the type of data transmit/receive link used to transfer information to/from the EMAC point and local PC 9 possesses a bandwidth capability compatible with normal network data, it may be convenient and useful to include this conventional network connection jack as part of the power receptacle assembly. Power receptacles are the most proliferated form of wired connection points within any home or building.

Also shown in FIGS. 5 and 6 are motion detectors 17. These can be especially useful in filling in the "blind spots" that occur if the only motion detector controlling a light is located in the wall switch assembly. To avoid unwanted detection of pet movement, the lenses for the motion detectors on power plug EMAC points can be fashioned so as to look to higher elevations for motion. Since power receptacles are so proliferated, using these locations for installing EMAC points provides a very thorough picture of temperature, motion, and even video, within the home or building.

Also shown in FIGS. 5 and 6 are circuits for controlling the power available at receptacle 20 in response to commands received from a remote communications link. In some implementations of such a power controlling circuit, the maximum allowable power that may be drawn through the receptacle may be artificially lowered by the presence of the controlling circuit. It therefore may be appropriate to provide a physical mechanism for overriding or bypassing the power controlling circuit such that the maximum allowable electrical current level for the plug receptacle is not artificially lowered.

As an alternative to the wired Ethernet connection shown in FIG. 6, a different connection methodology to allow devices or appliances within a particular room to communicate with an EMAC point for data communications would be the addition of a wireless transceiver to the EMAC point. This can be done by having a small, optional module that plugs into a connector on the EMAC point, deriving power from, and communicating with the EMAC point, while communicating in a wireless manner with other devices in the room. An example of such a wireless technology is that currently referred to as "Bluetooth". Many wireless technologies have a limited range within which they can operate reliably, for instance 10 to 30 meters. The range of wireless technologies can vary considerably, especially within a home environment, depending upon the number of walls the signal must pass through and the structural content of each particular wall. Within a particular room, however, wireless technology can be very convenient, especially when interfacing with a portable computer or entertainment equipment. An example of a wireless communication module attached to an EMAC point is module 65 shown in FIG. 21.

FIG. 7 shows a possible overall connection scheme for a home/building according to this invention where all EMAC points can connect with local PC 9 that, in turn, communicates via the Internet 11 where a central source of information will supply energy cost rates and other utility-related information. The central source of information could be a Utility Company 22 or a third-party supplier such as Data Service Company 23. Information may also be transferred to and from a Security Company 24 such that any security related information such as ***surveillance*** video, motion detector outputs, or window/door open detection indications may be viewed at the Security Company.

The overall system of FIG. 7 includes wall switches 4, receptacle plugs 5, directly wired loads 6, and breaker boxes 2 (both conventional and "Smart"--per FIGS. 10, 11, and 12). Included in FIG. 7 is the potential for the Utility Companies to provide a "***Smart Meter***" that would interface with the Internet 11 and could potentially communicate with the system described in this invention. Also, as shown in FIG. 11, a smart breaker box according to this invention can measure the current entering the breaker box and therefore is capable of checking the accuracy of the existing Utility Company meter.

FIG. 8 illustrates the scenario where video information is transferred from cameras contained at EMAC points to a central location using an analog transmission format as opposed to digital. Eventually the cost of converting video information from analog to digital and performing video compression will be reduced to the point that incorporating compression into each EMAC location will be inexpensive. Also, over time, the cost of a high bandwidth connection between EMAC locations will also be greatly reduced. However initially, it may be more cost-effective to transmit information as some form of analog signal to a central location where these signals are converted to digital form and the video compression and/or conversion technology is shared among the different video sources. Such a mechanism for sharing the video compression capability is shown as interface module 25 in FIG. 8.

The video compression function 26 shown in FIG. 8 may also be performed in the local PC 9 if the PC's processing capability is adequate. Also, as described earlier, the determination of which video signal to digitize and compress at any given point in time can be made at the local PC by examining the outputs of the motion detectors at the EMAC points from which the video signals are being sent.

FIG. 9 addresses the issue of how the data rate capabilities of available EMAC points may increase over time, and how the overall system will cope with this by offering a multi-data rate communications consolidation capability located near the local PC 9. The capability of communicating between local PC 9 and various EMAC points at different data rates is also important since different types of EMAC points may require different data rate capabilities even though they're all being purchased and installed at the same time. For instance, an EMAC point that is controlling and monitoring power consumption and temperature may require only a very low data rate capability. EMAC points that will offer networking connectivity capable of supporting a broadband Internet connection today might require a one megabit per second capability. To offer a normal 10 megabit Ethernet connection capability, EMAC points would obviously need to communicate at 10 megabits per second. To transfer digital video would also require a reasonably fast data rate. The cost of an EMAC point is therefore significantly affected by the data rate it must support, and therefore the most cost-effective overall solution for the home system may be to utilize EMAC points having a variety of data rates. Hence an implementation strategy such as that shown in FIG. 9 containing a form of a network hub 27 and receive/transmit units 28, which may all have different data rates, may be the appropriate solution to the problem.

A modular implementation for hub 27 can be constructed where there exist slots designed to accept cards or modules representing receive/transmit units 28, each of which may have a different data transfer rate capability. Besides having a different transfer rate, such modular receive/transmit units may still each conform to an industry standard for powerline communications. For instance, one might conform to the X10 standard, one to the CEBus standard, and others conforming to newer standards such as those being studied by the Home Plug Alliance organization, or any future standard. Such a modular approach allows the user to mix and match capabilities as required--producing the most cost-effective and conveniently assembled home system. A modular hub assembly as just described would have a host interface circuit that could support a variety of output standards, such as standard Ethernet, USB, and/or any other, and would interface with local PC 9 or a processor performing the Residential Gateway function, or alternately a device located somewhere on the Internet.

FIG. 10 shows a "Smart" breaker box where each breaker 29 has associated with it an EM (Energy Monitoring) point 30. EM points located in breaker boxes typically contain the current sensing, receive, transmit, and possibly display functions, but typically do not perform a control function. Sensing temperature would also not be an appropriate function within a breaker box relative to providing useful ambient temperature readings, since there is usually a natural build-up of heat within a breaker box. However, a temperature sensor might be useful if the user wished to know of the occurrence of an unusually high temperature build-up within the breaker box itself.

Information supplied by these EM points can be correlated with information sent from EMAC points located downstream of each breaker to assist in providing a clear and complete picture of where all electrical power is being consumed within the electrical circuit being served by that particular breaker. For some power-consuming devices that are directly wired, inserting an EMAC point at the breaker location may be the easiest way to retrofit the EMAC capability.

FIG. 11 shows an alternate form of a "smart" breaker box where the current sensing, display and communications capabilities commonly associated with the EMAC points of this invention, can be retrofitted into a standard breaker box. The retrofit EM (Energy Monitoring) control unit 31 supports the connection of multiple current sensing units 32, including current sensor 33 which measures current entering the breaker box from the incoming A/C power line. Keyboard 34 on EM unit 31, if present, aids in the identification of the particular breaker units in the box which is necessary for proper processing of energy related data at the local PC 9, but also useful to aid the user in understanding which breaker relates to which area of their home. It is a well-known fact that in most homes, the correlation between specific breakers and the energy use locations that they supply is typically very poorly documented.

FIG. 12 shows an additional way to provide a similar capability of installing EM capability without having to retrofit the entire breaker box in an existing home/building. Here, the feedback/monitor point functions would be incorporated into the circuit breakers 35 themselves which, in turn, would fit into an existing, conventional breaker box. Obviously, breaker-related EM points would concentrate on electrical current measurement as their primary function. Integrating the EM function into the breaker itself obviously would require a high degree of miniaturization, especially if integral (and optional) display 36 is included.

It should be noted that in FIGS. 10, 11, and 12, all relating to measurement of electrical current entering or leaving a breaker box or other electrical distribution box, that the ability to measure the incoming current with a reasonable degree of accuracy will allow the user to correlate their power consumption with that registered by their utility company's power meter, as reflected in their power bill. Many utility company power meters are extremely old and may not be consistent or properly calibrated, thereby overcharging the user.

Also, relative to the breaker box solutions shown in FIGS. 10, 11, 12, a particular installation may be done such that all of the loads "downstream" of a particular breaker do not include EMAC points. In fact, for some breakers, no EMAC points may exist downstream. In these circumstances, a useful method for identifying the power consumed by connected devices is to establish an "energy signature" for each device by turning on only one at a time, during a set-up/calibration process, and recording the typical energy usage for each device. This "signature" may also include any unique characteristics of the waveform shape for the ramp-up of the instantaneous electrical current consumption, or the effect on the measured voltage waveform at the breaker box, when the device is initially turned on. These "signatures" can later be used for identifying the energy used by particular electrical energy consuming devices when performing an overall profile according to this invention.

FIG. 13 shows an EMAC point designed to work in conjunction with an "old-fashioned" light bulb socket. These sockets are still prevalent in attics and garages today. In addition to monitoring the power their light bulbs use (they can easily be left on accidentally for long periods of time), since they are located in attics and garages, they can also provide an important thermal feedback function. Attics and garages tend to act as heat reservoirs that can be a source of energy in winter and a drain (due to fan/air conditioning power consumption) in summer. Notice that EMAC point 37 is somewhat remotely located from light bulb 38 to reduce any thermal contamination from the heat produced by the bulb. Intercept adapter 39 is included to divert the power to EMAC unit 37, which is separated from bulb 38 by thermal isolation distance 40. Also, for the unit of FIG. 13 to monitor temperature and transmit that information to the central computer, a power control function may be an absolute necessity if the bulb is to remain off when light is not required (especially important in the attic) depending on whether the bulb socket is remotely switched or not.

To demonstrate that other forms of power outlets can be adapted to include EMAC points, FIG. 14 shows how a common power strip 41 can include these capabilities. Another form of portable, add-on EMAC point is discussed in FIG. 22 in more detail.

FIG. 15 shows how the concepts described previously can be extended to other forms of energy monitoring/feedback with an emphasis on oil and natural gas used to produce thermal energy. Flow meters 42 and 43 are inserted into the line carrying the gas/oil to the thermal energy-producing device. The output of each flow meter is then connected to interface modules 44 and 45 respectively that act as EMAC points in a manner somewhat similar to the examples shown in the previous figures. In a similar way, point-of-use feedback is provided and data is transmitted to central PC 9 for use in assembling the overall profile of energy usage for the home/building.

Software operating on central PC 9, among other functions, will be able to create a multi-dimensional map of energy usage as well as prioritized listings of where different amounts of energy are used. Some examples of this capability are described next.

FIG. 16 shows a two-dimensional plan layout for an example home where locations for all power plugs 46, wall switches 47, and dedicated energy using appliances 48 are identified accordingly. This layout plan forms the basis for energy profiling diagrams that can be presented to the user, thereby allowing easy identification of energy usage anomalies or to better guide the user in implementing more efficient energy usage.

FIG. 17 shows the overall layout for a home where electrical energy usage has been annotated for each of the EMAC points deployed. A blow up view 49 of one section of the home shows how energy usage parameters 50 can be annotated to show the specific energy consumption at any EMAC location. The sample numbers shown for parameters 50 might be in instantaneous Watts, however alternatively, these parameters could be shown as an average consumption over a specific time period. Also, as has been previously shown for the direct feedback energy consumption displays incorporated into EMAC points, the energy consumption parameters in FIG. 17 could display information indicating the cost per time of the energy consumed, again either instantaneously or over some specific time period. The display of FIG. 17 could easily highlight each particular EMAC location designator in a different color according to the level of energy being consumed. Since the diagram of FIG. 17 is shown in black and white, the relative level of energy consumption has been shown visually by the relative thickness of the borders surrounding the plug or switch EMAC point designator. For instance power plug 51 consuming 930 watts, the largest amount consumed of any EMAC point within blowup 49, has the widest border. EMAC point 52 having the next highest level of energy consumption (700 watts) is shown with the second widest border. In an actual software product implementing such a display for the user, the highest energy consuming points might be displayed in the brightest red color, while the lowest energy consuming points might be displayed in darkest blue, with mid ranges of consumption levels being displayed in intermediate shades of color.

Information from temperature sensors 16 is displayed locally at the particular EMAC point for direct visual feedback, but is also sent to the local PC 9 for processing to allow the creation of a temperature profile for the home/building. FIG. 18 shows a similar layout plan to that of FIG. 17 except that the annotated information reflects the local temperature at each EMAC location. FIG. 18 displays the overall temperature profile in two dimensions (for each level of a multi-level home/building) and can provide feedback (including time-related information) that can help the user reduce (thermal) energy costs by way of a number of useful mechanisms: 1) Areas of the home/building that are being heated or cooled unnecessarily will stand out and the user can take the appropriate corrective action. For instance, overheated areas 53 indicate rooms that are much hotter than necessary, prompting the user to take corrective action such as closing vents that are unnecessarily open. This information can also drive a more elaborate automation scheme where automated control of thermal delivery mechanisms is used. Such delivery mechanisms are exemplified by the electrically controlled wall/floor air flow registers manufactured by EWC Controls of Englishtown, N.J. Other forms of electrically controlled vents, ducts, and registers having controllable, variable air flow are manufactured by a number of other suppliers. 2) Software on the central PC that operates on the thermal profile of the home/building can detect thermal gradients and may be useful in pointing out areas of thermal leakage such as poor weather seals on exterior doors and windows. Notice that EMAC point 54 located near a door of the home displays a temperature of 65 degrees even though the thermostat set at 72 degrees is just around the corner. This would tend to indicate that the seal around the door is most probably inadequate and causing significant energy leakage. The greater the number of temperature sensing points that are placed around the home/building, and especially within a particular room, the more accurate a gradient profile will be able to be produced. To further display temperature gradients in a form familiar to most users, additional software could display extrapolated temperature gradient information in a manner similar to that shown for temperature profiling on weather maps. The more temperature sensors are located in a particular area of the home or building, the more accurate these extrapolated thermal gradient maps would be.

It should be noted that a profiling capability can also be implemented on a Smart Thermostat that is network-connected. Even if such a thermostat does not possess the display size and resolution of a PC or Gateway, useful information can still be provided. For instance, with only one EMAC point in each room or zone in a house, the temperature in each room or zone can be displayed. Also, rooms that are being overheated or overcooled can be enunciated. In one embodiment, a Smart Thermostat could even have a panel display and a miniature keyboard (possibly "QWERETY" style) together enabling a more capable user interface, more familiar identification of rooms and zones, and even a multidimensional thermal profile display.

To make accurate use of the temperature sensor information, it is important that any heat energy generated in the switch or plug receptacles not affect the measurement. For this reason, the temperature sensor will usually be located at the lowest point within a switch or plug EMAC location. It may also be necessary to make the faceplate larger to move the temperature sensor farther from any source of potentially-interfering heat. A switch or plug location is a natural heat generator simply due to the contact resistance where the wiring is attached, the contact resistance of a switch, or the resistance formed at the interface where a plug is pushed into a receptacle socket. Additional heat can also be generated if the EMAC location includes a controlling capability where a semiconductor device is used to clip the A/C waveform--a process having less than 100% efficiency and therefore generating additional heat.

Other variations on a temperature sensor may be possible. In particular, a sensor might be constructed where multiple IR temperature sensing elements are used in conjunction with a prism or alternately where each sensor is directional and is aligned in a different direction, thereby gathering temperature information from different areas of the room such that a spatial image of the thermal gradients in the room can be established.

FIG. 19 shows what can be accomplished when the distributed temperature data collection mechanism of EMAC points is utilized to allow a more intelligent control of the temperature in multi-room or multi-cubicle environments while still utilizing a single thermostat (at the existing location) to control existing heating/cooling units. FIG. 19 shows an office environment containing both enclosed offices and an array of cubicles--however the same principles embodied here can be employed in any home or building environment employing EMAC points. Also, the capabilities that will be described relative to FIG. 19 do not require all of the previously described EMAC functionality to be present. In fact, a system consisting of distributed temperature sensors with some form of network interface capability, communicating with a smarter thermostat also having network communication capability, will suffice. Note that a "smarter" network connected thermostat such as 55 and 58 in FIG. 19, should contain a default mode wherein the thermostat reverts to the mode of operation of a traditional thermostat if its ability to collect distributed temperature information is compromised, or if a switch on the thermostat is thrown to force the thermostat into the "traditional" mode of operation.

Also, note that a similar functionality to that described above for FIG. 19 can be achieved by having the network-enabled temperature sensors communicate with any of a number of intelligent controllers, including local PC 9, a Residential Gateway, a dedicated intelligent thermal control system, or even a remote device located elsewhere on the Internet.

The problem being addressed in FIG. 19 is that where the temperature observed at the thermostat location is not at all indicative of the average temperature over the area being served. For instance, thermostat 55 located in one office might control the heating and cooling for the entire row of offices. Due to variations in the ducting and vent structure, as well as the temperature variation across the row of offices during the course of a day as the position of the sun changes, it is not uncommon for some offices to be painfully cold or warm relative to the office possessing the thermostat. For instance, without the control capability embodied in this invention, thermostat 55 may be set to 72 degrees, temperature sensor 56 might register 70 degrees, and temperature sensor 57 might register 80 degrees. With network connected temperature sensors installed in all offices, including the offices containing sensors 56 and 57, the thermostat can compute an average temperature over all of the offices and control the heating/cooling system to reach an overall compromise of temperatures as shown in FIG. 19, thereby eliminating the excessively hot or cool locations that would previously have occurred.

A similar capability can be implemented for an array of open cubicles such as cubicle array 59 where the heating and cooling is controlled by thermostat 58 possessing a network connection. It should be noted that the distributed temperature collection capability required to implement the functionality of FIG. 19 does not require network connectivity over power lines as described in most embodiments of this invention. A smart temperature sensor connected to an Ethernet port would suffice to implement this capability, and in most office and cubicle environments today, Ethernet connections are plentiful. Also, the existing thermostat location and connections can be utilized with the addition of a network connection.

A variation on the capability shown in FIG. 19, and applicable to any environment having the ability to collect temperature information in a distributed manner, relates to a home where multiple EMAC points have been installed around a room or around multiple rooms. Here, a smart thermostat communicating with these EMAC points can be programmed to achieve a desired temperature at a specific location within each room during specific time periods (essentially ignoring the temperature at the thermostat itself). For instance, the system could seek to achieve a temperature of 70.degree. in the Kitchen from 5:00 to 7:00 PM and then seek a temperature of 70.degree. at the Living Room couch location from 7:00 PM to 10:00 PM.

Of course, a more desirable overall thermal result could be achieved for scenarios similar to those described for FIG. 19 if the controlling device (smart thermostat, PC, or other form of intelligent processor) is also able to control the amount of airflow allowed through a multitude of distributed, electrically controlled, variable airflow vents, ducts, or registers.

FIG. 20 shows how an EMAC point can offer a closure detection capability that, when connected to a closure-sensing switch 60 on a window 63, can determine whether the window is open or closed. While this feature certainly has application in performing a security function, a very common loss of energy in many homes occurs when windows are inadvertently left open. Therefore such a closure detection capability is valuable within an energy management scheme as well. While FIG. 20 shows an additional jack 61 on the EMAC wall outlet, the wire from the closure sensor could connect directly with network jack 62 assuming the closure sensor had an Ethernet connection capability. FIG. 21 shows a window closure detection capability similar to FIG. 20, except that a wireless closure sensor 64 communicates with wireless communication module 65 located on the EMAC point. This wireless communication module 65 could be a very simple low bandwidth low-cost unit, given the simplicity of its task, and its close proximity to the windows within the room it services. Even a simple wireless communication module 65 could be designed to communicate with multiple wireless closure sensors 64 within a single room.

Alternately, wireless communication module 65 might have a higher bandwidth capability, allowing more sophisticated local communications within a room or zone. A more sophisticated wireless communication module might be implemented with a technology such as "Bluetooth", previously referred to as an alternative local connection capability in the description relating to FIG. 6. Such a more sophisticated wireless module could still communicate with window closure detection modules 65, but could also communicate with any wireless network-enabled device or appliance within the room being served that was capable of communicating via the "Bluetooth Standard". This wireless configuration can even support communication with a wireless-enabled laptop/notebook computer that can move about within a room or zone.

Other standards than Bluetooth can be supported in this way, including the IEEE 802.11 standard commonly used today for local wireless communications. As mentioned earlier, communicating between EMAC points through power lines circumvents difficulties encountered with wireless communication in many home environments (including 802.11), where wireless signals often have great difficulty traveling through multiple walls.

In the configuration described in the previous paragraph, there would be multiple local wireless communication modules 65, sometimes one to a room or one to a zone if the range of a single module can successfully penetrate a wall or two. Each of these local modules is now essentially a host in its own right. The home or building environment now resembles a cellular phone system with multiple hosts and zones, and requires a management scheme that may be similar. A moveable wireless device might switch from communicating with one particular module 65 to a different module 65 as its location changes. Alternately, a wireless client device having a fixed location, like window closure detector 64, can be programmed to communicate exclusively with a specific wireless communication module 65.

FIG. 22 shows a form of portable/add-on EMAC point 67 that can easily plug into an existing wall outlet plug receptacle installed in electrical junction box 66. While this capability is very similar to the power strip EMAC point shown in FIG. 14, it is different in that it would replace the cover plate on the plug receptacle at junction box 66 and after being plugged in, would effectively become a new cover plate, but with considerably enhanced capabilities. FIG. 22 also shows, in addition to previously described temperature sensor 16 and motion detector 17, a light intensity detector 68 that may be useful if, for instance, this portable EMAC point is the only EMAC point installed in a particular room. One of the benefits of having a portable, easily added unit like that in FIG. 22, is that it allows the user to purchase a limited number of EMAC points in order to start using their capabilities, without making a more permanent installation by replacing actual plug receptacles or wall switches. Therefore, it may be useful to have a light detection capability such that a profile of lighting usage can be established by software running on central PC 9. Also notice that portable EMAC point 67 may contain any number of plug receptacle locations 20 (six are shown here). Having multiple outlets not only offers the user the convenience of not having to use a multiple outlet extension cord or power strip when more than two power consuming devices/appliances must be plugged in, it also provides independent energy monitoring for each of these receptacle locations thereby providing more precise information on energy utilization. In addition, display 14 in FIG. 22 can display the total power consumption at the receptacle location and even provide a warning if the maximum allowable power level for a receptacle assembly is being exceeded. Alternately, an audio emitting transducer within unit 67 could provide a similar warning.

When a system according to this invention is installed in a home or building whereby a multitude of EMAC points are distributed throughout multiple rooms, it then becomes necessary to identify the location of each EMAC point in order for software running on local PC 9 to perform profiling of data relating to energy consumption. The larger the quantity of EMAC points, the more complex and time-consuming this task becomes. It therefore becomes useful to have a mechanism to automate this process of identifying specific EMAC point locations. Another related task is that of drawing an electronic representation of the two-dimensional plan layout for the home or building that is required for proper display of the profiling information. For most existing homes, and even some new homes, this electronic representation will either be nonexistent or inconvenient to gain access to. A method for automatically creating an electronic plan layout and, at the same time, identifying all EMAC points, would be both efficient and useful.

Portable EMAC identification unit 70, shown in FIG. 23, can be used to perform this capability. This particular unit relies on a wireless antenna 71 constructed in such a manner that when receiving signals from multiple transmission beacons, the position of unit 70 can be accurately determined through triangulation. Principles such as those used in the GPS (Global Positioning System) may be utilized where the beacons and receiver all contain synchronized clocks and signal travel times from different beacons (similar in concept to GPS satellites) are compared--the position being determined by triangulation. Different frequencies and signal strengths would have to be used to enable the penetration of walls of the home or building.

Alternately, a similar system can be constructed where unit 70 contains a transponder. The transponder echoes each signal received back to the source beacon where the distance is determined by phase shift information that is then communicated back to unit 70. EMAC identification unit 70 can identify EMAC locations by plugging into a power plug 72, or simply by placing it adjacent to a power consuming switch, or a device with dedicated wiring, and indicating through integral keypad 73 or optional keyboard 74, the device being located. As will be explained later in FIG. 27, each EMAC point may have an integral serial number that can be used as part of the identification process.

FIG. 24 shows an overall view of a home or building where identification unit 70 receives signals from a plurality of wireless transmission beacons 75. The exact placement of these beacons may not be critical since, once a reference point has been established for identification unit 70, only relative position information is necessary to establish the locations of EMAC points, as well as the dimensions and layout plan of the home or building. If it is desirable to determine EMAC locations in three dimensions, a third beacon located at a different elevation setting from the initial two beacons 75 may be added. Accordingly, the antennae on identification unit 70 would have to be enhanced to allow position detection in three dimensions. More than three beacons may be useful in some circumstances where signals have difficulty penetrating the building structure in some places.

In fact, given proper frequencies along with the appropriate circuitry and antenna system within the identification unit, it would be possible to establish positions with a resolution of distances to a fraction of an inch. In this case, the system described in FIG. 24 is also capable of becoming a measurement system. Such a measurement system could be developed and used independent of any specific use relative to energy or thermal information, being used solely as a semi-automatic way to obtain precise dimensions of an existing home or building in order to create an accurate drawing. The need to create an accurately dimensioned drawing of an existing home or building occurs quite frequently when modifications to an existing structure are being planned.

FIG. 25 shows how audio information, in particular music, can be transmitted via a digital communications circuit through power lines, thereby enabling an audio output node unit 76 containing a Speaker 77 as well as interface circuit 78. Interface circuit 78 would have the ability to receive and transmit information as well as convert a digital audio stream to an amplified signal capable of driving Speaker 77. Interface circuit 78 may also contain some form of remote control receiver 79 which could be either infrared or wireless. With this remote control capability included, interface circuit 78 may also contain a transmit capability such that any control requests can be forwarded to similar audio output nodes and/or to the source of the audio information via the powerline network.

FIG. 26 shows how the integral display contained in many of the EMAC points of this invention could be constructed as a general purpose video panel display 80. Of course, video display 80 could provide all of the energy-related information described for variations of integral display 14 shown in earlier figures. In addition, given a connection with sufficient bandwidth (either digital or via analog video signal), display 80 can show a picture captured by any video camera 15 within the home or building, or alternately can display video information being transferred to the home or building via the Internet. Essentially, this creates a "video intercom" capability. When combined with audio intercom 18, a multimedia intercom capability is created, which can be controlled either by control buttons 118 located on the assembly, or by voice recognition commands, or both. For instance, by observing a video display in the master bedroom, a user could check for activity in different rooms throughout the house. This capability is further enhanced if the user can initiate a command that controls lighting throughout the house, thereby illuminating the rooms to be observed. Similarly, lights illuminating the outside perimeter of the house can be controlled, and video cameras mounted so as to observe these areas and supply information that can be viewed on display 80. The form of control buttons 118 in FIG. 26 can be expanded to include a lighted keypad to allow command input regarding what room is to be observed and/or illuminated. Such a keypad could have specific buttons/keys that are marked with the names of the particular rooms that might be observed.

Another use of display 80 is to enable interactive video conferencing, not just within the home, but with someone located at a remote location via the Internet. Although such video conferencing is of course possible on any PC given an attached camera, the unit shown in FIG. 26 allows a more spontaneous form of conferencing. For instance, a parent, while at work, might observe the activity of a child at home and spontaneously initiate a conference via the assembly shown in FIG. 26 which is directly accessible to the child in whatever room they happen to be.

As mentioned earlier, in order to properly identify EMAC points within a home or building, some form of integral serialization for each EMAC unit may be desired. This can be accomplished in a number of manners, the simplest being to add a form of programmable memory within one of the integrated circuits contained within the EMAC unit. During the manufacturing process, each EMAC unit would then be briefly connected to a programming system that would install a unique serial number in each EMAC unit. However, it may be overly expensive to include a memory chip, or build any of the required semiconductor devices on a process capable of supporting electrically programmable memory. If the cost of this method is prohibitive, an alternative approach would be to include some form of electrically scan-able matrix on a PCB (Printed Circuit Board) within the unit, such as matrix 81 shown in FIG. 27. This matrix is scanned by applying patterns to the wires oriented along a first axis while observing the values that appear on the wires oriented along the axis orthogonal to the first axis, thereby scanning the matrix and determining which intersections are connected and which are not. If the matrix is comprised of wiring traces on the PCB, it would be normal to initially have the matrix fully connected at each intersection, and then selectively delete connections at certain intersections in order to affect the programming pattern for the serial number.

This deletion could be performed by a number of methods including laser cutting, or use of a burnable fuse structure at each matrix intersection, all of which are-techniques known in the art. An alternative to deleting conductive material at a matrix intersection would be to have the ability to selectively add conductive material at selected intersections and to have all matrix intersections start out in an electrically unconnected state.

EMAC points are also quite useful at the exterior of a home or building as shown for a light mounted on exterior wall 84 of a home or building in FIG. 28. Here, junction box extension unit 82 is added between exterior electrical junction box 83 and exterior light 87. Extension unit 82 has both motion detector 85 and video camera 86 attached and also includes a circuit for controlling exterior light 87. Also included in extension unit 82 is a communication circuit capable of sending digital information to and from any remote device by way of the electrical power line available at the junction box. Video information is digitized, compressed, and sent over the powerline communication link. Also, motion detection information, temperature information, and power consumption information for light 87 can also be transmitted in a similar manner. Exterior light 87 can also be controlled remotely via the communications link.

Note that, in this specification, where a single video camera is shown as part of an assembly, multiple video cameras can also be included within the same assembly thereby covering a larger overall viewing area. Also, multiple cameras within the same assembly may also share some of the video compression circuitry and other support circuitry that may also exist in the assembly.

Where it is desired to conceal the ***surveillance*** camera, a pinhole camera like that shown in FIG. 29 may be used. Here, image sensor 88 is mounted behind pinhole 89 in wall plug face plate 90, using the normal location for the mounting screw to hide the pinhole. The face plate may be secured to junction box 92 by way of mounting studs 93.

Typically, security control panels are mounted centrally in the home, usually near an entrance or sometimes in a central location such as the kitchen. They typically require special mounting and wiring. The Security "QuikView" panel shown in FIG. 30 is compact and is designed to mount at a standard junction box location such as switchplate 94 as demonstrated in FIG. 30. Here, video display 96 can show ***surveillance*** activity in other rooms in the house. Lighted Buttons 95 can choose which room in the house will have its camera image displayed. Also, upon pressing any of these buttons, a control signal can be sent via powerline or wireless communications to a light in the chosen room to turn on that light to provide a better view or alternately frighten an intruder. If the remote ***surveillance*** cameras distributed around the home have infrared detection capability, an intruder may be observed without additional lighting. In such cases, the remote activation of conventional lights would mostly be used for signaling the intruder to leave or alternately capturing a better image of the intruder on a conventional image sensor which may also be present in the camera. Thus it may be useful to incorporate cameras that have image sensors for both visible and infra red spectrums. Motion detection may be used as described previously in this specification. The detection of motion in a particular room may automatically cause the corresponding camera's image to be displayed.

The QuikView Panel of FIG. 30 may be easily mounted in the master bedroom by installing at any wall switch location. However, most home intrusions happen in the night when the occupant is in bed. Requiring the occupant to get out of bed, walk to the QuikView panel and, while half-awake, operate the controls is not the optimal scenario. A better solution is shown in FIG. 31 where the QuikView Panel has been packaged in a display and control (QuikView) console unit 98 suitable for use on a conventional bedside table as shown in inset image 97. Console unit 98 includes a flat panel display 99 which may, in some embodiments also be a touchscreen display. Lighted buttons 100 may be included to choose which room's camera is displayed and also to optionally control lights in a particular room. The function of these buttons may also be implemented in "soft" buttons where the name of the corresponding room is annotated on the display or alternately the entire button appears on the display and is activated by a touchscreen capability. Motion indicators 101 may be included separately or on the display. Direct access buttons 102 for signaling the police and or the security company may be included as shown.

These provide easy access when the occupant is half-awake. An intercom may be included and activated by button 103. The intercom speaker and microphone 104 also allow the occupant to communicate with the police (essentially a speakerphone capability), without having to pickup and dial a phone, when a phone line is connected to the console unit.

FIG. 32 shows an alternate approach based on the configuration shown in FIG. 31 where the screen on flat panel display 99 is split into 4 quadrants, each on showing the image for a different room. Different numbers of split regions may be used.

In FIGS. 30-35, mode buttons marked A, R and E are shown as examples of mode controls that might be utilized with the invention. For instance, the button marked R might provide a mechanism for choosing a particular room in a home while the button marked A might initiate the action of advancing from one mode to another for the chosen room. The button marked E could function as an enter button, thereby causing actions to be taken relative to the mode configuration desired.

Typically, there is little room on most bedside tables, and the space for a ***surveillance*** monitor may be an issue for the occupant. Therefore, it is useful to combine the QuikView console with other common bedside functions such as an alarm clock/radio, and possibly also a phone and/or a TV. FIG. 33 shows a clock/radio function included in the console. As shown, display 99 might show only the clock function until a motion detector in another room is activated. Then the display would change to include room images as shown in FIG. 32, FIG. 34, or some variation. In FIG. 33, microphone 106 is shown facing the occupant while speaker 107 has been moved to the side where there is more space. Volume and tuning controls 108 have been added for the radio and time set buttons 105 are added for the clock function. Radio tuning and clock operation can also be accomplished through a remote control. FIG. 34 shows the clock included in one of the four display quadrants with ***surveillance*** images in the other three quadrants. Note that a phone cradle could be molded into the top of the console and a telephone (probably cordless) could be added to the console system to further save space on the bedside table. When a telephone handset is included, note that it may be desirable to delete intercom microphone and speaker 104.

FIG. 35 carries the concept of a multi-function Security QuikView console even further and adds a personal TV to the system. Remote control 109 is used for most TV functions and mode control buttons 110 have been added as an alternate means to select the primary mode of the console. A headphone jack can also be provided for listening to the radio or TV. Alternately, headphones could be wireless.

* * * * * *

Therefore, a ***surveillance*** and control system intended to minimize the possibility of personally confronting an intruder has been described. Also, given the vantage point afforded by a typical wall switch located at the entry to a room as well as other standard junction box locations, video cameras may be easily added in different rooms in the home.

It should be understood that the particular embodiments described above are only illustrative of the principles of the present invention, and various modifications could be made by those skilled in the art without departing from the scope and spirit of the invention. Thus, the scope of the present invention is limited only by the claims that follow.

United States Patent **6,993,417**
Osann, Jr. **January 31, 2006**

System for energy sensing analysis and feedback

Abstract

A system is described where the existing proliferation of standard electrical junction boxes in a typical home or building implement a form of "Bio-Feedback for Home Energy", increasing user awareness and enabling more effective and efficient energy usage. Energy-related information is gathered by way of EMAC (Energy Monitoring And Control) points typically installed at standard electrical junction boxes used for power plug receptacles and wall switches. In addition to being visually displayed at the point of energy use or measurement, energy-related information--electrical and thermal--is typically communicated through a powerline or wireless data link to a centrally located intelligent device where it is monitored, analyzed, profiled, viewed, and also used for energy-related control functions. Energy consumption can be alternately displayed in terms of cost-per-time. Energy monitoring may be also added at the electrical breaker box to supplement distributed EMAC points.

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Appl. No.: **09/949,551**
Filed: **September 10, 2001**

Current U.S. Class:	**700/291** ; 340/635; 702/62
Current International Class:	G06F 17/00 (20060101); G01R 19/00 (20060101)
Field of Search:	700/22,90,275,286,291,297 702/57,60-62,64-68,70,71 705/412 340/635,637,654

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Primary Examiner: Rodriguez; Paul

Claims

What is claimed is:

1. A portable energy monitoring point designed to plug into a standard power plug receptacle at an electrical junction box, including within said portable energy monitoring point: a plurality of power plug receptacles; integral current sensors capable of determining measured levels of electrical current consumed by electrical loads connected to any of said plurality of power plug receptacles; an integral circuit for providing said measured levels of electrical current in digital form; an integral digital communications circuit capable of sending and receiving digital information, including said measured levels of electrical current consumed, to and from a remote device; and an integral digitally controlled display.

2. The portable energy monitoring point of claim 1, where said digital communications circuit capable of sending and receiving digital information to and from a remote device does so by way of a power line connection available at the junction box.

3. The portable energy monitoring point of claim 2, further including: an integral sensor for measuring an ambient temperature; and an integral circuit for providing said measured ambient temperature in digital form and making said digital ambient

temperature available to said digital communications circuit and/or an integral display.

4. The portable energy monitoring point of claim 1, further including: an integral sensor for measuring an ambient temperature; and an integral circuit for providing said measured ambient temperature in digital form and making said digital ambient temperature available to said digital communications circuit and/or an integral display.

Description

CROSS REFERENCE TO RELATED DOCUMENTS

This application is based on disclosure document Ser. No. 493,964 filed on May 21, 2001 under the USPTO disclosure document program, entitled "Home/Building Monitor and Control System with Emphasis on Energy Feedback and Profiling", incorporated by reference herein.

FIELD OF THE INVENTION

This invention generally relates to the field of electronic systems for homes and buildings, including systems for home networking, home energy and appliance controls, and home security***/surveillance*** systems, with special emphasis on energy monitoring, feedback and profiling, and in particular, the use of electrical junction boxes for purposes they do not normally perform. Although many of the features of this invention will be described in relation to a residential home environment, it is understood that they are generally applicable to many office and industrial building applications as well.

BACKGROUND

Many products have been introduced over the last 25 years for controlling electrical and electronic devices and appliances within homes and buildings. It is well known to use a variety of communications mediums to enable this control (power lines, phone lines, and purpose built network connectivity such as cabled Ethernet or wireless networks).

More recently, it is known to extend this control to connection via the Internet allowing a further degree of remote control and communication. In addition, ***surveillance*** capabilities have been added by using video cameras that can transmit images to monitors in other parts of the home/building as well as supplying these images to remote locations via the Internet. Also, there is discussion that future home and building appliances (washing machines, refrigerators, etc.) will connect to the Internet such that they can communicate over the Internet directly. Among other possible remote interactions, they can communicate their condition and signal the need for service before breakdowns occur, as well as enable diagnostics to be performed remotely via the Internet.

The move toward home and building automation has not necessarily been prioritized according to how the general public accepts new things--especially in light of the fact that old habits are hard to break regarding how one deals with power consuming devices in homes and buildings. While most people may not be ready to have their lights and appliances controlled automatically, there are other motivations that may move them toward installing a home/building monitoring and control system: Saving money given increasing energy costs Security***/Surveillance***/Remote Care The pervasive nature of home networking and Internet connectivity Expansion of home entertainment capabilities Interaction of Monitoring/Feedback with Automated and Manual Control

The psychological element is extremely critical in the adoption rate of any system involving monitoring and/or control. Letting a computer control one's home/building appliances that in the past were controlled manually, is a sensitive issue. A monitoring and feedback system is much less disturbing or threatening, but for users who wish to add some amount of automatic control, there must be a carefully planned interaction between the two. It is not uncommon for some lights in homes, and especially in office buildings, to be controlled by circuits containing motion detectors. Invariably, there are occurrences where the motion detector causes the lights to be shut off at the wrong time. This can easily get annoying since, as is commonly known, it takes a multitude of positive interactions to overcome the emotional effect of a single negative interaction. Alternately, let's say that there exists a local PC (Personal Computer) running software for home automation and control, and a centrally controlled light switch that is programmed to shut off at 1:00 AM regardless of switch position to ensure that it is not left on all night accidentally.

Now, let's say the user has stayed up late and is in the room with this switch. At the programmed time, the automatic control system will shut off the power at the switch. (It may signal the user some time prior to shutting off by flashing the lights). To prevent the switch in question from causing the user great aggravation, it must have the ability to override the auto shutoff event. If the switch has a transmit capability such as that described below for EMAC (Energy Monitoring And Control) points, the user could, for instance, toggle the switch or push a mode button after the flashing warning (or if the light has turned off already), and that action would be transmitted back to the central controlling PC to allow a revised scenario to occur. Even if the override can be performed locally without interaction with the central PC, it is useful to transmit back to the central PC that the event has happened to aid in avoiding similar user aggravation in the future. For instance, the central control system could "learn" and, in this case, delay the auto shutoff of that particular light switch until 1:00 AM or later, or switch to a motion detector-controlled mode after 1:00.

The most common mechanism today for controlling lights is based on motion detectors incorporated into the controlling switch assembly or alternately incorporated into the light socket assembly. These work fairly well in some circumstances--especially in spaces where people seldom go such as attics and closets. However, in primary living areas, they can often cause a negative interaction with the user. For instance, the inventor installed a light switch with motion detector at the entry to his living room. Unfortunately, the detector's range does not cover the entire room, thus occasionally leaving the inventor "in the dark". Were there a multitude of motion detectors scattered around this same room--communicating through a data communications link such that the light control circuit was guided in a more informed manner (as described later in this invention)--the inventor would be more positively illuminated.

Interaction of Monitoring/Feedback with Audio/Video Functionality

Although this invention deals primarily with energy use, monitoring, feedback, and control, the overall system in a given home or building may also deal with the distribution and control of multi-media information including audio and video. Over time, the communications link between the EMAC points of this invention and the central controlling device (usually a PC or Residential Gateway), will have more and more bandwidth capability, such that this link also becomes the primary means for distributing digital multimedia information throughout the home or building. Thus, there will be a coexistence, if not a functional link, between the elements of this invention focused on energy monitoring, feedback, and control, and elements focused on audio/video integration and control. This transmission of audio/video information can be for communications, security, or entertainment purposes.

No Feedback on Energy Consumption

At the time of this writing, energy costs have risen substantially and are likely to continue to do so. One of the first, and most important problems consumers are faced with is knowing exactly where, and how much power is being consumed in specific areas/appliances in their homes and buildings. Today's home and building automation systems are much more focused on controlling than on providing energy usage feedback. Meanwhile, the typical occupant may have little or no idea of where the energy is actually being consumed.

Simplistic Control of Heating and Cooling Systems based on Limited Information

Today's typical control system for heating and cooling, the traditional thermostat, does not take advantage of networked connectivity and the information gathering that it affords, thereby missing the opportunity to provide a much more comfortable and energy efficient thermal environment. Even today's "programmable" thermostat observes only the temperature at it's own location. It is therefore very common for rooms or offices not containing the thermostat to be overheated or overcooled. Such rooms or offices waste energy if they are not occupied, or make the occupants uncomfortable if they are occupied.

Security Systems

The International Association of Chiefs of Police estimates that between 95% and 98% of all home-alarm calls are false, costing police departments nationwide about $600 million a year. If a Security Company, or the Police, could remotely view the interior of the home or building where the alarm has just been activated, most of this money could be saved. Security companies offer video ***surveillance,*** but the systems are complex and expensive and not easily adapted to existing homes without extensive additional wiring and adding provisions for mounting and powering the video cameras.

SUMMARY

Overall, the home system described in this invention relates to the energy distribution systems in a home or building. Much of the uniqueness in this invention deals with the combining of diverse functionalities that heretofore have not been combined in similar ways. Although the digital communications networks or links described in this invention are typically based on communication by sending signals through existing electrical power wiring (hence the term "powerline communications"), not all embodiments are restricted to this form of communications. However, when powerline communication is utilized herein, the result is a system that uses electrical wiring for energy distribution, monitoring, and control as well as security, audio/video communications and entertainment, and general network communications such as file transfers and Internet connectivity.

Energy consumption in most homes/buildings today is made up of both electrical power and some form of oil/gas based power. Some homes and buildings use electrical power only. This invention deals with both, although many of the features described can be optionally used in different combinations as desired by the customer.

A primary aspect of this invention is to provide a form of "biofeedback" for home and building energy consumption. By providing easy to understand information to consumers, they can adjust their usage of energy and still have normal control of their power-consuming devices--over time transitioning to automated control as they desire. Also, some specific capabilities of this invention enhance the effectiveness of automated energy controls.

Electrical energy is typically consumed by devices attached to electrical junction boxes. These junction boxes are typically proliferated throughout a home or building. As a result, they become not only convenient locations to measure and display electrical power consumption--they also provide a convenient means to proliferate temperature sensors, motion detectors, and video cameras. The same communications mechanism used for transmitting power-related data is typically used for these additional functionalities which aid in the enhancement of energy control (both thermal and electrical) while enhancing security at the same time.

This invention has the following primary goals regarding energy feedback: 1) Provide "instant feedback" at the point of usage. 2) Provide electrical energy usage profiling with multi-dimensional graphics on a centrally located PC, or Residential Gateway.

Include both spatial usage and usage over time. Transfer related information via the Internet as necessary and desired. 3) Provide thermal profiling on a centrally located PC, Residential Gateway, or Smart Thermostat. Use multi-dimensional graphics as useful or appropriate. Include both spatial profiling and profiling over time. 4) Provide more intelligent and efficient thermal energy usage by combining a multi dimensional thermal profile with an enhanced and more intelligent (thermostat) control system for heating and cooling.

Another object of this invention is to allow easy retrofit of all components into existing homes/buildings with minimal or no modification to the home/building or special skills required on the part of the installer. This goal is greatly facilitated by attachment to and communications through existing electrical junction boxes.

Another object of this invention is to provide integration of the energy feedback and profiling mechanisms with various known and/or new types of control mechanisms.

A home/building system according to this invention provides a unique solution for energy profiling and feedback, while including network connectivity, energy control, ***surveillance,*** communications, and entertainment functionality as deemed necessary, useful, or desired. This invention essentially creates a "bio-feedback" mechanism for energy use, covering both electrical and thermal energy, through a system architecture that enables a more thorough and broad-based gathering of energy related information. This information is used by the occupant to allow manual control of power consumption in a more informed and effective manner, and also to allow either partial or fully automatic control of energy consumption to be more effectively performed as well.

For the most part, this invention takes advantage of the pervasiveness of electrical junction boxes, typically implementing power plug outlets and the wall switches, within any home or building. These become convenient locations for installing what are called EMAC (Energy Monitoring And Control) points. As explained later, an EMAC point will typically contain one or more forms of energy sensor, often containing both electrical current sensors and a temperature sensor. Since EMAC points typically reside at locations having convenient access to electrical power, they are normally powered directly by this available source, and also typically contain a digital communications circuit that communicates with the central computer, Residential Gateway, or other data gathering and/or controlling device via power line communications, although other forms of data communications--such as wireless--can be used under the right circumstances. This communication link then affords a basic backbone infrastructure for network connections in general. EMAC points may also communicate with other EMAC points as appropriate.

Thus, in an environment where network connectivity has not yet been made readily available (typically referring to the home environment), the installation of EMAC points creates a local network infrastructure that can be built upon before adding other capabilities in addition to normal computer connectivity. These include facilities for enabling home ***surveillance,*** security, and entertainment. Not all EMAC points contain a "control" capability. In some cases it is not appropriate due to the type of energy consuming device that is connected, either because it must be "on" all the time, or because it is already controlled by some other mechanism (for instance a thermostat and/or relay), or because the level of power consumption is high enough to cause a control capability to be too expensive or inappropriate.

Wall switches for controlling lights are also convenient and effective locations for mounting video security cameras. There is usually a wall switch at the entrance to a room and usually it has a relatively commanding view. The easy proliferation of video cameras throughout a home or building, by way of installation at existing junction boxes, has considerable security benefit. In particular, such a system could allow a Security Company or even the Police to view inside and around the home or building in the case of an alarm being set off, so that a "false alarm" condition can be determined without having to visit the location.

Wall switches are also convenient locations for incorporating intercom functionality. Wall mounted power plug receptacles typically have a high degree of proliferation within any room as a result of convention and also building codes. Power plug receptacles are therefore especially useful for gathering temperature information since their proliferation allows gathering a thorough profile of the temperature distribution within any room.

Power plug receptacles are also very convenient locations to offer network connection jacks where any computer or network compatible device or appliance may be attached. They are also convenient locations for adding motion detectors in order to provide a proliferation of detectors in order to enable thorough coverage of rooms not easily covered from a single vantage point.

EMAC points dealing specifically with electrical power consumption may also be added to the electrical breaker box by: 1) Retrofitting EMAC capability into an existing breaker box. 2) Adding smart (EMAC enabled) breakers to an existing box, or 3) Having a replacement breaker box that has EMAC points added in series with conventional breakers.

To effectively provide the aforementioned "biofeedback capability" for energy consumption, this invention offers two forms of feedback--local/instant feedback at the point of use, and general profiling over both time and space provided to the user by software which typically runs on a central PC or Residential Gateway. To assist in creating an overall multi dimensional model for a home or building, capabilities are also described that enable either automatic or semiautomatic identification of EMAC points and their location within the home or building.

To allow a more effective, efficient, and intelligent control of thermal energy utilization, the concept of collecting temperature information in a highly distributed manner is also utilized to enhance the capabilities of the traditional thermostat transforming it into a "smart", network enabled thermostat.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described with respect to particular exemplary embodiments thereof and reference is accordingly made to the drawings in which:

FIG. 1 shows an overall system view including power distribution, communications circuits and connectivity, central controlling elements (local PC or Residential Gateway, smart thermostat) and various forms of EMAC points;

FIG. 2 shows a typical wall switch assembly including an EMAC point;

FIG. 3 shows a wall switch assembly including an EMAC point with a variety of display formats for direct visual communication of energy consumption;

FIG. 4 shows a wall switch assembly including an EMAC point with an alternative display format for direct visual communication of energy consumption and local temperature, including a data read out and a suite of enunciators;

FIG. 5 shows a wall-mounted power-outlet assembly including an EMAC point;

FIG. 6 shows a wall-mounted power-outlet assembly with alternate functionality;

FIG. 7 shows an overall system view with emphasis on connectivity through the Internet between the local system and utility companies, security companies, and a data service company supplying information to specifically support the configuration of the particular local system;

FIG. 8 shows one form of connectivity for video ***surveillance*** where video information is transferred from EMAC points to a central location in the analog format, and are digitized and compressed at that central location before being supplied to the local PC;

FIG. 9 shows a network hub capability allowing EMAC points having different data rate transmission capabilities to all talk to the local PC;

FIG. 10 shows a smart breaker box where a form of EMAC point is used in conjunction with conventional breakers to determine the amount of electrical current being consumed by all devices that are wired to a particular breaker;

FIG. 11 shows how an EMAC point can be retrofitted in a standard, conventional breaker box, providing sensing of all incoming and outgoing electrical current;

FIG. 12 shows how smart breakers incorporating EMAC points can be retrofitted in a standard, conventional breaker box;

FIG. 13 shows how an EMAC point is used in conjunction with a conventional light bulb socket of the type typically found in attics and garages;

FIG. 14 shows how an assembly including an EMAC point is incorporated into a multi-outlet power strip;

FIG. 15 shows how an assembly including an EMAC point can be connected to flow meters monitoring natural gas or heating oil consumption to allow communication of this information to a local PC;

FIG. 16 shows a two dimensional layout drawing for a typical home that has been fully instrumented with EMAC points at wall switch and power plug locations as well as some dedicated locations for directly wired devices;

FIG. 17 shows a two dimensional layout drawing for a typical home including a detailed blow-up showing a possible visual representation for an electrical energy utilization profile;

FIG. 18 shows a two dimensional layout drawing for a typical home including a possible visual representation for a temperature profile;

FIG. 19 shows a two dimensional layout drawing for an office environment with distributed temperature sensors communicating through network connections with smart thermostats;

FIG. 20 shows an EMAC-enabled wall-outlet having a closure detection provision allowing the unit to determine when a nearby window is open;

FIG. 21 shows an EMAC-enabled wall-outlet having a closure detection provision allowing the unit to determine when a nearby window is open, including wireless communication between the EMAC point and the closure detection sensor;

FIG. 22 shows a portable or add-on EMAC wall outlet assembly that can easily be plugged into an existing conventional wall outlet and can also be easily moved to other locations within a home or building;

FIG. 23 shows a portable EMAC identification unit that is used in proximity to, or attached to, an EMAC point. When operating in conjunction with appropriate position locating apparatus, this device will assist the user in creating a two dimensional layout map of a home or building while automatically identifying the location of EMAC points;

FIG. 24 shows how a portable EMAC identification unit might be used with multiple wireless transmitting beacons to determine its position in a manner similar to that used in the GPS (Global Positioning System) system;

FIG. 25 shows how audio information can be transmitted to an EMAC point over the data connection and then be converted to audible sound by circuitry which is powered by the same power line that carried the data;

FIG. 26 shows how a full motion video panel display can be incorporated into an

EMAC point allowing a multi-media intercom/teleconferencing capability as well as viewing of other areas of the home for ***surveillance*** purposes, in addition to displaying energy consumption and temperature data;

FIG. 27 shows how assemblies including EMAC points can be serialized by use of a scanned, programmable wiring matrix implemented on a PCB (Printed Circuit Board).

FIG. 28 shows an EMAC point that functions as an extension to an electrical junction box, providing a re-creation of the junction box interface, and including a video camera and motion detector.

DETAILED DESCRIPTION OF THE INVENTION

The diagram of FIG. 1 shows an architectural overview of how the present invention might be implemented in a typical home or building. The incoming AC power line passes through the Utility Company meter 1 on its way to one more breaker boxes 2 before being generally distributed throughout the home or building through conventional power wiring 3. Throughout the home/building there are user-accessible, electrical junction box power access locations such as wall switch assembly 4 and power plug receptacle assembly 5. In addition, there are power-consuming devices 6 that are directly connected by way of interface module 7. Some, most, or all of these power connection locations can be implemented, within the scope of this invention, incorporating Energy Monitoring And Control (EMAC) points. Each EMAC point contains at a minimum an energy sensing capability (electrical, thermal, or both) and a digital communications circuit enabling communication with a central intelligence such as a local PC 9 (personal computer) or Residential Gateway residing in the same home/building. Note that throughout this document, "local PC" is considered to be synonymous with "central PC" and "Residential Gateway" in that they all represent a form of centrally located intelligence that may perform analysis, control, and communications functions. In today's vernacular, a Residential Gateway is considered to be always in the "ON" condition and provides a constantly available connection to the Internet 24/7 (24 hours a day and 7 days a week). Depending on the particular installation, a local PC can be "ON" for 24/7 and also perform this function. Alternately, there may be an additional device that specifically performs the Residential Gateway function shown as local PC 9. Note that a "smart" thermostat can also be a form of "centrally located intelligence" that communicates with EMAC points.

Note that from the perspective of an EMAC point, a local PC, a Residential Gateway, a Smart Thermostat, or a device located somewhere on the Internet, as well as other EMAC points, are all considered "remote devices". Also, much of the functionality attributed to local PC 9 can also be performed by an intelligent device located at a different physical location and connected via the Internet by way of local PC 9 or some form of Residential Gateway.

In addition to these basic capabilities, EMAC points can incorporate a number of other additional functionalities, all of which will be described herein. Also, although most figures describing the capabilities of EMAC points show current sensing as the means to measure electrical power consumption, it is understood that to compute the true power consumption, the voltage must also be known. If it is desired to measure power consumption in an accurate manner that correlates with the Utility Company power bill, then the voltage measurement used for computing power consumption should be made as close (from an electrical resistivity standpoint) to the Utility Company power meter as possible. Where any EMAC capability is included at the primary breaker box location, a voltage measurement on the input side would be a good location.

Although not strictly limited to power lines, communication between EMAC points will typically be carried out by signals sent over power lines since this medium is obviously convenient at any junction box power connection location. Where electrical devices are directly wired (not plugged-in or switched), interface modules 7 may be inserted to allow the EMAC function to be performed. Other possible locations to insert EMAC functions include light bulb sockets, circuit breaker boxes, and circuit breakers themselves, just to mention a few). Although power line communication is a focal point of this invention, depending upon the evolution of data communication technology for the home or building environment, it may become suitable to utilize other forms such as Wireless Communications in the future. It may also be that some forms of information, such as video in its analog form, may be better suited to a wireless transmission. Also, for systems implemented in office buildings, it may be convenient to communicate by way of pre-existing network connections such as Ethernet.

Another interface module 8 is used to connect between the power lines and a local PC 9 to enable the communication function to be performed. Other intelligent devices may also connect to this power line-based networking capability. In addition to the smart thermostat 10 shown in FIG. 1, this networking infrastructure backbone for the home/building can also be used to implement capabilities in the area of home ***surveillance,*** home entertainment, or simply connecting computers so that they may exchange data or connect to the Internet 11. Although throughout the description of this invention, reference will often be made to communication between EMAC points and a local PC 9, it is understood that with the necessary functionality incorporated into an EMAC point, this communication could instead transfer information directly between an EMAC point and a website or other entity via the Internet. EMAC points can also be capable of transferring information among themselves, without having to communicate with any central form of intelligence such as local PC 9, a Residential Gateway, or the Internet 11.

EMAC Points

Energy monitoring, local feedback, data transmission/reception and control, along with other functions (such as video ***surveillance*** and/or motion detection, and general-purpose network connections), can be included at a variety of locations within the home/building. A few examples include conventional electrical junction boxes where wall switches, power plug receptacles, light bulb sockets, and other power consuming and/or power-controlling devices may be installed. Other possible locations for installing EMAC functionality include circuit breaker boxes, or circuit breakers themselves.

FIG. 2 shows how a replacement light switch assembly 12 attached to an electrical junction box might be implemented to include EMAC functionality. A current sensor 13 measures the power to the load. These sensors can use any of a number of known technologies including inductive or resistive (current shunt). An optional control unit (if present) can optionally turn the power on/off or dim (for lights) in response to a remote command, or can effect various forms of local control for dimming (for lights). Such control modes and others, as well as their implementations--(often relying on SCR (Silicon Controlled Rectifier) devices--are well known in the art. Also, various interactions that may take place between a remote device (local PC 9, a smart thermostat, or some remote device communicating via the Internet 11) and a wall switch EMAC point will be discussed later. The implementation of any EMAC point that includes a switch should always include a means for sensing the switch position (open or closed), regardless of whether or not current is flowing through it. There may be circumstances where a control element in the EMAC point has blocked electrical current from passing through the switch, however it is necessary for the position of the switch to be communicated back to local PC 9 or to some other networked device.

Where a power control function is included in an EMAC point, it is important that the EMAC point operate consistently and predictably, even when the power to the home or building fluctuates or goes off and on, or when a problem arises with a remote device that may issue control commands to the particular EMAC point. A "power-on-reset" circuit should be included to insure the EMAC point never gets "confused" by power fluctuations. Also, when the EMAC point is operating in a mode where its function is being controlled by local PC 9 or some other remote device, the EMAC point may, from time to time, poll the remote device to ensure that the communications link (and the remote device) are still functioning properly. If the remote device did not respond, indicating a possible problem, the EMAC point should switch to its default mode--for instance, if there is a light switch, the power should be applied according to the position of the switch.

The multi-digit display 14 shown in FIG. 2, as well as the displays shown in the many other figures included herein, may be used for many different purposes. A few examples are listed below: 1) Identify to the user the particular switch or outlet assembly and the individual switches/outlets/devices within the assembly 2) Display the current or power (KW/time) being used by the load at a switch, outlet, device, or breaker. 3) Display the cost per time of operating the load attached to a switch, outlet, device, or breaker. 4) Display any mode-related information in response to the optional mode button(s), in response to voice commands, and/or in response to the central PC. 5) Display the temperature recorded by the temperature sensor. 6) Provide feedback for calibration of the temperature sensor, the optional video camera, or the optional motion detector.

FIG. 2 also shows an optional video camera 15 as well as temperature sensor 16, motion detector 17 and intercom capability 18 comprising microphone 18a, and speaker 18b. Some implementations may allow a single transducer to be used for both the microphone and speaker. Circuit 13a shown in FIG. 2 includes a digital communications circuit containing all functionality necessary for data transmission and reception. Circuit 13a also contains the power supply necessary to power any circuitry within the assembly from the available AC power located within the particular junction box, as well as any power control circuitry for an electrical load connected to the assembly. In addition, 13a contains all display driver functionality as well as any circuit functionality necessary to interface with the optional video camera--including video digitization and compression functionality. Various functionalities for video digitization and compression are well known in the art.

FIG. 3 and FIG. 4 both show possible implementations of this local display. In the case of electrical energy consumption, the purpose of these displays is to provide instant visual feedback to the user on energy consumption at the point of use. When displaying temperature, these displays are a guide to thermal energy efficiency by showing the user instantly where certain areas of the home/building have been made overly hot or overly cool beyond what is desired or necessary thereby consuming excess and therefore wasted energy.

These local displays may have any number of digits, depending on the specific requirement. The multi-digit display need not only be of the seven-segment variety as shown in enlarged view 14a. One or more of the digits could be alphanumeric (either with additional segments, or a full matrix as indicated by 14b and 14c [e.g. 5.times.7, 7.times.12, etc.]). Utilizing more than a simple seven-segment capability may provide a more informative and intuitive user interface. This may be especially useful in displaying symbols like "$" or " " in the scenario described below.

A key element of this invention is related to display purpose number (3) listed above ("Display the cost per time of operating the load attached to the switch, outlet, device, or breaker."). The local PC 9 (or Internet 11 directly) can supply the current cost per unit of energy (kW, Therm, etc.) for the consumer's home/building which, in turn, is used to convert the energy consumption level to a cost-per-time parameter, for instance $/month. Energy cost parameters can be automatically accessed from time to time over the Internet. (Energy cost parameters could also be accessed directly over the Internet by an EMAC function, if this EMAC function was designed to incorporate enough intelligence to directly access the Internet.) The energy consumption value at the point of use is then displayed on the switch panel thereby providing instant feedback to the consumer. The conversion calculation from "current consumption" to "cost per time" can be performed in the local controller at the switch or at local PC 9. FIG. 3 shows how another alternate form of the local display can be implemented.

In addition to the forms of display shown in FIGS. 3 and 4, it is also possible to utilize a generalized LCD matrix display (discussed later with reference to FIG. 26) similar to those now found in small wireless communication devices and/or hand-held video games. Incorporation of an LCD matrix display would allow a full motion video image to be shown, further enhancing the overall system capability by allowing the user to view images being recorded at cameras elsewhere in the home from any room having an EMAC point with such an LCD matrix display. Since it is possible according to this invention to also add ***surveillance*** cameras which observe activity around the exteriors of the home, this capability to add video-capable LCD displays to EMAC points is also useful to enhance the security***/surveillance*** capabilities of the overall system.

Both FIGS. 2 and 3 show optional control buttons 118 that can be used to determine the form of the information displayed, and/or affect the operation of an EMAC function. An alternative to using any control buttons on an EMAC point and a way of adding additional functionality is to incorporate a voice recognition technology into the system. This recognition function can be performed by hardware and software contained within the EMAC point. Alternately, it can be performed without adding additional hardware cost to the EMAC point itself by utilizing the microphone, such as that required to implement intercom 18 in FIG. 2. This microphone will receive voice information that in turn can be digitized and sent to local PC 9 for analysis. Voice recognition software is well known and can be trained to respond well to the voices of the home's primary occupants. This incorporation of voice recognition software can be used for a variety of purposes in conjunction with EMAC points including remote control of functionality at the particular EMAC point receiving the voice command or alternately controlling other EMAC points within the home. Control of any Home Systems functionality by a user interfacing with a particular EMAC point can alternately be accomplished by some form of remote control receiver--either IR (Infrared) or wireless--that is incorporated into an EMAC point.

The display incorporated into an EMAC point can also be used for displaying the temperature or other parameters. Where more parameters are to be displayed than there are digits or space available, the display can alternately display different parameters in multiplexed intervals. This is also the methodology shown in FIG. 4 for displaying the power consumption for each of multiple receptacles. Enunciator LEDs could be used or, if necessary, an additional digit can be added to indicate the position of a particular receptacle whose parameter is being displayed at the moment. To indicate what type of information is being displayed and/or what units of measurement are being displayed, other forms of display means can be used. For instance, enlarged view 14d of display 14 in FIG. 4 shows that multiple enunciator icons 19 representing parameters or identifying power consuming loads (switches, outlets, etc.) can exist on the display. The appropriate one(s) of these enunciator icons are then illuminated/highlighted depending on what energy or temperature information is being displayed at the moment. The display technology can be LED, LCD, gas discharge, or any other available and appropriate technology. Depending upon the display technology chosen, an additional display driver chip may need to be incorporated into the EMAC function.

Also shown in FIG. 4, are a number of optional functions including temperature sensor 16, video camera 15, and motion detector 17. If motion detection is desired, it can be done through a standard sensor (usually IR), or could alternately be performed by image analysis performed on the video image either locally or remotely. Each method has advantages and disadvantages.

The easy proliferation of video cameras throughout a home or building, by way of installation at existing junction boxes, has considerable security benefit. Since video camera 15 is connected to local PC 9 through a communications link, it can be viewed remotely via the Internet after the video information has been digitized and compressed. The video camera can be statically mounted and include a wide-angle lens and manually operated gimbal capability. Optionally, the video camera could include a motorized gimbal to allow remotely controlled movement (even via the Internet). In many instances, it may be desirable to include On/Off switch 15a to control video camera 15 such that the camera may be turned off when privacy is desired. Information regarding the position of this switch may also be made available through the communications link to local PC 9 and/or a remote device on the Internet.

Regardless of how the video camera is controlled, images that have been transferred to the central PC can also be automatically moved to an off-site web/domain server for storage. Thus, if the ***surveillance*** camera detects and captures images of an intruder or some important event, the images will be preserved even if the PC in the home/building is damaged, destroyed or stolen. A buffer of the video ***surveillance*** information storing video information for some fixed period of time into the past, can be stored at an off site location, via the Internet. In a mode where the system is armed for intruder detection, or alternately tied into a conventional security system for intruder detection, and an intruder is detected; this historical buffer of the information can be preserved to aid in the identification of the intruder and the recreation of the event. Any video information moved offsite is probably encrypted to ensure the privacy of the occupant.

The detection of a possible intruder can be performed by the elements of this invention, by a separate conventional security system, or both working together. Given the inconvenience and expense of false alarms, the distributed video capability of this invention, made easier to implement due to its installation and communications through existing junction boxes, could allow a Security Company or even the Police to view inside and around the home or building in the case of an alarm being set off, so that a "false alarm" condition can be determined without having to visit the location. To make such a capability acceptable to the occupant, especially in the case of a residence, it would be imperative that there exist a privacy mechanism (in software) such that the local PC or Residential Gateway does not allow any viewing by the Police or Security Company unless an intruder detection alert is in progress.

In general, transmission and storage of video information can be based on motion information derived from the motion detectors in each room. If no motion is occurring, storing a static snapshot taken at regular intervals may be completely adequate. When motion is detected, the video information from that area of the home or building can be recorded completely and buffered. A remote interface via the Internet coupling into this Home System can show a plan of the home or building, wherein the user can see a two dimensional map of where motion has been detected and also see the most recent snapshots (in small "thumbnail" pictures) allowing the user to click on a room or camera location and immediately see the live action video from that location.

Depending on the available bandwidth of the connection in the home/building between the video camera and local PC 9, it may not be necessary to have full speed/live action video to serve a useful purpose. Even a "jerky" picture or one with reduced resolution may still constitute a very useful function if it is available at a significantly lower price and if the low price allows a much more prolific deployment throughout the home/building. Also, regardless of the bandwidth available to transfer digitized video images to local PC 9 or directly to the Internet, the cost of the video camera may be significantly reduced (with a corresponding reduction in image quality) by using a newly available video sensor technology. Here, video sensor arrays can be constructed on a standard CMOS semiconductor process and potentially integrated onto the same chip with other functions required to implement the various features of an EMAC function. It may also be acceptable to use black & white video if it is available at a much lower price than color.

An alternative mechanism for sending video information from an EMAC point to local PC 9 and the Internet may include analog video transmission from the EMAC point to a device, located near local PC 9, which receives, digitizes and optionally compresses the video as will be shown in FIG. 8.

FIG. 5 shows an EMAC configuration similar to FIG. 2 except that it describes a power plug receptacle assembly, containing at least one receptacle location 20, instead of a switch. FIG. 5 also includes an optional video camera 15. Note that according to this invention, any electrical junction box is a possible location for installing a video camera, and that when installed, the camera can be powered by the source of AC power available at the junction box, and the video signal, after being digitized and compressed, may be transmitted digitally by way of the available power connection to local PC 9 or some other remote device.

FIG. 6 shows a power receptacle assembly similar to FIG. 5 except that optional network connection jack 21 is included. This network connection jack can offer standard Ethernet compatibility. If the type of data transmit/receive link used to transfer information to/from the EMAC point and local PC 9 possesses a bandwidth capability compatible with normal network data, it may be convenient and useful to include this conventional network connection jack as part of the power receptacle assembly. Power receptacles are the most proliferated form of wired connection points within any home or building.

Also shown in FIGS. 5 and 6 are motion detectors 17. These can be especially useful in filling in the "blind spots" that occur if the only motion detector controlling a light is located in the wall switch assembly. To avoid unwanted detection of pet movement, the lenses for the motion detectors on power plug EMAC points can be fashioned so as to look to higher elevations for motion. Since power receptacles are so proliferated, using these locations for installing EMAC points provides a very thorough picture of temperature, motion, and even video, within the home or building.

Also shown in FIGS. 5 and 6 are circuits for controlling the power available at receptacle 20 in response to commands received from a remote communications link. In some implementations of such a power controlling circuit, the maximum allowable power that may be drawn through the receptacle may be artificially lowered by the presence of the controlling circuit. It therefore may be appropriate to provide a physical mechanism for overriding or bypassing the power controlling circuit such that the maximum allowable electrical current level for the plug receptacle is not artificially lowered.

As an alternative to the wired Ethernet connection shown in FIG. 6, a different connection methodology to allow devices or appliances within a particular room to communicate with an EMAC point for data communications would be the addition of a wireless transceiver to the EMAC point. This can be done by having a small, optional module that plugs into a connector on the EMAC point, deriving power from, and communicating with the EMAC point, while communicating in a wireless manner with other devices in the room. An example of such a wireless technology is that currently referred to as "Bluetooth". Many wireless technologies have a limited range within which they can operate reliably, for instance 10 to 30 meters. The range of wireless technologies can vary considerably, especially within a home environment, depending upon the number of walls the signal must pass through and the structural content of each particular wall. Within a particular room, however, wireless technology can be very convenient, especially when interfacing with a portable computer or entertainment equipment. An example of a wireless communication module attached to an EMAC point is module 65 shown in FIG. 21.

FIG. 7 shows a possible overall connection scheme for a home/building according to this invention where all EMAC points can connect with local PC 9 that, in turn, communicates via the Internet 11 where a central source of information will supply energy cost rates and other utility-related information. The central source of information could be a Utility Company 22 or a third-party supplier such as Data Service Company 23. Information may also be transferred to and from a Security Company 24 such that any security related information such as ***surveillance*** video, motion detector outputs, or window/door open detection indications may be viewed at the Security Company.

The overall system of FIG. 7 includes wall switches 4, receptacle plugs 5, directly wired loads 6, and breaker boxes 2 (both conventional and "Smart"--per FIGS. 10, 11, and 12). Included in FIG. 7 is the potential for the Utility Companies to provide a "***Smart Meter***" that would interface with the Internet 11 and could potentially communicate with the system described in this invention. Also, as shown in FIG. 11, a smart breaker box according to this invention can measure the current entering the breaker box and therefore is capable of checking the accuracy of the existing Utility Company meter.

FIG. 8 illustrates the scenario where video information is transferred from cameras contained at EMAC points to a central location using an analog transmission format as opposed to digital. Eventually the cost of converting video information from analog to digital and performing video compression will be reduced to the point that incorporating compression into each EMAC location will be inexpensive. Also, over time, the cost of a high bandwidth connection between EMAC locations will also be greatly reduced. However initially, it may be more cost-effective to transmit information as some form of analog signal to a central location where these signals are converted to digital form and the video compression and/or conversion technology is shared among the different video sources. Such a mechanism for sharing the video compression capability is shown as interface module 25 in FIG. 8.

The video compression function 26 shown in FIG. 8 may also be performed in the local PC 9 if the PC's processing capability is adequate. Also, as described earlier, the determination of which video signal to digitize and compress at any given point in time can be made at the local PC by examining the outputs of the motion detectors at the EMAC points from which the video signals are being sent.

FIG. 9 addresses the issue of how the data rate capabilities of available EMAC points may increase over time, and how the overall system will cope with this by offering a multi-data rate communications consolidation capability located near the local PC 9. The capability of communicating between local PC 9 and various EMAC points at different data rates is also important since different types of EMAC points may require different data rate capabilities even though they're all being purchased and installed at the same time. For instance, an EMAC point that is controlling and monitoring power consumption and temperature may require only a very low data rate capability. EMAC points that will offer networking connectivity capable of supporting a broadband Internet connection today might require a one megabit per second capability. To offer a normal 10 megabit Ethernet connection capability, EMAC points would obviously need to communicate at 10 megabits per second. To transfer digital video would also require a reasonably fast data rate. The cost of an EMAC point is therefore significantly affected by the data rate it must support, and therefore the most cost-effective overall solution for the home system may be to utilize EMAC points having a variety of data rates. Hence an implementation strategy such as that shown in FIG. 9 containing a form of a network hub 27 and receive/transmit units 28, which may all have different data rates, may be the appropriate solution to the problem.

A modular implementation for hub 27 can be constructed where there exist slots designed to accept cards or modules representing receive/transmit units 28, each of which may have a different data transfer rate capability. Besides having a different transfer rate, such modular receive/transmit units may still each conform to an industry standard for powerline communications. For instance, one might conform to the X10 standard, one to the CEBus standard, and others conforming to newer standards such as those being studied by the Home Plug Alliance organization, or any future standard. Such a modular approach allows the user to mix and match capabilities as required--producing the most cost-effective and conveniently assembled home system. A modular hub assembly as just described would have a host interface circuit that could support a variety of output standards, such as standard Ethernet, USB, and/or any other, and would interface with local PC 9 or a processor performing the Residential Gateway function, or alternately a device located somewhere on the Internet.

FIG. 10 shows a "Smart" breaker box where each breaker 29 has associated with it an EM (Energy Monitoring) point 30. EM points located in breaker boxes typically contain the current sensing, receive, transmit, and possibly display functions, but typically do not perform a control function. Sensing temperature would also not be an appropriate function within a breaker box relative to providing useful ambient temperature readings, since there is usually a natural build-up of heat within a breaker box. However, a temperature sensor might be useful if the user wished to know of the occurrence of an unusually high temperature build-up within the breaker box itself.

Information supplied by these EM points can be correlated with information sent from EMAC points located downstream of each breaker to assist in providing a clear and complete picture of where all electrical power is being consumed within the electrical circuit being served by that particular breaker. For some power-consuming devices that are directly wired, inserting an EMAC point at the breaker location may be the easiest way to retrofit the EMAC capability.

FIG. 11 shows an alternate form of a "smart" breaker box where the current sensing, display and communications capabilities commonly associated with the EMAC points of this invention, can be retrofitted into a standard breaker box. The retrofit EM (Energy Monitoring) control unit 31 supports the connection of multiple current sensing units 32, including current sensor 33 which measures current entering the breaker box from the incoming A/C power line. Keyboard 34 on EM unit 31, if present, aids in the identification of the particular breaker units in the box which is necessary for proper processing of energy related data at the local PC 9, but also useful to aid the user in understanding which breaker relates to which area of their home. It is a well-known fact that in most homes, the correlation between specific breakers and the energy use locations that they supply is typically very poorly documented.

FIG. 12 shows an additional way to provide a similar capability of installing EM capability without having to retrofit the entire breaker box in an existing home/building. Here, the feedback/monitor point functions would be incorporated into the circuit breakers 35 themselves which, in turn, would fit into an existing, conventional breaker box. Obviously, breaker-related EM points would concentrate on electrical current measurement as their primary function. Integrating the EM function into the breaker itself obviously would require a high degree of miniaturization, especially if integral (and optional) display 36 is included.

It should be noted that in FIGS. 10, 11, and 12, all relating to measurement of electrical current entering or leaving a breaker box or other electrical distribution box, that the ability to measure the incoming current with a reasonable degree of accuracy will allow the user to correlate their power consumption with that registered by their utility company's power meter, as reflected in their power bill. Many utility company power meters are extremely old and may not be consistent or properly calibrated, thereby overcharging the user.

Also, relative to the breaker box solutions shown in FIGS. 10, 11, 12, a particular installation may be done such that all of the loads "downstream" of a particular breaker do not include EMAC points. In fact, for some breakers, no EMAC points may exist downstream. In these circumstances, a useful method for identifying the power consumed by connected devices is to establish an "energy signature" for each device by turning on only one at a time, during a set-up/calibration process, and recording the typical energy usage for each device. This "signature" may also include any unique characteristics of the waveform shape for the ramp-up of the instantaneous electrical current consumption, or the effect on the measured voltage waveform at the breaker box, when the device is initially turned on. These "signatures" can later be used for identifying the energy used by particular electrical energy consuming devices when performing an overall profile according to this invention.

FIG. 13 shows an EMAC point designed to work in conjunction with an "old-fashioned" light bulb socket. These sockets are still prevalent in attics and garages today. In addition to monitoring the power their light bulbs use (they can easily be left on accidentally for long periods of time), since they are located in attics and garages, they can also provide an important thermal feedback function. Attics and garages tend to act as heat reservoirs that can be a source of energy in winter and a drain (due to fan/air conditioning power consumption) in summer. Notice that EMAC point 37 is somewhat remotely located from light bulb 38 to reduce any thermal contamination from the heat produced by the bulb. Intercept adapter 39 is included to divert the power to EMAC unit 37, which is separated from bulb 38 by thermal isolation distance 40. Also, for the unit of FIG. 13 to monitor temperature and transmit that information to the central computer, a power control function may be an absolute necessity if the bulb is to remain off when light is not required (especially important in the attic) depending on whether the bulb socket is remotely switched or not.

To demonstrate that other forms of power outlets can be adapted to include EMAC points, FIG. 14 shows how a common power strip 41 can include these capabilities. Another form of portable, add-on EMAC point is discussed in FIG. 22 in more detail.

FIG. 15 shows how the concepts described previously can be extended to other forms of energy monitoring/feedback with an emphasis on oil and natural gas used to produce thermal energy. Flow meters 42 and 43 are inserted into the line carrying the gas/oil to the thermal energy-producing device. The output of each flow meter is then connected to interface modules 44 and 45 respectively that act as EMAC points in a manner somewhat similar to the examples shown in the previous figures. In a similar way, point-of-use feedback is provided and data is transmitted to central PC 9 for use in assembling the overall profile of energy usage for the home/building.

Software operating on central PC 9, among other functions, will be able to create a multi-dimensional map of energy usage as well as prioritized listings of where different amounts of energy are used. Some examples of this capability are described next.

FIG. 16 shows a two-dimensional plan layout for an example home where locations for all power plugs 46, wall switches 47, and dedicated energy using appliances 48 are identified accordingly. This layout plan forms the basis for energy profiling diagrams that can be presented to the user, thereby allowing easy identification of energy usage anomalies or to better guide the user in implementing more efficient energy usage.

FIG. 17 shows the overall layout for a home where electrical energy usage has been annotated for each of the EMAC points deployed. A blow up view 49 of one section of the home shows how energy usage parameters 50 can be annotated to show the specific energy consumption at any EMAC location. The sample numbers shown for parameters 50 might be in instantaneous Watts, however alternatively, these parameters could be shown as an average consumption over a specific time period. Also, as has been previously shown for the direct feedback energy consumption displays incorporated into EMAC points, the energy consumption parameters in FIG. 17 could display information indicating the cost per time of the energy consumed, again either instantaneously or over some specific time period. The display of FIG. 17 could easily highlight each particular EMAC location designator in a different color according to the level of energy being consumed. Since the diagram of FIG. 17 is shown in black and white, the relative level of energy consumption has been shown visually by the relative thickness of the borders surrounding the plug or switch EMAC point designator. For instance power plug 51 consuming 930 watts, the largest amount consumed of any EMAC point within blowup 49, has the widest border. EMAC point 52 having the next highest level of energy consumption (700 watts) is shown with the second widest border. In an actual software product implementing such a display for the user, the highest energy consuming points might be displayed in the brightest red color, while the lowest energy consuming points might be displayed in darkest blue, with mid ranges of consumption levels being displayed in intermediate shades of color.

Information from temperature sensors 16 is displayed locally at the particular EMAC point for direct visual feedback, but is also sent to the local PC 9 for processing to allow the creation of a temperature profile for the home/building. FIG. 18 shows a similar layout plan to that of FIG. 17 except that the annotated information reflects the local temperature at each EMAC location. FIG. 18 displays the overall temperature profile in two dimensions (for each level of a multi-level home/building) and can provide feedback (including time-related information) that can help the user reduce (thermal) energy costs by way of a number of useful mechanisms: 1) Areas of the home/building that are being heated or cooled unnecessarily will stand out and the user can take the appropriate corrective action. For instance, overheated areas 53 indicate rooms that are much hotter than necessary, prompting the user to take corrective action such as closing vents that are unnecessarily open. This information can also drive a more elaborate automation scheme where automated control of thermal delivery mechanisms is used. Such delivery mechanisms are exemplified by the electrically controlled wall/floor air flow registers manufactured by EWC Controls of Englishtown, N.J. Other forms of electrically controlled vents, ducts, and registers having controllable, variable air flow are manufactured by a number of other suppliers. 2) Software on the central PC that operates on the thermal profile of the home/building can detect thermal gradients and may be useful in pointing out areas of thermal leakage such as poor weather seals on exterior doors and windows. Notice that EMAC point 54 located near a door of the home displays a temperature of 65 degrees even though the thermostat set at 72 degrees is just around the corner. This would tend to indicate that the seal around the door is most probably inadequate and causing significant energy leakage. The greater the number of temperature sensing points that are placed around the home/building, and especially within a particular room, the more accurate a gradient profile will be able to be produced. To further display temperature gradients in a form familiar to most users, additional software could display extrapolated temperature gradient information in a manner similar to that shown for temperature profiling on weather maps. The more temperature sensors are located in a particular area of the home or building, the more accurate these extrapolated thermal gradient maps would be.

It should be noted that a profiling capability can also be implemented on a Smart Thermostat that is network-connected. Even if such a thermostat does not possess the display size and resolution of a PC or Gateway, useful information can still be provided. For instance, with only one EMAC point in each room or zone in a house, the temperature in each room or zone can be displayed. Also, rooms that are being overheated or overcooled can be enunciated. In one embodiment, a Smart Thermostat could even have a panel display and a miniature keyboard (possibly "QWERETY" style) together enabling a more capable user interface, more familiar identification of rooms and zones, and even a multidimensional thermal profile display.

To make accurate use of the temperature sensor information, it is important that any heat energy generated in the switch or plug receptacles not affect the measurement. For this reason, the temperature sensor will usually be located at the lowest point within a switch or plug EMAC location. It may also be necessary to make the faceplate larger to move the temperature sensor farther from any source of potentially-interfering heat. A switch or plug location is a natural heat generator simply due to the contact resistance where the wiring is attached, the contact resistance of a switch, or the resistance formed at the interface where a plug is pushed into a receptacle socket. Additional heat can also be generated if the EMAC location includes a controlling capability where a semiconductor device is used to clip the A/C waveform--a process having less than 100% efficiency and therefore generating additional heat.

Other variations on a temperature sensor may be possible. In particular, a sensor might be constructed where multiple IR temperature sensing elements are used in conjunction with a prism or alternately where each sensor is directional and is aligned in a different direction, thereby gathering temperature information from different areas of the room such that a spatial image of the thermal gradients in the room can be established.

FIG. 19 shows what can be accomplished when the distributed temperature data collection mechanism of EMAC points is utilized to allow a more intelligent control of the temperature in multi-room or multi-cubicle environments while still utilizing a single thermostat (at the existing location) to control existing heating/cooling units. FIG. 19 shows an office environment containing both enclosed offices and an array of cubicles--however the same principles embodied here can be employed in any home or building environment employing EMAC points. Also, the capabilities that will be described relative to FIG. 19 do not require all of the previously described EMAC functionality to be present. In fact, a system consisting of distributed temperature sensors with some form of network interface capability, communicating with a smarter thermostat also having network communication capability, will suffice. Note that a "smarter" network connected thermostat such as 55 and 58 in FIG. 19, should contain a default mode wherein the thermostat reverts to the mode of operation of a traditional thermostat if its ability to collect distributed temperature information is compromised, or if a switch on the thermostat is thrown to force the thermostat into the "traditional" mode of operation.

Also, note that a similar functionality to that described above for FIG. 19 can be achieved by having the network-enabled temperature sensors communicate with any of a number of intelligent controllers, including local PC 9, a Residential Gateway, a dedicated intelligent thermal control system, or even a remote device located elsewhere on the Internet.

The problem being addressed in FIG. 19 is that where the temperature observed at the thermostat location is not at all indicative of the average temperature over the area being served. For instance, thermostat 55 located in one office might control the heating and cooling for the entire row of offices. Due to variations in the ducting and vent structure, as well as the temperature variation across the row of offices during the course of a day as the position of the sun changes, it is not uncommon for some offices to be painfully cold or warm relative to the office possessing the thermostat. For instance, without the control capability embodied in this invention, thermostat 55 may be set to 72 degrees, temperature sensor 56 might register 70 degrees, and temperature sensor 57 might register 80 degrees. With network connected temperature sensors installed in all offices, including the offices containing sensors 56 and 57, the thermostat can compute an average temperature over all of the offices and control the heating/cooling system to reach an overall compromise of temperatures as shown in FIG. 19, thereby eliminating the excessively hot or cool locations that would previously have occurred.

A similar capability can be implemented for an array of open cubicles such as cubicle array 59 where the heating and cooling is controlled by thermostat 58 possessing a network connection. It should be noted that the distributed temperature collection capability required to implement the functionality of FIG. 19 does not require network connectivity over power lines as described in most embodiments of this invention. A smart temperature sensor connected to an Ethernet port would suffice to implement this capability, and in most office and cubicle environments today, Ethernet connections are plentiful. Also, the existing thermostat location and connections can be utilized with the addition of a network connection.

A variation on the capability shown in FIG. 19, and applicable to any environment having the ability to collect temperature information in a distributed manner, relates to a home where multiple EMAC points have been installed around a room or around multiple rooms. Here, a smart thermostat communicating with these EMAC points can be programmed to achieve a desired temperature at a specific location within each room during specific time periods (essentially ignoring the temperature at the thermostat itself). For instance, the system could seek to achieve a temperature of 70.degree. in the Kitchen from 5:00 to 7:00 PM and then seek a temperature of 70.degree. at the Living Room couch location from 7:00 PM to 10:00 PM.

Of course, a more desirable overall thermal result could be achieved for scenarios similar to those described for FIG. 19 if the controlling device (smart thermostat, PC, or other form of intelligent processor) is also able to control the amount of airflow allowed through a multitude of distributed, electrically controlled, variable airflow vents, ducts, or registers.

FIG. 20 shows how an EMAC point can offer a closure detection capability that, when connected to a closure-sensing switch 60 on a window 63, can determine whether the window is open or closed. While this feature certainly has application in performing a security function, a very common loss of energy in many homes occurs when windows are inadvertently left open. Therefore such a closure detection capability is valuable within an energy management scheme as well. While FIG. 20 shows an additional jack 61 on the EMAC wall outlet, the wire from the closure sensor could connect directly with network jack 62 assuming the closure sensor had an Ethernet connection capability.

FIG. 21 shows a window closure detection capability similar to FIG. 20, except that a wireless closure sensor 64 communicates with wireless communication module 65 located on the EMAC point. This wireless communication module 65 could be a very simple low bandwidth low-cost unit, given the simplicity of its task, and its close proximity to the windows within the room it services. Even a simple wireless communication module 65 could be designed to communicate with multiple wireless closure sensors 64 within a single room.

Alternately, wireless communication module 65 might have a higher bandwidth capability, allowing more sophisticated local communications within a room or zone. A more sophisticated wireless communication module might be implemented with a technology such as "Bluetooth", previously referred to as an alternative local connection capability in the description relating to FIG. 6. Such a more sophisticated wireless module could still communicate with window closure detection modules 65, but could also communicate with any wireless network-enabled device or appliance within the room being served that was capable of communicating via the "Bluetooth Standard". This wireless configuration can even support communication with a wireless-enabled laptop/notebook computer that can move about within a room or zone.

Other standards than Bluetooth can be supported in this way, including the IEEE 802.11 standard commonly used today for local wireless communications. As mentioned earlier, communicating between EMAC points through power lines circumvents difficulties encountered with wireless communication in many home environments (including 802.11), where wireless signals often have great difficulty traveling through multiple walls.

In the configuration described in the previous paragraph, there would be multiple local wireless communication modules 65, sometimes one to a room or one to a zone if the range of a single module can successfully penetrate a wall or two. Each of these local modules is now essentially a host in its own right. The home or building environment now resembles a cellular phone system with multiple hosts and zones, and requires a management scheme that may be similar. A moveable wireless device might switch from communicating with one particular module 65 to a different module 65 as its location changes. Alternately, a wireless client device having a fixed location, like window closure detector 64, can be programmed to communicate exclusively with a specific wireless communication module 65.

FIG. 22 shows a form of portable/add-on EMAC point 67 that can easily plug into an existing wall outlet plug receptacle installed in electrical junction box 66. While this capability is very similar to the power strip EMAC point shown in FIG. 14, it is different in that it would replace the cover plate on the plug receptacle at junction box 66 and after being plugged in, would effectively become a new cover plate, but with considerably enhanced capabilities. FIG. 22 also shows, in addition to previously described temperature sensor 16 and motion detector 17, a light intensity detector 68 that may be useful if, for instance, this portable EMAC point is the only EMAC point installed in a particular room. One of the benefits of having a portable, easily added unit like that in FIG. 22, is that it allows the user to purchase a limited number of EMAC points in order to start using their capabilities, without making a more permanent installation by replacing actual plug receptacles or wall switches. Therefore, it may be useful to have a light detection capability such that a profile of lighting usage can be established by software running on central PC 9. Also notice that portable EMAC point 67 may contain any number of plug receptacle locations 20 (six are shown here). Having multiple outlets not only offers the user the convenience of not having to use a multiple outlet extension cord or power strip when more than two power consuming devices/appliances must be plugged in, it also provides independent energy monitoring for each of these receptacle locations thereby providing more precise information on energy utilization. In addition, display 14 in FIG. 22 can display the total power consumption at the receptacle location and even provide a warning if the maximum allowable power level for a receptacle assembly is being exceeded. Alternately, an audio emitting transducer within unit 67 could provide a similar warning.

When a system according to this invention is installed in a home or building whereby a multitude of EMAC points are distributed throughout multiple rooms, it then becomes necessary to identify the location of each EMAC point in order for software running on local PC 9 to perform profiling of data relating to energy consumption. The larger the quantity of EMAC points, the more complex and time-consuming this task becomes. It therefore becomes useful to have a mechanism to automate this process of identifying specific EMAC point locations. Another related task is that of drawing an electronic representation of the two-dimensional plan layout for the home or building that is required for proper display of the profiling information. For most existing homes, and even some new homes, this electronic representation will either be nonexistent or inconvenient to gain access to. A method for automatically creating an electronic plan layout and, at the same time, identifying all EMAC points, would be both efficient and useful.

Portable EMAC identification unit 70, shown in FIG. 23, can be used to perform this capability. This particular unit relies on a wireless antenna 71 constructed in such a manner that when receiving signals from multiple transmission beacons, the position of unit 70 can be accurately determined through triangulation. Principles such as those used in the GPS (Global Positioning System) may be utilized where the beacons and receiver all contain synchronized clocks and signal travel times from different beacons (similar in concept to GPS satellites) are compared--the position being determined by triangulation. Different frequencies and signal strengths would have to be used to enable the penetration of walls of the home or building.

Alternately, a similar system can be constructed where unit 70 contains a transponder. The transponder echoes each signal received back to the source beacon where the distance is determined by phase shift information that is then communicated back to unit 70. EMAC identification unit 70 can identify EMAC locations by plugging into a power plug 72, or simply by placing it adjacent to a power consuming switch, or a device with dedicated wiring, and indicating through integral keypad 73 or optional keyboard 74, the device being located. As will be explained later in FIG. 27, each EMAC point may have an integral serial number that can be used as part of the identification process.

FIG. 24 shows an overall view of a home or building where identification unit 70 receives signals from a plurality of wireless transmission beacons 75. The exact placement of these beacons may not be critical since, once a reference point has been established for identification unit 70, only relative position information is necessary to establish the locations of EMAC points, as well as the dimensions and layout plan of the home or building. If it is desirable to determine EMAC locations in three dimensions, a third beacon located at a different elevation setting from the initial two beacons 75 may be added. Accordingly, the antennae on identification unit 70 would have to be enhanced to allow position detection in three dimensions. More than three beacons may be useful in some circumstances where signals have difficulty penetrating the building structure in some places.

In fact, given proper frequencies along with the appropriate circuitry and antenna system within the identification unit, it would be possible to establish positions with a resolution of distances to a fraction of an inch. In this case, the system described in FIG. 24 is also capable of becoming a measurement system. Such a measurement system could be developed and used independent of any specific use relative to energy or thermal information, being used solely as a semi-automatic way to obtain precise dimensions of an existing home or building in order to create an accurate drawing. The need to create an accurately dimensioned drawing of an existing home or building occurs quite frequently when modifications to an existing structure are being planned.

FIG. 25 shows how audio information, in particular music, can be transmitted via a digital communications circuit through power lines, thereby enabling an audio output node unit 76 containing a Speaker 77 as well as interface circuit 78. Interface circuit 78 would have the ability to receive and transmit information as well as convert a digital audio stream to an amplified signal capable of driving Speaker 77. Interface circuit 78 may also contain some form of remote control receiver 79 which could be either infrared or wireless. With this remote control capability included, interface circuit 78 may also contain a transmit capability such that any control requests can be forwarded to similar audio output nodes and/or to the source of the audio information via the powerline network.

FIG. 26 shows how the integral display contained in many of the EMAC points of this invention could be constructed as a general purpose video panel display 80. Of course, video display 80 could provide all of the energy-related information described for variations of integral display 14 shown in earlier figures. In addition, given a connection with sufficient bandwidth (either digital or via analog video signal), display 80 can show a picture captured by any video camera 15 within the home or building, or alternately can display video information being transferred to the home or building via the Internet. Essentially, this creates a "video intercom" capability. When combined with audio intercom 18, a multimedia intercom capability is created, which can be controlled either by control buttons 118 located on the assembly, or by voice recognition commands, or both. For instance, by observing a video display in the master bedroom, a user could check for activity in different rooms throughout the house. This capability is further enhanced if the user can initiate a command that controls lighting throughout the house, thereby illuminating the rooms to be observed. Similarly, lights illuminating the outside perimeter of the house can be controlled, and video cameras mounted so as to observe these areas and supply information that can be viewed on display 80. The form of control buttons 118 in FIG. 26 can be expanded to include a lighted keypad to allow command input regarding what room is to be observed and/or illuminated. Such a keypad could have specific buttons/keys that are marked with the names of the particular rooms that might be observed.

Another use of display 80 is to enable interactive video conferencing, not just within the home, but with someone located at a remote location via the Internet. Although such video conferencing is of course possible on any PC given an attached camera, the unit shown in FIG. 26 allows a more spontaneous form of conferencing. For instance, a parent, while at work, might observe the activity of a child at home and spontaneously initiate a conference via the assembly shown in FIG. 26 which is directly accessible to the child in whatever room they happen to be.

As mentioned earlier, in order to properly identify EMAC points within a home or building, some form of integral serialization for each EMAC unit may be desired. This can be accomplished in a number of manners, the simplest being to add a form of programmable memory within one of the integrated circuits contained within the EMAC unit. During the manufacturing process, each EMAC unit would then be briefly connected to a programming system that would install a unique serial number in each EMAC unit. However, it may be overly expensive to include a memory chip, or build any of the required semiconductor devices on a process capable of supporting electrically programmable memory. If the cost of this method is prohibitive, an alternative approach would be to include some form of electrically scan-able matrix on a PCB (Printed Circuit Board) within the unit, such as matrix 81 shown in FIG. 27. This matrix is scanned by applying patterns to the wires oriented along a first axis while observing the values that appear on the wires oriented along the axis orthogonal to the first axis, thereby scanning the matrix and determining which intersections are connected and which are not. If the matrix is comprised of wiring traces on the PCB, it would be normal to initially have the matrix fully connected at each intersection, and then selectively delete connections at certain intersections in order to affect the programming pattern for the serial number.

This deletion could be performed by a number of methods including laser cutting, or use of a burnable fuse structure at each matrix intersection, all of which are techniques known in the art. An alternative to deleting conductive material at a matrix intersection would be to have the ability to selectively add conductive material at selected intersections and to have all matrix intersections start out in an electrically unconnected state.

EMAC points are also quite useful at the exterior of a home or building as shown for a light mounted on exterior wall 84 of a home or building in FIG. 28. Here, junction box extension unit 82 is added between exterior electrical junction box 83 and exterior light 87. Extension unit 82 has both motion detector 85 and video camera 86 attached and also includes a circuit for controlling exterior light 87. Also included in extension unit 82 is a communication circuit capable of sending digital information to and from any remote device by way of the electrical power line available at the junction box. Video information is digitized, compressed, and sent over the powerline communication link. Also, motion detection information, temperature information, and power consumption information for light 87 can also be transmitted in a similar manner. Exterior light 87 can also be controlled remotely via the communications link.

Note that, in this specification, where a single video camera is shown as part of an assembly, multiple video cameras can also be included within the same assembly thereby covering a larger overall viewing area. Also, multiple cameras within the same assembly may also share some of the video compression circuitry and other support circuitry that may also exist in the assembly.

Therefore, a system for incorporation in homes or buildings has been described that allows energy related information to be gathered by way of EMAC points typically installed at convenient locations such as electrical junction boxes used for plug receptacles and wall switches. In addition to being visually displayed at the point of energy use or measurement, this energy related information is typically communicated through a power line data link to a centrally located, local PC or directly to a device on the Internet where this information can be used for energy profiling and or control. Also, taking advantage of the data transmission capability required for communication of energy related information, as well as taking advantage of the power available at junction boxes, network access points are easily made available. Given the vantage point afforded by a typical wall switch located at the entry to a room, video cameras and/or video displays may also be included in the assembly implementing a wall switch EMAC point.

It should be understood that the particular embodiments described above are only illustrative of the principles of the present invention, and various modifications could be made by those skilled in the art without departing from the scope and spirit of the invention. Thus, the scope of the present invention is limited only by the claims that follow.

United States Patent **7,561,977**
Horst , et al. **July 14, 2009**

Total home energy management system

Abstract

A system that facilitates and implements energy savings decisions by a home owner. The system will provide a mechanism to reduce the peak level of energy demand. A controller in logical communication with energy consuming appliances responds to request for energy from energy consuming appliances and devices by permitting or curtailing energy supply to the appliances or devices based on evaluation of a plurality of logical considerations. The controller may be operated to provide energy to fewer than all of the energy requesting appliances to reduce the energy demand on an energy supply source, including the instantaneous peak demand.

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Appl. No.: **10/460,885**
Filed: **June 13, 2003**

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Application Number	Filing Date	Patent Number	Issue Date<TD< TD>
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Current U.S. Class:	**702/62** ; 700/295; 702/60; 702/61
Current International Class:	G01R 21/00 (20060101); G06F 17/40 (20060101)
Field of Search:	702/62,57,60,61,64,65,122,124,126,183,187,188 700/22,286,291-293,295-297,412 324/142,103R,141 307/125,126,116,35,38,39 340/870.01,870.02,870.16,500,635,636.12,637,657,3.1 705/412

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Parent Case Text

This application is a non-provisional of provisional application 60/389,013, filed on Jun. 13, 2002, the entire contents of which are hereby incorporated by reference.

Claims

What is claimed is:

1. A method for managing the supply of energy to a plurality of energy consuming devices connected to a power distribution system of an energy supplying system, comprising: receiving an energy demand request associated with an energy consuming device in need of energy at an electronic controller; receiving energy supply data including energy cost rate data from an energy provider at the controller which provides for differing cost rates at different times throughout the day; the electronic controller deciding whether the energy supply is to be utilized by the energy consuming device making an energy demand request immediately or at a delayed time based on the energy demand request and the energy supply data; and the electronic controller connecting the energy supply to the energy consuming devices at the decided time to minimize the cost of the supplied energy.

2. The energy managing method of claim 1, where the plurality of energy consuming devices are located within a single residence.

3. The energy managing method of claim 1, where the plurality of energy consuming

devices are located within a plurality of residences.

4. The energy managing method of claim 3, and further comprising: providing a plurality of home energy controllers and an energy demand controller, each house includes a home energy controller in communication with a plurality of energy consuming devices, and the energy demand controller is located remote from a plurality of houses and is in communication with each of the plurality of home energy controllers.

5. The energy managing method of claim 1 wherein at least one of said energy consuming devices is selected from a group consisting of a cooking appliance, a dishwashing appliance, a fabric care appliance, a food preservation appliance, a water management appliance, an electrical panel, and an air control appliance.

6. The energy managing method of claim 1 further comprising: receiving community energy data from an energy supplier, and controlling the energy supply to selectively provide energy to fewer than all of the energy consuming devices to reduce a level of energy demand on an energy supply source in response to said community energy data.

7. The method according to claim 1 further comprising: controlling the energy supply to the energy consuming devices to reduce the peak energy load.

8. The method according to claim 7 wherein the control of energy to the energy consuming device is staggered to reduce the peak energy load.

9. The method according to claim 1 further comprising: controlling the energy supplied by controlling the level of energy supplied.

10. The method according to claim 9 wherein the level of energy supplied is one of supplying normal energy levels, supplying reduced energy levels, and supplying no energy.

11. The energy managing method of claim 1 further comprising: receiving device specific data from at least one of said energy consuming devices, and controlling the energy supply to selectively provide energy to fewer than all of the energy requesting devices to reduce a level of energy demand on an energy supply source in response to said device specific data.

12. The energy managing method of claim 1 further comprising: receiving device user data from a source of the user data, and controlling the energy supply to selectively provide energy to fewer than all of the energy requesting devices to reduce a level of energy demand on an energy supply source in response to the user data.

13. An energy management system for managing a plurality of energy consuming devices connected on a power distribution system of an energy supplying system, comprising: a logical communication device associated with at least one of the energy consuming devices to generate an energy demand request; and a controller in logical communication with the energy supplying system to receive energy supply data including energy cost rate data which provides for differing cost rates at different times throughout the day from the energy supplying system, in logical communication with the logical communication device to receive the energy demand request, and configured to control the supply of energy to the at least one of the energy consuming devices between a current time and a future time by making an energy supply decision based on the energy supply data including energy cost rate data and the energy demand request to minimize the cost of the supplied energy.

14. The energy management system of claim 13 wherein said controller further comprises input means for user input of at least one type of user data selected from a group consisting of household status data, personal preference data, and specific data relating to a curtailable device, said energy management system further comprising: said controller being adapted to process said energy supply data, and said user data to selectively generate a logical command to curtail power to said curtailable device.

15. The energy management system of claim 14 wherein said logical communication device is adapted to provide device data selected from a group consisting of device type data, current device operational status data, device specific curtailment preference data, request for power data, and alternative cycle data, said energy management system further comprising: said controller being adapted to process said energy supply data, said user input data and said device data to selectively generate a logical command to curtail power to said curtailable device.

16. The energy management system of claim 13 wherein said logical communication device further is adapted to provide device data selected from a group consisting of

device type data, current device operational status data, device specific curtailment preference data, request for power data, and alternative cycle data, said energy management system further comprising: a curtailable device being one of the energy consuming devices; and said controller being adapted to process said energy supply data, and said device data to selectively generate a logical command to curtail power to said curtailable device.

17. The energy management system of claim 16 wherein: said device data further comprises said alternative cycle data, and said controller selectively generates a logical command comprising a curtailment command or an alternate cycle command.

18. The energy management system of claim 13 wherein at least two of said energy consuming devices are curtailable devices.

19. The energy management system of claim 13 wherein the at least one energy consuming device is selected from a group consisting of a cooking appliance, a dishwashing appliance, a fabric care appliance, a food preservation appliance, a water management appliance, an electrical panel, and an air control appliance.

20. The energy management system of claim 13 wherein said controller is further adapted to collect energy use data from said power distribution system.

21. The energy management system of claim 13 wherein the plurality of energy consuming devices comprise a logical communication device that generates an energy demand request and the controller is configured to control the supply of energy to the plurality of energy consuming devices based on the energy demand requests and the energy supply data.

22. The energy management system of claim 13 wherein the controller is configured to control the supply of energy to the plurality of energy consuming devices to reduce the peak energy required.

23. The energy management system of claim 22 wherein the controller is configured to stagger the supply of energy to the plurality of energy consuming devices to reduce the peak energy required.

24. The energy management system of claim 13 wherein the controller controls the

energy supplied to the at least one of the energy consuming devices by controlling the level of energy supplied.

25. The energy management system of claim 24 wherein the level of energy supplied is one of a normal energy supply level, a reduced energy supply level, and no energy supplied level.

26. The energy management system of claim 13 wherein the energy supply data comprises at least one of a current energy rate data, scheduled energy rate data, curtailment request data, emergency curtailment demand data, invitation to consume energy, consumption delay request data, request for projected energy usage.

Description

BACKGROUND OF THE INVENTION

The present invention relates generally to managing energy consumption of home energy consuming devices through an energy demand controller.

Just about all homes employ energy consuming appliances and other devices. Although each appliance in a home usually is operated independently from one another, each draws energy from the home energy distribution system. In turn, each home draws energy from the energy distribution system of an energy provider. During certain times of the day, such as morning or early evening, the draw on the energy provider energy distribution system is so great that the energy provider either brings on line additional power plants or buys additional power from other suppliers. This peak energy demand creates additional costs for the energy provider. The energy provider passes these additional costs onto each consumer.

The increased cost has several causes. The energy supplier must build, manage, supply and maintain facilities capable of producing and handling the maximum amount of power required during peak times. This includes additional production facilities that are idle during non-peak times and therefore decrease both the dollar and energy efficiency of the overall system. Furthermore, since some of these facilities need rapid startup to avoid brown out conditions, they may be of a type that is less efficient than other facilities even while operating at peak capacity. Additionally, all components of the energy delivery system, including wires and transformers must be capable of handling the peak load and therefore are more expensive and less efficient than they would be if the peak load were closer to the average load they experience.

Energy providers, appliance manufacturers, consumers, and the government each desire to reduce peak power demands and save energy and cost. For example, some energy providers provide cost savings incentives for consumers who volunteer not to run their appliances during peak energy demand. Most appliance manufacturers work towards producing more efficient appliances. Consumers may elect not to run their dishwasher, clothes washer, or clothes dryer in the morning or early evening. The government enacts laws to regulate the behavior of energy providers, appliance manufacturers, and consumers.

Conventionally, the decision on how to save energy has largely remained in the hands of energy providers, appliance manufacturers, and the government. A main reason for this is that consumers lack detailed control over the management of their collective home energy use. A secondary reason for this is that energy providers and others have no way of receiving control from the homes of individual customers over the energy demand from the homes of individual customers.

The traditional response to this problem, building more production capacity, operating less efficient peak plants at time of peak demand, and building an energy distribution infrastructure capable of handling the increasing peak demand is costly, not only in terms of pollution and consumption of non-renewable resources, but also in terms of allocation of monetary resources and land. Time of use pricing and setback programs are only as effective as the ability of consumers of energy to respond and brown outs and mandatory curtailments during peak times can be draconian and economically devastating on businesses affected.

However, it has been demonstrated that when consumers are provided with information and incentives to reduce energy consumption, some will modify their appliance purchasing behavior as well as their energy usage behavior. Energy pricing and curtailment programs encourage voluntary demand side management, but the consumer needs more tools to take advantage of such programs.

What is needed is an energy management system that encourages and facilitates energy and cost efficiency by providing a home owner with more information and control over energy savings.

SUMMARY OF THE INVENTION

Recent trends in appliances include more electronic sensing and control of appliance functionality as well as an increased capability to exchange data between an appliance and computers and other devices external of the appliance. As a result of the trend towards electronic control, many methods and devices are well known to remotely communicate with appliances to sense, monitor and control them. Many methods and devices are also known to provide devices, such as smart modules built into electrical sockets or disposed along the power distribution system to an appliance or other energy consuming device, to selectively supply or curtail power to that appliance or device. Such devices and methods may include means for detecting whether an appliance is operating and even for determining what type of appliance or device is drawing power and gathering diagnostic information from the appliance or device. This presents an unobvious opportunity to facilitate residential energy management.

In light of the above noted problems, the invention provides a system that distributes the primary decision making ability over energy savings to a home owner. When implemented, this system will reduce the level of energy demand on an energy supply source.

A specific aspect to the system is that there may be a plurality of inputs into a device that may make curtailment decisions to produce a variety of outputs to one or more energy consuming devices that are selected from at least two choices to control two curtailment levels. As part of the system, a controller may be placed in communication with energy consuming appliances. Request for energy may be received at the controller from the plurality of energy consuming appliances. Each request for energy may originate from an energy requesting appliance. The controller may be operated to provide energy to fewer than all of the energy requesting appliances to reduce a level of energy demand on an energy supply source.

Another aspect of this invention is that a controller in logical communication with an appliance may make an intelligent decision about control of the appliance after balancing a plurality of inputs selecting inputs selected from a group consisting of a power rate schedule, household status, personal preferences, curtailment requests from a power supplier, power requests and usage from other household appliances, power usage grants from a power supplier.

These and other objects, features, and advantages of the present invention will become apparent upon a reading of the detailed description and a review of the accompanying drawings. Specific embodiments of the present invention are described herein. The present invention is not intended to be limited to only these embodiments. Changes and modifications can be made to the described embodiments and yet fall within the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a regional energy distribution system;

FIG. 2A is a graph illustrating a typical electrical averaged home energy demand of a residential community over a twenty-four-hour operating period;

FIG. 2B is a graph illustrating an example of the total electrical demand on a power supplier;

FIG. 2C is a graph illustrating an example of the total electrical demand on a power supplier when several appliances in a single household are started simultaneously;

FIG. 2D is a graph illustrating the total electrical demand on a power supplier when the starting time of the same appliances in a single household are staggered;

FIG. 3 is a schematic diagram of a distributed intelligence energy management system according to the present invention at a community level;

FIG. 4 is a schematic diagram of a distributed intelligence energy management system according to the present invention at a single residence level;

FIG. 5 is a flow diagram of an example of the logical structure of an intelligent energy management system according to the present invention.

FIGS. 6A through 6E are screen shots of a display device illustrating an example of the optional historical data output of the preferred version of the controller of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a schematic diagram of an energy distribution system 100. Included within the energy distribution system 100 may be an energy provider 102, such as a utility company, and a community 104 of homes, such as home 106, home 108, home 110, home 112, home 114, and home 116. The energy provider 102 may provide a supply of energy and be responsible for the delivery of that energy to homes 106-116. Each home 106-116 may include various energy consuming devices that utilize energy to operate. Examples of energy consuming devices include household appliances such as washers, dryers, ovens, dishwashers, refrigerators, freezers, hot water heaters, heating and cooling appliances, humidity control appliances, as well as lights, thermostats, ventilation and cooling infrastructure, and other pumps, heaters.

To deliver energy to one or more homes, the energy distribution system 100 may further include a power grid 118, connected to home 106, home 114, and home 116, and a power grid 120, connected to home 108, home 110, and home 112. The acceptance by a home 106-116 of delivered energy may be thought of as the energy demand of that home. The collective of the energy demand for homes 106-116 within the community 104 may be thought of as the energy demand of the community 104.

When a home 106-116 accepts delivered energy, the consumer may incur a charge from the energy provider 102 for that energy at the going rate of the energy for the community 104. The cost for this energy typically depends upon the time of day. FIG. 2A is a graph illustrating a typical off-peak and on-peak electrical averaged home energy demand of the community 104 over a twenty-four-hour operating period. The graph illustrates an example of a time-varying cost for the energy and a public demand by the community 104 for the energy.

From midnight to about six in the morning, the demands for energy by average home in the community 104 may be low, such that off-peak energy rates (or off-peak energy period) 202 may apply. From about six in the morning to about eleven in the morning, demands for energy by that home may be high, such that on-peak energy rates (or on-peak energy period) 204 may apply. The average home energy demand may drop in the afternoon to below about 5.0 kilowatts (kW) per hour and pick up around five in the afternoon. From around five in the afternoon to around nine in the evening, the home demands for energy again may be high. These high demands may increase the cost of energy to on-peak energy rates 204. The demands for electrical energy by the average of homes in the community 104 may be so great that special on-peak energy rates 206 may apply. For example, energy used during off-peak may cost the consumer in United States dollars around 2 to 3 per kilowatt-hour (kWh), while on-peak energy may cost anywhere from 6 per kWh to 50 or more per kWh.

FIG. 2b illustrates another example of total energy demand on a power supplier which includes residential and commercial power consumption. In this example, the power demand 210 increases throughout the day to a peak in the evening, then drops rapidly until the next morning. The demand is met by having a supply system based on base power 212, intermediate power 214 and peak power 216. Peak power is more expensive to provide than intermediate power, and intermediate power is more expensive than base power. As shown in FIG. 2b, the peak demand drive inefficiencies including the need to generate more expensive peak power and the need to have a power delivery system capable of handling the peak power. Therefore, it is desirable to empower the consumer to shift demand from peak time to non-peak time.

FIG. 2C illustrates the instantaneous power demand 220 that occurs when all major appliances in a home are started simultaneously, as compared with FIG. 2D, which illustrates the instantaneous power demand 230 which occurs when the starting times are staggered. For this reason, to merely shift the start of appliances to the time when demand is expected to drop as indicated in FIGS. 2A and 2B or when the rates drop as provided in a time of use rate system could result in a new peak demand, at least within the residence 106 or the community 104 that adopts such an approach. Instead, it is beneficial to provide controlled start or curtailment of devices so as to stagger the operation and produce the lower maximum demand 230. This not only affects the efficiency of the energy supply for the community 104 but the maximum energy level for which the wiring and other systems in the home are designed.

The energy provider 102 may be in the best position to know the available supply of energy. Based on this, the energy provider 102 conventionally has served as the primary decision maker in decisions such as energy consumption curtailment, load balancing, and peak limitations. Energy management systems where the energy saving decisions are primarily in the hands of the energy provider 102 may be thought of as a centralized intelligence energy management system. Under a centralized intelligence system, each home within a community may be charged an energy tariff according to the average energy use of the homes within that community. Under such a system, individual homes that do not exceed the off-peak energy demand of, for example, 5 kW per hour, during on-peak periods may still be charged at on-peak rates. Thus, there is little incentive for a home under such a system to manage their energy demand to remain below 5 kW per hour, for example.

Individual consumers may be in the best position to know which energy consuming devices the consumer needs or can do without. Surveys have shown that energy providers would find it very desirable to distribute the decision to save energy to consumers. Part of the reason for this is that the energy providers provide incentives to consumer to manage their energy demand to remain below the 5 kW per hour in the example of FIG. 2A.

FIG. 3 is a schematic diagram of a distributed intelligence energy management system 300. Included within the distributed intelligence energy management system 300 may be one or more home energy controllers 302 and one or more energy demand controllers 304. Also included within the distributed intelligence energy management system 300 may be an interface 306.

Each home energy controller 302 and each energy demand controller 304 may be programmed with instructions that decide whether to accept or reject energy delivered by the utility company 102. The instructions also may allocate that accepted energy to various energy consuming devices within the home. For example, the consumer may select an energy consuming device from all the energy consuming devices in the home to modify the energy usage of the selected device with an overall goal to reduce energy.

The interface 306 may be any network or interconnected system of networks. The interface 306 may pass communications between the energy provider 102, each home energy controller 302, and each energy demand controller 304. An example of the interface 106 may be the Internet.

In the distributed intelligence energy management system 300, primary control over energy consumption curtailment, load balancing, and peak limitations may be distributed from the energy provider 102 to an individual consumer through the home energy controller 302. As shown in FIG. 3, the consumers of homes 106 and 108 each maintain a home energy controller 302 to manage their energy consuming devices. A group of consumers may come together as a consumer cooperative so that energy management decisions may be performed by the consumer cooperative.

As shown in FIG. 3, the consumers of home 108, home 112, and home 116 manage their energy consuming devices through the energy demand controller 304. Home 110 and home 114 are shown not participating in the distributed intelligence energy management system 300 and thus may be subject to the energy tariff schedule of a centralized intelligence energy management system. Moreover, the consumer of home 108 may experience the greatest cost savings by maintaining the consumer's home energy controller 302 in communications with the energy demand controller 304.

In the single residence intelligence energy management system 400, which may function with or without a coordinated community level energy management system, energy primary control over energy consumption curtailment, load balancing, and peak limitations may be distributed from the energy provider 102 to an individual consumer through the home energy controller 410, as shown in FIG. 4 The energy controller 410 controls a plurality of energy consuming devices within the residence including appliances and fixtures. For example, the energy controller 410 can control the environmental conditioning fixtures and appliances in the home such as the HVAC and thermostat 412. It may control water quality devices such as the water heater 414, or a water softener (not shown) or water purifier (not shown). Similarly, the energy controller 410 can control food preservation appliances, food preparation appliances and cleanup appliances such as a dishwasher 418, a microwave oven 420, a combination oven and range 422, a refrigerator 424, an automatic clothes washer 246 and a clothes dryer 428.

The energy controller 410 may communicate as shown at data exchange channel 430 directly with the utility company directly or may communicate with an intermediate service provider, or with a community controller or manager. As will be described herein in further detail, among the information exchanged with the utility company or intermediate service provider may include projected consumption data, rate data, curtailment data, brownout warnings, and emergency condition information.

The energy controller 410 may exchange with the controlled devices 412 through 428, as shown at exemplary data exchange channel 440, different types of information depending on the capability of the controller and the device. It is contemplated that the data may include control data, requests for power, grant of power, order of curtailment, status inquiry, status cycle data, device type data, and other demand management data.

It is contemplated that some devices controlled by the energy controller 410, such as lights, may not be inherently intelligent devices. However, such devices may still be controlled by the energy controller 410 by having an intelligent device associated with such device supplying power to such device, such as an intelligent electrical panel 414.

In the preferred embodiment, the energy controller 410 further exchanges data along a data channel 450 with a user interface 480, which may be integrated with the controller, separate and disposed locally with the controller or disposed remotely from the controller. The user interface 480 may be used for the direct entry of configuration data, such as types of devices, user preferences, rate schedules, household status (such as vacation mode) and for providing the user with current and/or historical energy usage data.

FIGS. 6A through 6E provide examples of graphical information and user inputs that may be displayed by the user interface 480.

The energy supplier 102 or some other business may participate directly as a primary decision maker in the distributed intelligence energy management system 300 or 400. For example, the energy supplier 102 may operate the energy demand controller 304 or 410. The energy supplier 102 may also participate indirectly. For example, the energy supplier 102 may supply information such as time-of-day pricing structures to each home energy controller 302 and each energy demand controller 304.

Basing the energy rate or tariff for an individual home 106-116 on the average actions of the community, the consumer may incur a charge from the energy provider 102 for that energy at the going rate of the energy for the community 104.

The system permits the user to manage the energy demand to instantaneous peak caused by activating significant energy consuming devices surge. For example, the system permits a consumer to manage usage from 8 KW down to 5 KW so as to remain within an off-peak energy demand rate. The system also accounts for an instantaneous energy draw or surge of power demand that may move the consumer's immediate energy usage from the non-peak rates to the on-peak rates. This may occur, for example, where a consumer starts a clothes washer when both the clothes dryer and dishwasher are operating. The effect may be an instantaneous peak caused by activating significant energy consuming devices surge.

The system may account for staged restrictions. The restrictions may be applied differently depending on, for example, the appliances involved and the consumer's preference. Thermal energy storage systems may be incorporated into the system. The system may simultaneously use energy supplier rate data and consumer preferences to control attached energy consuming devices.

The system may account for the use of tokens. A token is different from a restriction since a token may be viewed as permission to take a power surge where a restriction is the prevention of taking a power surge. A token may give a consumer permission to contribute to the on-peak period at off-peak rates.

As an output of the system, the energy management system may be used with a backup generator to manage surges and manage appliance usage. For example, the consumer may prioritize the sources of energy for the home or for particular energy consuming devices. Sources of energy for the home may include a remote power supplier, a home generator, home solar panels, and the like. The consumer may, under some circumstances, engage the generator and disengage drawing from the remote energy provider.

The system may respond to shutoff signals, pause signals, and restriction signals. The system may make smart selection and interpretation between shutoff and pause signals. A shut off command may turn the energy consuming device off. A pause command may cause the system to literally pause, even if there is water in the system being run. The system may then recognize that the system cannot pause over a certain time frame given the water in the system condition. The system may cycle to shutoff if the pause is greater than a predetermined period.

For example, if an icemaker is filling up and the system receives a shutoff signal half way through the icemaker fill cycle, the system is configured to recognize the action being taken by the icemaker as one that needs little energy and will last a short time. Recognizing this, the system will delay the shutoff cycle until the icemaker fills. As another example, the system may recognize that a clothes washer may be operating in a drain cycle, the system may delay any shutoff until the water in the clothes washer is drained.

A specific aspect to the system is that there may be a plurality of inputs into a device that may make curtailment decisions to produce a variety of outputs to one or more energy consuming devices that are selected from at least two choices to control two curtailment levels. One curtailment level may be a shut off, another curtailment level may be a pause, a third curtailment level may be a reduced power, such as to 70% normal operating power.

The system may be configured to make smart interpretations for a plurality of descriptions that may be received from a power company in view of other factors, such as specific curtailment instructions, signals that might vary depending on the type of device to which it is sending that signal. Moreover, the energy consuming device attached to the system may or may not respond in a smart way to that signal.

As noted above, a token may be permission to surge and momentarily use a lot of energy where a coupon may be permission to use a lot of energy over a period of time. A restriction may reward with a rebate for those consumers responding to the restriction. Moreover, there may be penalties for not complying with a restriction.

The system may curtail the smarter devices, and self manage the controlled devices.

A power plant may respond intelligently to data collected from each controller on the system. The house may confirm the power company's projection of power consumption and in the present form contingent projections based on the current power consumption levels such as through an instantaneous negotiation between the power company and a home or the collective of homes.

The system encompasses an entire bartering structure such as used on websites like eBay.com where a consumer's home offers to buy energy for a given price.

Energy management inputs to the system may include, restriction data, rate date, consumer preferences, device status, time (clock), geographic basis (neighborhood), consumer account status, local conditions such as the weather, coupons, tokens, modes, rewards, advisories, and restrictions. Energy modes may include indications that the consumer is at home, away at work or on vacation, that there is a break in (refrigerator door opened while in away mode), opt-out, and/or ***Sabbath*** mode.

Signals from one home device may activate or contribute to the control over another energy consuming device.

Pricing information may be set by the energy provider 102 utilizing a variety of factors. For example, the energy provider 102 may use time of day, season, such as summer, fall, or winter, brownouts.

In operation, the system may shift approximately 212 KWh per month for each home from on-peak periods to off-peak periods. For example, a dishwasher typically runs five loads a week for a total energy usage of about 120 KWh energy per month. A clothes washer typically consumes about 70.0 kWh of energy per month. With the approximately 130.0 kWh of energy per month utilized by an electric clothes dryer, a home typically utilizes 320 kWh of energy per month through a dishwasher, a clothes washer, and a clothes dryer. Typically, the timing of the operation of a dishwasher, a clothes washer, or a clothes dryer is not critical. Thus, the system provides setting inputs that operate the time of use for a dishwasher, a clothes washer, or a clothes dryer. By setting the time of use for these appliances to an off-peak period, the consumer may shift 320 kWh of energy per month from the on-peak period to the off-peak period.

The system works to provide automatic management of energy consuming devices to both reduce energy peak demand (consumption) and reduce energy cost for the energy consumer. By combining rate data, demand management input from the power utility and consumer, a system having a controller connected to energy consuming devices may manage energy demand in a way that saves money for the consumer as well as controlling energy demand in accordance with power utility needs. For example, the energy controller may schedule devices for savings in utility rate plans and control peaks by managing concurrency and enabling energy restrictions and emergencies with minimal impact to the consumer.

The system may include a mechanism to receive energy data directly from a utility company or other off-site data center to automate synchronization with utility rates, plans, and incentives. In one embodiment, the consumer may view current and past energy consumption patterns on a display device and observe savings and potential savings in their consumption of energy. The energy controller may be configured to manage energy consuming devices automatically with little or no impact to the consumer lifestyle. Further savings are enabled whereby the consumer may optionally enroll in rate reductions through special energy management programs offered by their local utility company. These may include curtailment options and rate incentives for peak management automation.

Anyone, such as a consumer, employing the system may control energy consumption to allow the consumer to operate equipment at a time of day that is most favorable for cost structures and energy demand management. Through the system, the consumer may limit, control, and manage peak energy demands. The consumer may achieve this by orchestrating the power consumption and concurrency of operation for the energy consuming equipment under the control of the energy management controller module. The consumer may schedule or reschedule energy consuming devices to manage energy costs and consumption. Through the system, the consumer may include the ability to set energy management control parameters (both wired and wirelessly) from remote locations.

The system may include a security interface that may be designed for access by an energy provider or other involved party. The security interface may permit the third party to interface with one of the controllers in the system. The system may include software that permits a user to download energy pricing structure and other information into a controller. The controller may be configured to utilize the information to manage the facility's power consumption.

A third party, such as an energy provider, may access the system to curtail energy demand during high use or emergency situations without regard for those specific energy consuming devices that will be affected. The controllers may be configured to limit, reschedule, or stop energy consuming devices based on real-time information updated from either the consumer or the energy provider.

The system may further include an interface that permits communication with both intelligent and non-intelligent energy consuming devices. This may allow a consumer to coordinate energy consumption management features built into the individual control systems of consumer appliances, HVAC equipment, water heaters, and any other powered device.

The system further may be configured to permit a consumer to establish energy restrictions and device priorities to suit the individual needs and preferences of the consumer.

FIG. 5 illustrates an example of the operation of the residential controller 302 according to the preferred embodiment of the present invention.

Various inputs are provided to the controller from time to time from the power company at 502 or from an intermediate service provider at 504, as described in greater detail above herein, informing the controller about the availability and cost of power, as well as emergency and special conditions. Similarly, inputs are provided to the controller 302 from time to time at 506 from the user, smart appliances and others, as described in greater detail above herein, including user preferences, device types, household status or mode.

The controller 302 monitors the status of energy demands in the residence. Where there is a controller 304 at the community level, the controller 302 optionally also monitors community energy demands.

When a user managed energy consuming device requests power at 510, the controller schedules operation of the device at 512 to a control algorithm and, when scheduled, initiates a request for operation of the device at 514. Alternatively, a request for immediate power may originate at 508 directly from an automatic device, such as a HVAC fan or a lighting timer, or from a user operated device, such as a light switch.

The request for power from a managed device at 514 or from an unmanaged device at 508 is received by the controller at 520. The controller decides at 522 if power is available, as defined by user preferences received at 506 and based on data from the energy supplier or intermediate vendor received at 504. If power is deemed not available, the controller checks at 524 to determine if the consumer enabled energy management for the device, in which case the controller runs at 526 the appropriate scheduler to reschedule operation of the device. If the power is deemed not available at 522 and energy management is found at 526 to not be enabled, then the controller will not provide power to the device as shown at 527.

Unmanaged devices are started at 540 if energy is deemed available.

Even if energy is deemed available at 522, however, the energy controller 302 preferably determines at 528, based on demand side data such as user inputs and supply side data such as energy supplier data, whether cost can and should be reduced by rescheduling operation. Managed devices are redirected at 530 to invoke the demand scheduling algorithm at 526.

Refer now to FIGS. 6A through 6C illustrating various graphical displays for a user interface for a total home energy management system.

FIG. 6A graphically displays exemplary bar graph showing, for example, by device, how much power was consumed by various household appliances controlled by the energy controller 302. For example, stacked bars 602 and 604 could illustrate how much energy was consumed by the oven at peak rate and at a lower rate respectively over some designated time period. Similarly, stacked bars 606 through 616 could illustrate power consumed at two or more rates for the refrigerator, dishwasher and microwave oven. Hypertext buttons 618a, 618b, and 618c, permit navigation to different power consuming devices and different time periods.

FIG. 6B illustrates an exemplary input screen for user managed control of a energy consuming device, such as a dishwasher in the example illustrated. The screen provides for the selection of managed control at 622 or alternatively the input of a proposed start time at 624 as well as selection of a cycle at 626 and subcycle parameters at 628, 630 and 632. The screen also has hypertext buttons 640 and 642 to start and cancel operation as well as a display of operational status of the device at 644.

FIG. 6C illustrates a timer 650 in window format for direct input of a delay time for operation of a managed device.

FIG. 6D illustrates, in window format, a pie chart 652 comparing the cost of operation of various selected appliances that are managed by the controller 302.

FIG. 6E provides a graph 654 illustrating time of use billing to facilitate desired consumer to shift energy consumption to non-peak and therefore lower cost times.

The energy management system of the present invention therefore allows consumers to take advantage of rate based incentive programs and to cooperate with emergency curtailment and setback programs. It further allows such incentives to be more flexibly offered and timed, or even automated, since their acceptance can be automated in the residential controller, thereby making the entire energy supply and distribution system more responsive to changing conditions to control peaks and reduce the need for adverse curtailments.

With an energy controller according to the present invention, the consumer can seamlessly enfold energy management into their lifestyle, schedule appliance usage with energy managed automation, view current and past energy consumption history, participate in special rate plans with their power utility with minimal inconvenience, participate in energy management as desired, and override at will. The energy controller will manage home energy consumption considering data from energy provider device and family schedules, personal energy preferences including Time of Use (TOU), price incentives, restrictions in effect, max and peak limitation incentives, emergency restrictions, and other incentives.

The system permits a consumer to select the consumer participation level in those energy demand management incentives provided by an energy provider. Under certain circumstances, a consumer may dynamically opt out of energy curtailment for either individual appliances or equipment and for part or all of the entire curtailment period. The system is configured to permit a consumer to participate in community energy rate incentive programs to optimize energy and financial benefits. The system could be flexible enough to permit a consumer to manage the consumer's concurrency of energy demand to maintain the total instantaneous energy demand below target levels. Through the system, the consumer may target a maximum level of instantaneous energy demand established by the energy provider. The system also is flexible enough to automatically receive and process updates sent from an energy provider to a controller of the system. An overall effect is that the system works to maximize benefits of an energy price structure where cost of energy is determined by the time of day when the energy is consumed.

The present invention has been described utilizing particular embodiments. As will be evident to those skilled in the art, changes and modifications may be made to the disclosed embodiments and yet fall within the scope of the present invention. The disclosed embodiments are provided only to illustrate aspects of the present invention and not in any way to limit the scope and coverage of the invention. The scope of the invention is therefore to be limited only by the appended claims.

Appendix Sabbath mode

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