



US007058524B2

(12) **United States Patent**
Hayes et al.

(10) **Patent No.:** **US 7,058,524 B2**
(45) **Date of Patent:** **Jun. 6, 2006**

(54) **ELECTRICAL POWER METERING SYSTEM**

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

(21) Appl. No.: **10/280,533**

(22) Filed: **Oct. 25, 2002**

(65) **Prior Publication Data**

US 2004/0083066 A1 Apr. 29, 2004

(51) **Int. Cl.**
G06F 19/00 (2006.01)

(52) **U.S. Cl.** **702/62; 702/57; 702/189;**
340/870.01; 709/217; 375/220; 375/222;
379/90.01; 379/106.03; 700/1; 700/73; 700/90

(58) **Field of Classification Search** **702/57,**
702/60-62, 189, 190; 340/870.01; 709/100,
709/102; 375/220, 222; 379/90.01, 106;
700/1, 73, 90

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,481,259 A	1/1996	Bane	340/870.03
5,493,287 A	2/1996	Bane	340/825.52
5,631,636 A	5/1997	Bane	340/825.69
5,699,276 A *	12/1997	Roos	379/106.03
5,726,646 A	3/1998	Bane	340/870.03
5,748,104 A	5/1998	Argyroudis et al.	340/870.11
5,930,773 A	7/1999	Crooks et al.	705/30
6,035,285 A	3/2000	Schlect et al.	705/30
6,088,688 A	7/2000	Crooks et al.	705/412
6,122,603 A	9/2000	Budike, Jr.	702/182
6,128,290 A *	10/2000	Carvey	370/347

6,133,850 A	10/2000	Moore	340/870.02
6,150,955 A	11/2000	Tracy et al.	340/870.02
6,195,018 B1	2/2001	Ragle et al.	340/870.01
6,246,677 B1	6/2001	Nap et al.	370/346
6,300,881 B1	10/2001	Yee et al.	340/870.02
6,311,105 B1	10/2001	Budike, Jr.	700/291
6,366,622 B1 *	4/2002	Brown et al.	375/322
2001/0010490 A1	8/2001	Bellin	340/7.46

(Continued)

OTHER PUBLICATIONS

Thumaty et al., 'Development of Low-IF Receiver and a Fixed Wireless Utility Network', Mar. 2002, IEEE, pp. 935-938 □□.*

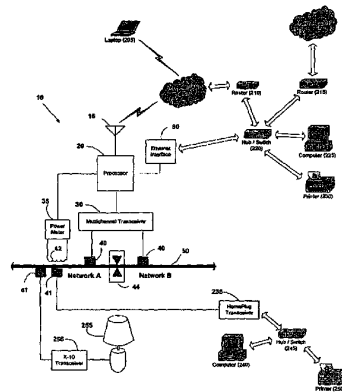
(Continued)

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(57) **ABSTRACT**

A wireless electrical power metering system is provided. A processor having a multichannel power line transceiver, a wireless transceiver, and a power meter attached thereto measures power consumption information on a power line inductively coupled with the power meter. The processor converts the power consumption information into IP-based data, and transmits same over the wireless transceiver. The information can be wirelessly received by a remote monitoring station or transmitted across the Internet for storage, analysis, and billing. The processor generates appliance control signals and generates same across the multichannel power line transceiver to remotely control appliances in response to power consumption trends. The processor provides firewall capabilities, and relays information between a wired or wireless network and a power line network, thereby expanding the size of existing household networks. Further, the processor allows multiple dwellings to be networked using power lines, and households to be connected to the Internet via a power line network.

37 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

2002/0013858	A1	1/2002	Anderson	709/245
2002/0018545	A1	2/2002	Crichlow	379/106.03
2002/0024424	A1	2/2002	Burns et al.	340/310.01
2002/0038279	A1	3/2002	Samuelson et al.	705/37
2002/0045992	A1	4/2002	Shincovich	702/58
2002/0054619	A1	5/2002	Haas	375/133
2002/0169848	A1*	11/2002	Esterman	709/217
2003/0009401	A1*	1/2003	Ellis	705/35

OTHER PUBLICATIONS

Ando et al., 'Automatic Meter Reading System adopting automatic routing technology', Jan. 2002, IEEE, pp. 2305-2309.*

Anderson et al., 'Unique EHV Current Probe for Calibration and Monitoring', Jan. 2001, IEEE, pp. 379-384.*

Delsing et al., 'The IP-Meter, Design Concept and Example Implementation of an Internet Enabled Power Line Quality Meter', IEEE Article, May 2000, pp. 657-660.*

Circon 200-Series Products- Map diagram from Circon web site- <http://www.circon.com/products/product-map.htm> .(1 page).

Lappin, "Country Road Warrior," Wired, Issue 3.08, Aug., 1995 (1 page).

"What were the Key Project Milestones—How Has the Project Evolved Over Time?," printout from <http://www.glasgow-ky.com/epb/faq01.htm#Question7> (1 page).

* cited by examiner

FIG. 1

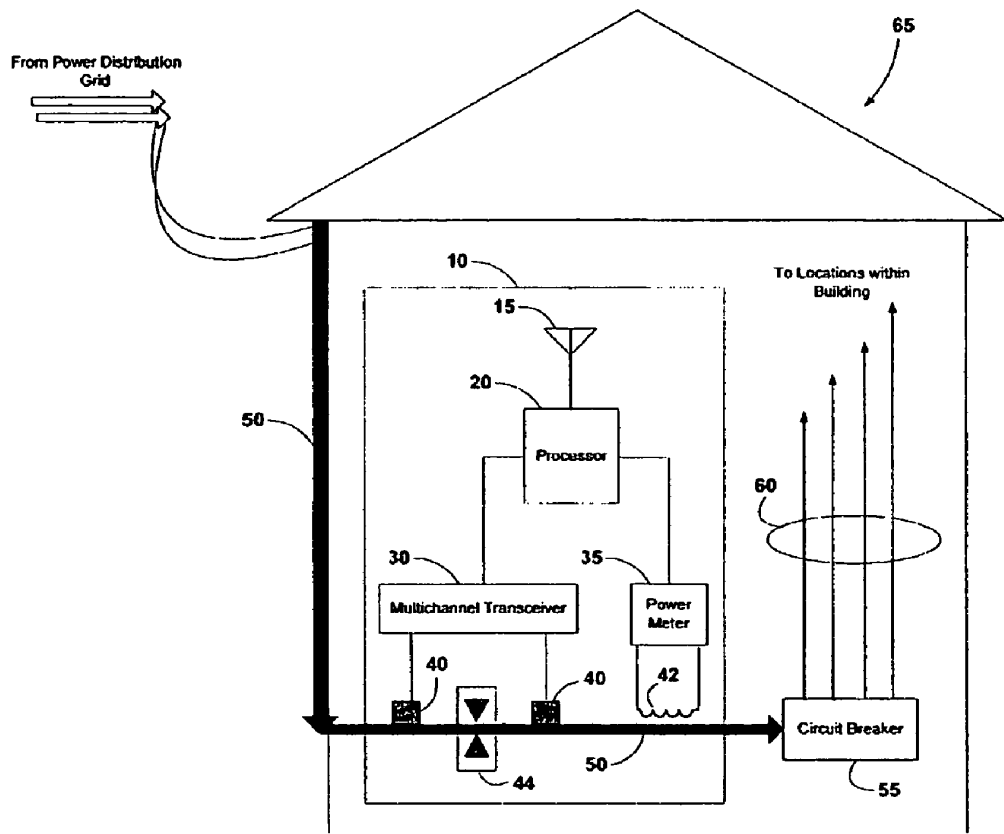


FIG. 2

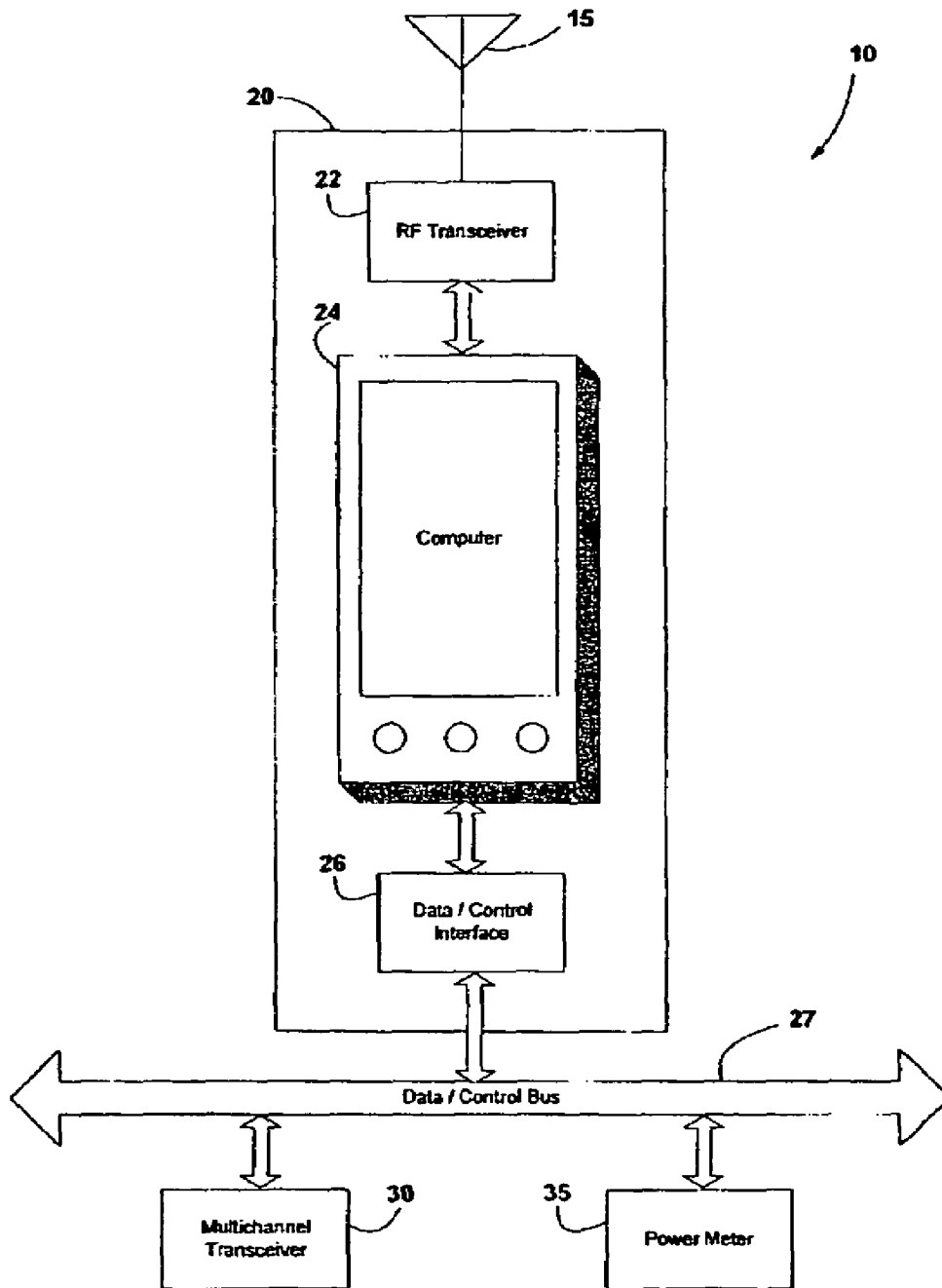


FIG. 3

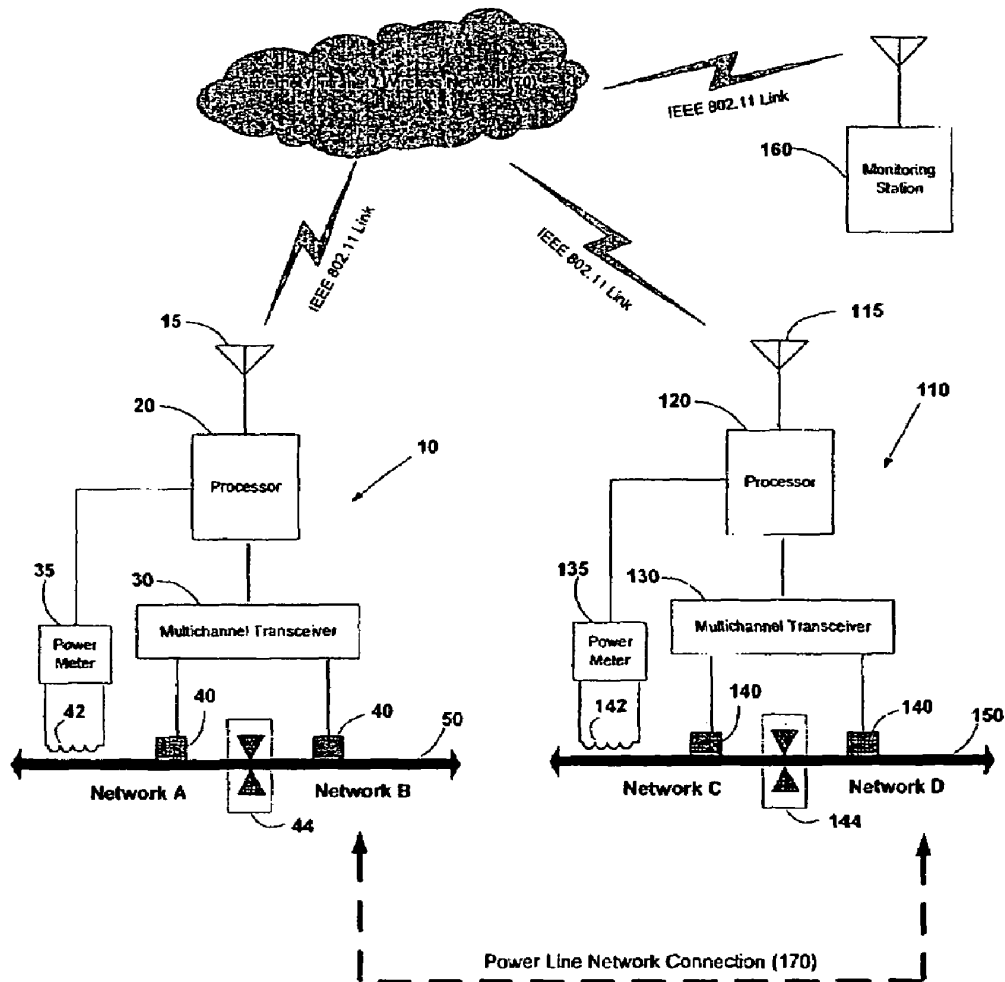


FIG. 4

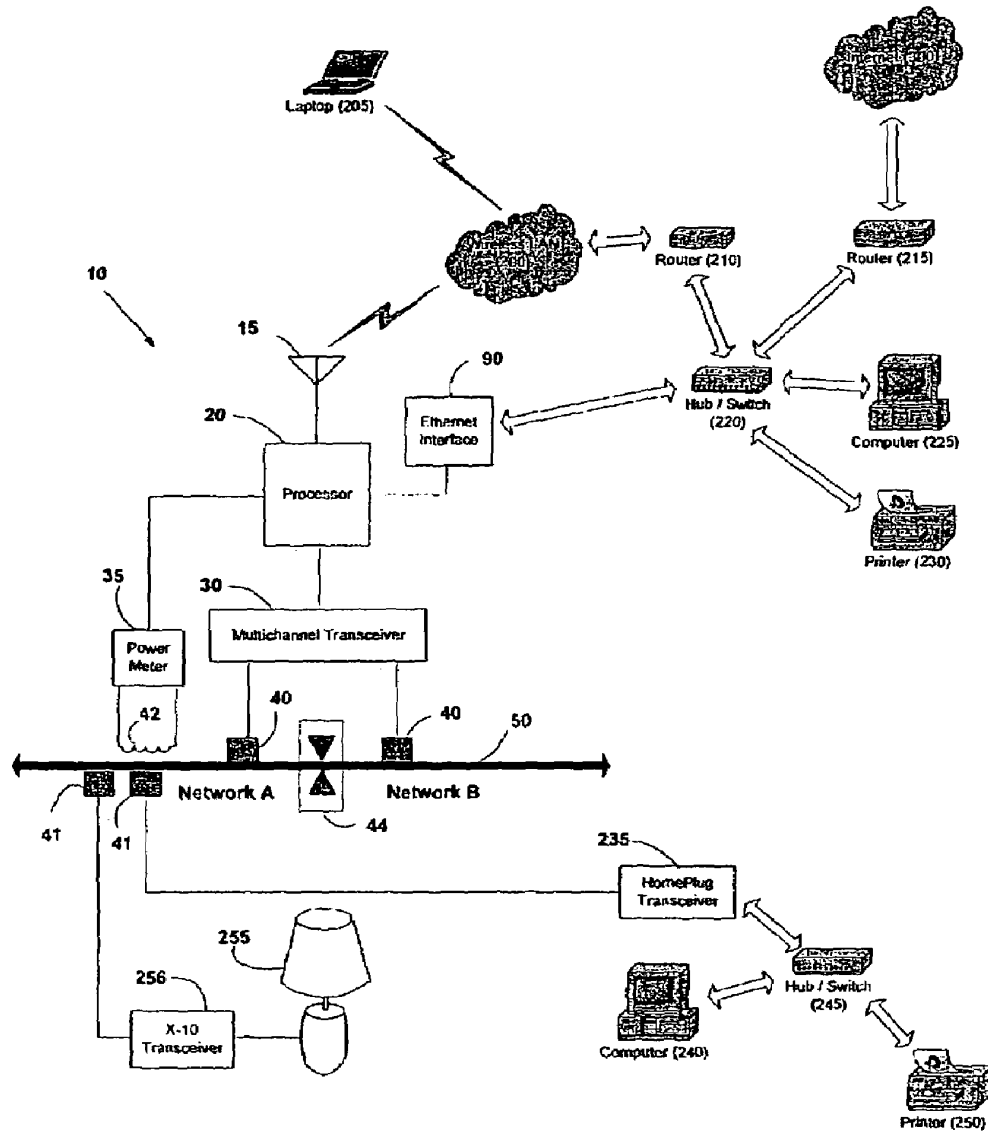


FIG. 5

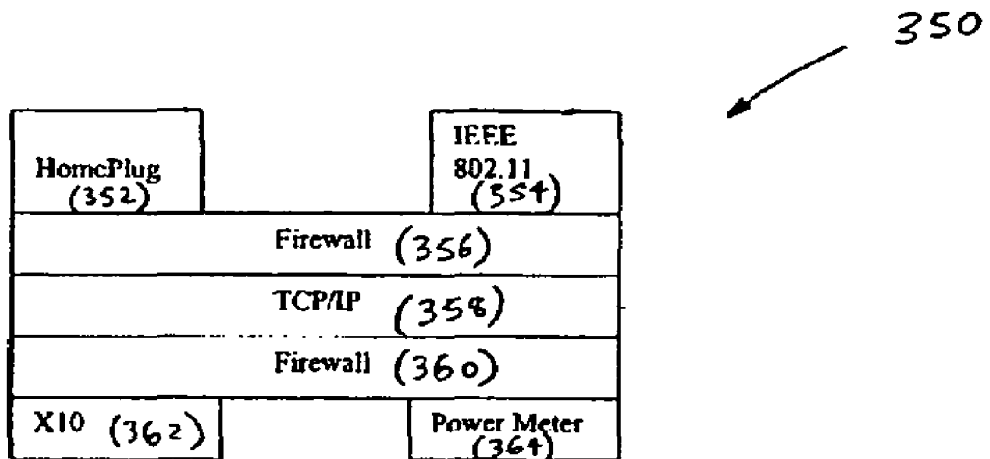


FIG. 6

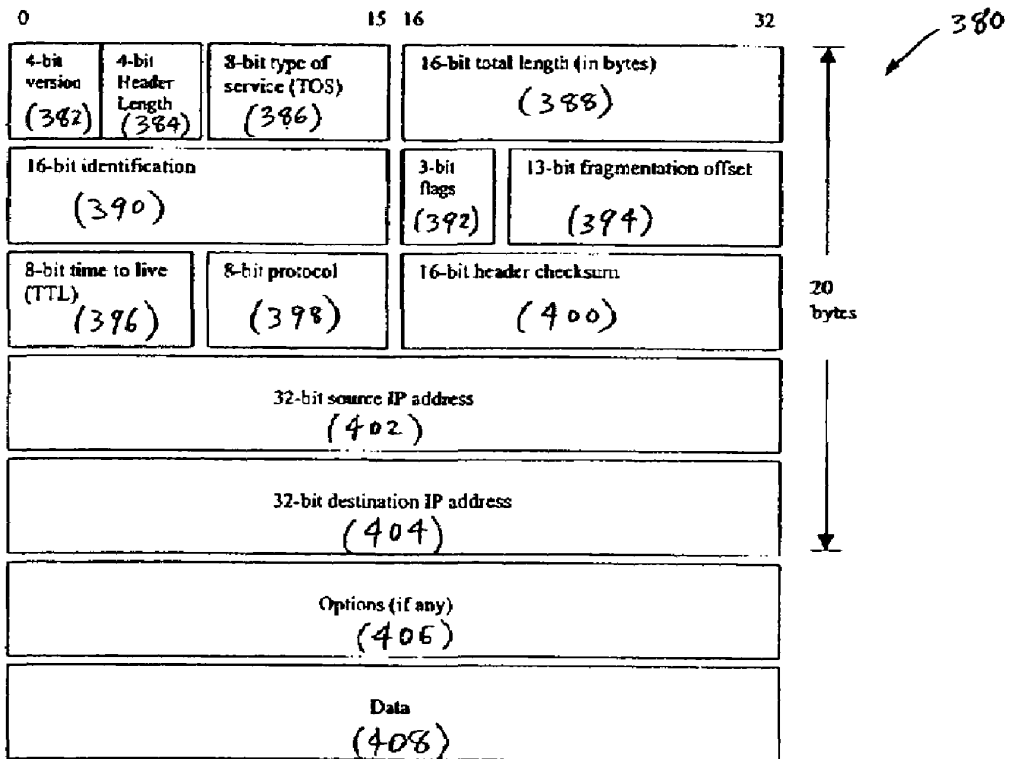


FIG. 7

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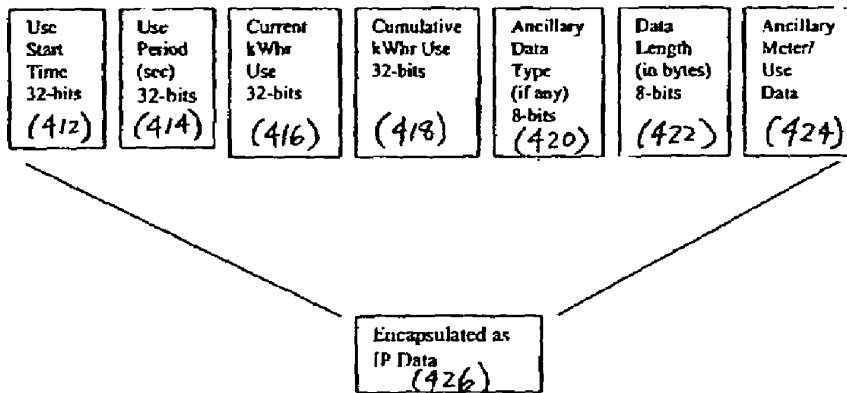
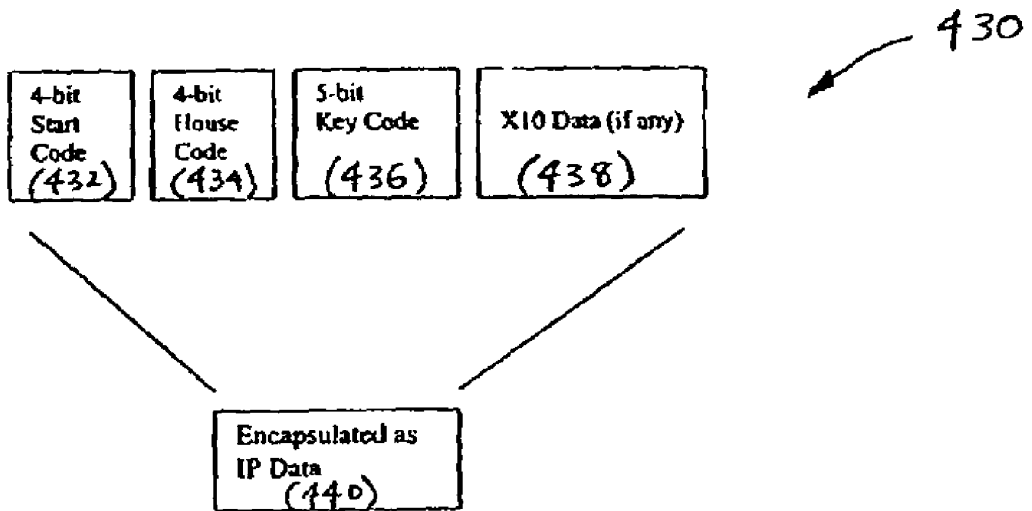


FIG. 8



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ELECTRICAL POWER METERING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to power consumption measurement, and more specifically, to an electrical power metering system for measuring electrical power consumption, converting the measurements to IP format, and delivering the information in one or more wired or wireless networks.

2. Related Art

In today's society, electrical power is being consumed at an increasing rate. As individuals continue to purchase electronic equipment, such as stereos, televisions, DVD players, personal computers, appliances, air conditioners, and other similar devices, the demand for electrical power increases. Further, increased electrical power consumption also results in an increase in the cost of electric utility bills.

Conventional power utility meters represent a type of energy consumption monitoring technology that is frequently used in residential and commercial settings. Such meters are predominantly analog (electromechanical), but digital models have also been developed. Frequently, a single power utility meter, whether analog or digital, services a multifamily dwelling and does not accurately reflect power consumption by individual families or occupants of the dwelling. Inaccuracies in billing can result, as many families split the total utility bill for the dwelling evenly and without regard to actual power consumption by each occupant. In addition to these shortcomings, current electrical power meters do not provide the ability to identify locations in the building where power is most frequently consumed and/or wasted.

Power metering systems using radio frequency ("RF") to remotely measure electrical power consumption have in the past been developed. Such systems, however, require the installation of numerous components at the dwelling. Further, these systems often require the presence of an RF back-haul station or base unit, and do not allow for the direct connection of the meter to the Internet via a wired or wireless network connection. Moreover, there has yet to be developed a wireless power metering system that allows for the transmission of power consumption data, in addition to standard network data, over one or more power lines within a dwelling.

Accordingly, what would be desirable, but has not yet been provided, is a wireless electrical power metering system that allows for the monitoring of electrical power consumption within a dwelling while providing both wired and wireless network connectivity.

SUMMARY OF THE INVENTION

The present invention relates to a wireless electrical power metering system. The invention comprises a computer or processor connected to a power line meter, a multichannel power line transceiver, and a wireless interface. The power line meter measures power consumption information, and the processor converts same for transmission as standard Internet Protocol (IP) traffic across a network. The processor can be connected to a household local area network (LAN), a wireless area network, a power line data network, or the Internet. Power consumption information can be measured and transmitted to a wireless monitoring station, one or more computers within the household, or directly to a utility company via the Internet. Appliances

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located in the dwelling can be selectively controlled by the processor to maximize energy savings.

The present invention also provides network connectivity between a power line network and an existing wired or wireless network within the dwelling. Information transmitted on the wired or wireless network is converted by the processor of the present invention for transmission across the power line. Multiple networks within the dwelling can be inter-networked, and firewall functionality can be provided by the processor. The present invention also includes a filtration device for controlling the flow of data across the power line.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other important objects and features of the invention will be apparent from the following Detailed Description of the Invention, taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic diagram showing the wireless power metering system of the present invention.

FIG. 2 is a block diagram showing the wireless power metering system of the present invention in greater detail.

FIG. 3 is a schematic diagram showing communication between two wireless power metering systems according to the present invention and a wireless monitoring station.

FIG. 4 is a schematic diagram showing the wireless power metering system of the present invention implemented in a household network.

FIG. 5 is a block diagram showing software components of the present invention.

FIG. 6 is a block diagram showing a standard Internet Protocol, Version 4 ("IPv4") packet utilized by the present invention.

FIG. 7 is a block diagram showing a sample IP packet according to the present invention for transmitting power consumption data.

FIG. 8 is a block diagram showing a sample IP packet according to the present invention for transmitting X-10 control data.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a wireless electrical power metering system. A computer, connected to a wireless transceiver, a multichannel power line transceiver, and a power meter that measures power consumption data from the power line, converts the measured data to IP format for transmission across a wired or wireless network. The present invention can also remotely control appliances in response to power consumption trends, and provides network connectivity and firewall capabilities between an existing network within a dwelling and a power line network. A wireless monitoring station allows power consumption data to be remotely monitored.

FIG. 1 is a schematic diagram showing the wireless power metering system of the present invention, indicated generally at **10** and installed in a dwelling **65**. A power line **50** connects the dwelling **65** to the local power distribution grid. The power line **50** can be any power line known in the art, such as a single phase, two-phase, or three-phase power line operating at any acceptable voltage (e.g., 120 or 240 volts). Power line **50** is connected to a conventional circuit breaker **55**, and electricity provided therefrom is distributed to various locations within the building via cables **60**. In a preferred embodiment of the present invention, the power

metering system **10** measures power consumption information on power line **50**, before the circuit breaker **55**. However, it is to be expressly understood that the power metering system **10** could be placed at any desired location along a power line within a single-family dwelling, multi-family dwelling, commercial business, or elsewhere, to measure power consumption data. For example, the power metering system **10** could be installed on one of the cables **60** to analyze power consumption trends on a given electrical branch stemming from circuit breaker **55**. Further, measurement of power consumption in multi-family dwellings can be achieved by positioning a plurality of power metering systems **10** of the present invention at various locations throughout the dwelling (e.g., by placing a single power metering system on each electrical branch that provides electricity for each family within the dwelling).

The power metering system **10** includes an antenna **15**, processor **20**, multichannel transceiver **30**, power meter **35**, one or more clamp contacts **40**, split-core transformer **42**, and clamp filter **44**, which operate together to provide data acquisition, power measurement, data conversion, and data transmission services. Clamp filter **44** preferably makes inductive contact with power line **50**. Split-core transformer **42** is inductively coupled with power line **50** and senses fluctuations in current flow in power line **50**, the fluctuations being indicative of rising and falling power consumption rates within the dwelling **65**. Output from the transformer **42** is fed to power meter **35** for processing.

In a preferred embodiment of the present invention, power meter **35** is an ADE7756 active energy metering IC with a serial interface, manufactured by Analog Devices, Inc. The ADE7756 incorporates two second-order, sigma-delta analog-to-digital (A/D) converters, reference circuitry, and associated signal processing circuitry to perform active power measurement from power line **50**. Real-time power consumption information, when processed by the ADE7756, is output in the form of a serial data signal capable of being read by any serial device (e.g., an RS-232 data port). Of course, any known power meter capable of producing a serial output signal corresponding to power consumption information can be substituted without departing from the spirit or scope of the present invention. The output from power meter **42** is fed to processor **20** and converted for transmission across a wired or wireless network, as will hereinafter be described in more detail.

The power metering system **10** includes a multichannel transceiver **30** that allows transmission of data, including power consumption, appliance control, and network data, across the power line **50**. The multichannel transceiver **30** interfaces with power line **50** via one or more clamp contacts **40**, or any other interface such as a direct plug connection into an outlet on the power line **50**. Importantly, transceiver **30** allows the processor **20** of power metering system **10** to transmit and receive IP data from power line **50** using known power line protocols such as X-10 or HomePlug. The X-10 protocol allows communication between appliances (e.g., lamps, fans, televisions) in stand-alone networks of **128** or fewer nodes.

The HomePlug protocol allows for the transmission of IP data across power lines at speeds of up to 13.75 Mbits/second, with guaranteed Quality of Service (QoS). The HomePlug protocol interfaces with the Media Access Control (MAC) layer of the software, allowing IP data to be transmitted over power lines. In a preferred embodiment of the present invention, transceiver **30** comprises a VS6801 CMOS chip manufactured by Valence Semiconductor, Inc. The VS6801 chip combines analog-to-digital (AID) con-

verters, digital-to-analog (D/A) converters, signal conditioning circuitry, and power line interface circuitry to allow transmission of data across power line **50** using Internet Protocol over the HomePlug protocol. Transceiver **30** preferably allows the transmission of data across power line **50** using both the X-10 and HomePlug protocols. Other protocols, of course, are considered within the scope of the present invention.

The power metering system **10** also includes a filter **44** for selectively filtering data transmitted across power line **50**. The filter **44** prevents undesired X-10 and IP data extant on power line **50** and originating from a source outside of dwelling **65** from entering the power lines therein. Further, the filter **44** prevents selected X-10 and IP data generated within dwelling **65** from exiting power line **50** and being transmitted across the power distribution grid. Moreover, the filter **44**, in conjunction with the processor **20**, provides the capability of allowing both internal and external X-10 signals to selectively control appliances within a household. In a preferred embodiment of the present invention, the filter **44** is a clamp filter designed to filter out X-10 frequencies external to the dwelling **65**.

FIG. 2 is a block diagram showing the power metering system **10** of the present invention in greater detail. The processor **20** of the present invention comprises an RF transceiver **22** connected to antenna **15**, a computer **24**, and a data/control interface **26** connected to the computer **24**. The RF transceiver **22** receives and transmits data between the computer **24** and a wireless network. Transceiver **22** could be substituted with a wired network interface, such as a 10-Base-T, 100-Base-T, or Gigabit Ethernet interface, without departing from the scope of the present invention. The computer **24** preferably has the processing power and functionality of a personal digital assistant (PDA). Indeed, a PDA, such as the Handspring Visor PDA manufactured by Handspring, Inc., or other similar personal digital devices, including a handheld computer or laptop, could be used. Further, the computer **24** could be an embedded device, and the entire processor **20** could be manufactured as a single, small unit having appropriate input and output ports. The data/control interface **26** connects the computer **24** via data/control bus **27** to both the multichannel transceiver **30** and power meter **35**. Preferably, the data/control interface **26** is a parallel interface, but other types of connections, such as an RS-232 serial interface or Universal Serial Bus (USB) connection, could be utilized.

Importantly, the processor **20** of the present invention allows data to be transmitted between a wireless (or wired) network connected to the computer **24** and a power line within a dwelling. This allows conventional wired and wireless networks within a dwelling to be expanded using the power lines within dwelling, or to selectively allow data from the network to be transmitted outside of the dwelling. Further, the processor **20** allows power consumption data to be transmitted across a wired or wireless network, and appliance control signals (e.g., X-10 control signals) to be sent across the power line connected to multichannel transceiver **30**. Additionally, the computer **24** contains routing functionality to selectively route and filter information between a wireless or wired network and the power line, or between sub-networks on the power line.

The computer **24** of the present invention may be programmed to convert a variety of different information types into different formats for internal and external transmission across wired, wireless, and power line networks. By the terms "internal" and "internally," it is meant transmission of data signals on a network located within the same building

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where the computer **24** is located. Conversely, by the term “external” and “externally,” it is meant transmission of data signals on a network located outside of the building where the computer **24** is located (e.g., to one or more dwellings located in the same community). The conversion procedures performed by computer **24** include, but are not limited to:

1. Selective conversion of internal or external X-10 control signals for internal or external IP transmission. This procedure allows internal or external X-10 control/data signals to be selectively converted to IP traffic for internal or external transmission on a wired, wireless, or power line (e.g., HomePlug) network. The resulting IP traffic can be directed to desired IP addresses using standard router and firewall mechanisms

2. Selective conversion of internal or external IP traffic for internal or external X-10 transmission. This procedure allows internal or external IP traffic to be selectively converted into X-10 control signals for internal or external transmission across a power line network. The user is provided with the ability to select IP traffic (e.g., by IP address, IP destination port, type of IP traffic, and content of IP traffic) to be converted, using a standard firewall mechanism. The resulting X-10 control signals can be directed to desired X-10 devices or codes.

3. Selective conversion of internal or external X-10 control signals for internal or external X-10 transmission. This procedure allows internal or external X-10 control/data signals to be converted for transmission on an internal or external X-10 network. The user has the ability to select the X-10 signals to be converted, based upon one or more codes embedded within the signal and using a standard firewall mechanism. Internal or external X-10 control/data signals can be used to control or pass data to internal or external X-10 devices.

4. Selective conversion of power consumption data for internal or external IP transmission. This procedure allows power consumption data acquired by the present invention to be converted to IP format for internal or external transmission on an IP network. This allows power consumption information to be measured within the building (e.g., at one or more computer stations connected to a home LAN or wireless network), proximal to the building (e.g., a handheld, remote monitoring station having a wireless interface), or external to the building (e.g., by a power utility company via the Internet).

FIG. **3** is a schematic showing communication between two wireless power metering systems according to the present invention and a wireless monitoring station. In this arrangement, a first power metering system **10**, a second power metering system **110**, and a monitoring station **160** communicate using network **70**, which may be, for example, a wireless IEEE 802.11 network known in the art. Further, the network **70** can be connected to the Internet, an intranet, or a wired Ethernet connecting the power metering systems **10**, **110** and the monitoring station **160**.

The first power metering system **10** monitors power consumption on power line **50**, which for purposes of illustration, is a power line existing in a first dwelling. The power line **50** has two power line networks A and B, which can be either X-10 sub-networks, IP sub-networks utilizing the HomePlug protocol, or any other type of sub-network. Preferably, power line networks A and B are HomePlug sub-networks that allow for the transmission of IP data thereon. Power consumption data is measured by power meter **35** via transformer **42**, and relays same to processor **20**. The multichannel transceiver **30** is connected to networks A and B via clamp contacts **40**, and allows data to be

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selectively transmitted and received across networks A and B. The filter **44** prevents stray X-10 signals from network A from interfering with network B, and vice versa. Further, the processor **20**, via a wireless interface and antenna **15**, can communicate with network **70** to transmit and receive data.

Similarly, the second power metering system **110** monitors power consumption on power line **150**, which for purposes of illustration, is a power line existing in a second dwelling. The power line **150** has two power line networks C and D. Preferably, power line networks C and D are HomePlug sub-networks that allow for the transmission of IP data. Power consumption data is measured by power meter **135** via transformer **142**, and relays same to processor **120**. The multichannel transceiver **130** is connected to networks C and D via clamp contacts **140**, and allows data to be selectively transmitted and received across networks C and D. The filter **144** prevents stray X-10 signals from network C from interfering with network D, and vice versa. Further, the processor **120**, via a wireless interface and antenna **115**, can communicate with network **70** to transmit and receive data.

The monitoring station **160** communicates with network **70** to transmit and receive information between power metering systems **10**, **110**. The monitoring station **160** could be a stand-alone PC, a handheld PDA with an IEEE 802.11 wireless interface similar to the wireless power meters **10**, **110** of the present invention, or any other suitable device. The monitoring station **160** allows for the remote monitoring of power consumption information captured by power meters **10**, **110** and transmitted wirelessly to monitoring station **160** via network **70**.

The monitoring station **160** could be used by a variety of individuals, including, for example, power utility meter reading personnel or a homeowner. A power utility meter reader could quickly and conveniently monitor power consumption information for a given household by walking near the vicinity of the household, wherein the power consumption information could be transmitted by the wireless power metering system of the present invention to the monitoring station **160**. The acquired information could then be logged in the monitoring station **160** for future billing. Further, the monitoring station **160** could be used by a homeowner to monitor power consumption trends within the household and adjust power consumption to minimize utility costs.

Importantly, the power metering systems **10**, **110** also allow for the transmission of data, including power consumption data, across the Internet. Thus, power consumption information could be transmitted directly to a power utility by power metering systems **10**, **110** for immediate processing and billing, thereby obviating the need for meter reading personnel. Further, appliances within the households connected to the power lines **50**, **150** can be selectively activated and de-activated by power metering systems **10**, **110** to maximize efficiency, wherein X-10 or other similar control signals are transmitted across power lines **50**, **150** and/or networks A–D to control desired appliances within the households.

Moreover, the power metering systems **10**, **110** allow for the transmission of non-appliance-related data (e.g., standard IP network traffic) across the power lines **50**, **150** and/or networks A–D. For example, IP-based traffic could be selectively transmitted between networks A and B of power line **50** in a first household by power metering system **10**. Similarly, traffic could be selectively transmitted between networks C and D of power line **150** in a second household by power metering system **110**. A power line network connection **170** could be provided between the two house-

holds for allowing the transmission of IP data therebetween, using a standard power line network protocol (e.g., the HomePlug protocol) between the power lines **50**, **150**. In such an arrangement, both of the power metering systems **10**, **110** could be configured to provide firewall services, so that only desired traffic external to each of the households is allowed. Further, both IP-based traffic, including IP-encapsulated power consumption data, can be shared between the power metering systems **10**, **110** using network **70**.

FIG. **4** is a schematic showing the wireless power metering system of the present invention implemented in a household network. As mentioned earlier, the wireless power metering system of the present invention, in addition to providing power consumption measurement, also provides network connectivity for a plurality of devices within a household. Thus, as shown in FIG. **4**, a variety of computer devices and peripherals, in addition to an appliance, can be linked using the power metering system **10** of the present invention.

For example, a hub or switch **220** could be set up within a household to link a computer **225** and a printer **230**, and to provide connectivity for the household to the Internet **300** via a router **215** (e.g., a cable or DSL modem) connected to the hub/switch **220**. Further, a second router **210** could be connected to the hub/switch **220** to provide connectivity to a household wireless LAN **200**, so that a laptop **205** having an IEEE 802.11 interface can wirelessly communicate with the computer **225**, printer **230**, or the Internet **300**.

The wireless power metering system **10** of the present invention can be utilized to extend a household network to include additional devices, such as the computer **240**, printer **250**, and lamp **255**, using the power line **50** of the household. The power metering system **10** can communicate with the wireless LAN **200** using an IEEE 802.11 link, or using a wired Ethernet connection between an Ethernet interface **90** and the hub or switch **220**. The processor **20** selectively converts IP traffic from wireless LAN **200** or hub/switch **220** for transmission across the power line **50** using power line protocols such as the HomePlug and X-10 protocols, via the multichannel transceiver **30** and clamp contacts **40**. Additionally, the processor **20** selectively converts X-10 and HomePlug traffic received from the power line **50** for IP transmission over the wireless LAN **200** or Ethernet interface **90**.

The computer **240** and printer **250** are connected to a hub/switch **245**, which, in turn, is connected to the power line **50** via a commercially available transceiver **235** and standard wall power outlet **41**. The transceiver **235** is similar to a portion of the multichannel transceiver **30**, allowing the transmission and reception of data from power line **50** using the HomePlug or other similar protocol. The transceiver **235** could comprise the VS6801 CMOS chip manufactured by Valence Semiconductor, Inc., or other similar chip. In this arrangement, IP-based data can be shared between the computer **240**, hub/switch **245**, and printer **250** (each of which may be located in a first location of the building (e.g., a den)), and the laptop **205**, router **210**, hub/switch **220**, router **215**, computer **225**, printer **230**, and Internet connection **300** (each of which may be located in a second location of the building (e.g., a basement)).

The lamp **255**, or any other appliance within the household and connected to the power line **50** via transceiver **256** and interface **41**, can be selectively controlled by X-10 signals generated by the processor **20** or any other X-10 control device connected to power line **50**. The transceiver **256** is similar to a portion of the multichannel transceiver **30**, allowing transmission and reception of data from power line

50 using the X-10 or other similar protocol. Further, the lamp **225**, or any other X-10 equipped appliance connected to the power line **50**, can be selectively controlled by signals generated externally or internally to the household, the signals being filtered and routed by the processor **20** in conjunction with the filter **44**. Additionally, traffic between networks A and B is filtered by the filter **44**. Power consumption information monitored by processor **20** can be accessed within the home by processor **20**, laptop **205**, computer **225**, computer **240**, remotely over the Internet **300**, by any wireless device in communication with wireless LAN **200**, by any wired device connected to hubs/switches **220**, **245**, or by any device connected to power line networks A or B.

FIG. **5** is a block diagram showing software modules of the present invention, indicated generally at **350**. Each of the software modules **350** can be embodied in any digital computer known in the art. In a preferred embodiment of the present invention, software modules **350** reside in non-volatile, random-access memory (RAM), read-only memory (ROM), or other data storage component, such as the computer **24** of the present invention. The core component of the software modules **350** is the Transmission Control Protocol/Internet Protocol (TCP/IP) stack **358**, which allows the wireless power metering system of the present invention to communicate using the Internet Protocol, version 4 (IPv4). It is conceivable that TCP/IP stack **358** could be expanded for use with the IPv6 protocol or other future protocol.

Firewall modules **356**, **360** interact with TCP/IP stack **360**, and accept data from HomePlug module **352**, IEEE 802.11 module **354**, X-10 module **362**, and power meter module **364**. The firewall modules **356**, **360** provide routing functionality, and control the flow of IP traffic between the modules **352**, **354**, **362**, and **364**. HomePlug module **352** accepts incoming IP-based HomePlug signals and relays same to firewall **356**, in addition to generating outgoing HomePlug signals from IP-based traffic provided by firewall **356**. IEEE 802.11 module **354** allows IP-based traffic to be wirelessly transmitted and received by firewall **356**. X-10 module **362** converts incoming X-10 signals to IP-based traffic and relays same to firewall **360**, in addition to generating outgoing X-10 signals from IP-based traffic provided by firewall **360**. Power meter module **364** converts incoming power consumption information measured by power meter **35** of the present invention into IP-based traffic, and routes same to firewall **360**.

FIG. **6** is a block diagram showing a standard Internet Protocol, Version 4 ("IPv4") packet utilized by the present invention and indicated generally at **380**. The IPv4 packet **380** comprises a number of sub-components, including version block **382**, header length block **384**, type-of-service (TOS) block **386**, total length block **388**, identification block **390**, flags block **392**, fragmentation offset block **394**, time-to-live (TTL) block **396**, protocol block **398**, header checksum block **400**, source IP address block **402**, destination IP address block **404**, options block **406**, and payload data block **408**. The present invention stores X-10 control signals and data, and power consumption data in the payload data block **408**, thereby encapsulating the data in an IP format and allowing transmission of same across any IP network. For example, the X-10 module **362** of the software modules **350** of FIG. **5** stores X-10 control data in the payload data block **408**, thereby converting X-10 data into IP-based data. The power meter module **364** of the software modules **350** of FIG. **5** stores power consumption information in the

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payload data block **408**, thereby converting power consumption information into IP-based data.

FIG. 7 is a block diagram showing the data portion of a sample IP packet **410** according to the present invention for transmitting power consumption data. The power consumption data measured by the present invention is stored in a plurality of data blocks **412-424**. Block **412** stores the start time of energy consumption for given use period as a 32-bit block. Block **414** stores the use period of energy consumption as a 32-bit block. The kilowatt-hour usage for the current use period is stored as a 32-bit value in block **416**. The cumulative kilowatt-hour usage value for all use periods (since setting the meter, or since the last roll-over) is stored as a 32-bit value in block **418**. Any ancillary data types (for future expansion or use) are stored as 8-bit values in block **420**. The data length of the power consumption message is stored as a 8-bit value in block **422**. Finally, any ancillary meter use data is stored in block **424**. Each of these components are stored in the payload data block **408** of FIG. 6, resulting in an encapsulated, IP-based power consumption data packet **426** which may be transmitted across any IP-based network.

FIG. 8 is a block diagram showing the data portion of a sample IP packet **430** according to the present invention for transmitting X-10 control signals or data. As mentioned earlier, X-10 control signals or data are stored by the present invention in the payload data block **408** of FIG. 6, allowing for the transmission of X-10 data as IP-based data. The X-10 control data comprises a 4-bit start code block **422**, a 4-bit house code block **434**, a 5-bit key code block **436**, and X-10 payload data block **438**. Each of these blocks are encapsulated to form an IP-based X-10 data packet **440** which may be transmitted across any IP network.

Having thus described the invention in detail, it is to be understood that the foregoing description is not intended to limit the spirit and scope thereof. What is desired to be protected by Letters Patent is set forth in the appended claims.

What is claimed is:

1. An electrical power metering system comprising:
 - a power meter coupled with a power line for measuring power consumption data from the power line, the power meter dividing the power line to form an internal network and an external power line network;
 - a processor connected to the power meter for converting the power consumption data measured by the power meter into Internet Protocol (IP) data;
 - a network interface connected between the processor and the internal network for transmitting and receiving IP data between the processor and the internal network;
 - a transceiver connected between the processor and the external power line network for transmitting and receiving IP data between the processor and the external power line network; and
 - means for selectively routing IP data between the external power line network and the internal network, said means selectively operable as a firewall for filtering IP data routed between the external power line network and the internal network;
 - wherein power consumption information is transmitted autonomously in IP format over the external power line network.
2. The system of claim 1, wherein the transceiver transmits and receives X-10 data and control signals across the external power line network.

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3. The system of claim 1, wherein the transceiver comprises a HomePlug power line interface for transmitting and receiving IP traffic between the processor and the external power line network.

4. The system of claim 1, wherein the network interface comprises a wireless interface for transmitting and receiving IP data between the processor and the internal network.

5. The system of claim 1, wherein the external power line network connects to the Internet.

6. The system of claim 1, wherein the power meter further comprises a split-core transformer inductively coupled with the power line.

7. The system of claim 1, wherein the processor comprises a personal digital assistant (PDA).

8. The system of claim 1, wherein the processor filters and routes data between an external source and the internal network.

9. The system of claim 1, wherein the processor converts X-10 data from the external power line network into IP data for transmission across an internal IP network.

10. The system of claim 1, wherein the processor converts IP data into X-10 data and control signals for transmission across the internal network.

11. The system of claim 1, wherein the transceiver further comprises first and second contacts coupled with the external power line network, the first contact allowing communication external to a residence using the external power line network and the second contact allowing communication within the residence using an internal power line network.

12. The system of claim 11, further comprising a filter coupled with the power line and positioned between the first and second contacts for separating internal communications on the internal power line network and external communications on the external power line network.

13. The system of claim 1, further comprising a remote monitoring station for remotely monitoring the power consumption information.

14. The system of claim 13, wherein the remote monitoring station further comprises a wireless interface for transmitting data to and receiving data from the power metering system.

15. The system of claim 1, wherein the power metering system transmits and receives information across the Internet.

16. The system of claim 1, further comprising a wired network interface for connecting the power metering system to a wired network.

17. A method of measuring power consumption information on a power line comprising:

- measuring current fluctuations in the power line;
- calculating power consumption information from the current fluctuations in a processor;
- converting the power consumption information into IP-based power consumption information in the processor; and
- transmitting the IP-based power consumption information from the processor to a destination autonomously in IP format over an external power line network.

18. The method of claim 17, further comprising: receiving the IP-based power consumption information at the destination; and

calculating a utility bill using the IP-based power consumption information.

19. The method of claim 17, further comprising transmitting the IP-based power consumption information over an IP-based network.

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20. The method of claim 17, further comprising wirelessly transmitting the IP-based power consumption information from the processor to the destination.

21. The method of claim 17, further comprising:
generating a control signal in the processor in response to
the power consumption information;
transmitting the control signal to an appliance; and
controlling the appliance with the control signal.

22. The method of claim 21, wherein the step of controlling the appliance comprises turning the appliance off in response to increased power consumption.

23. The system of claim 1, wherein the electrical power metering system is located at a first location and further comprises a network connection established between the electrical power metering system and a computer at a second location.

24. The system of claim 23, wherein the network connection comprises a wireless connection.

25. The system of claim 23, wherein the network connection comprises a power line connection.

26. The system of claim 23, wherein the network connection allows the computer in the second location to share an Internet connection provided at the first location.

27. A method for providing network connectivity and measuring power consumption information at a residence comprising:

interconnecting a power meter having a processor, a network interface, and a power line transceiver between a power line and an internal network at a residence, the power meter dividing the power line to form the internal network and an external power line network;

selectively routing Internet Protocol (IP) data between the external power line network and the internal network to provide access to the Internet at the residence using the external power line network;

calculating current and cumulative power consumption information at the residence using the power meter; and

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converting the power consumption information into IP data for transmission over the Internet autonomously in IP format via the external power line network.

28. The method of claim 27, further comprising selectively filtering IP data between the external power line network and the internal network using a firewall in the power meter.

29. The method of claim 27, wherein the step of converting the power consumption information into IP data comprises encapsulating the power consumption information into one or more IP packets.

30. The method of claim 29, further comprising storing a destination IP address in the one or more IP packets.

31. The method of claim 30, further comprising transmitting the one or more IP packets to a destination specified by the destination IP address using the Internet.

32. The method of claim 30, further comprising simultaneously transmitting the one or more IP packets to a plurality of destinations using the destination IP address.

33. The method of claim 27, further comprising selectively routing IP data from the internal network to a second network at a second residence using the power meter and the external power line network.

34. The system of claim 1, wherein the internal network comprises an internal power line network.

35. The system of claim 1, wherein the power consumption information is one of kilowatt-hour usage for a current use period and cumulative kilowatt-hour usage for all use periods.

36. The system of claim 1, wherein the power consumption information is measured on the external power line network.

37. The system of claim 1, wherein the power consumption information is measured on the internal network.

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