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(71) Applicant: THOMSON LICENSING [FR/FR]; 1-5, rue
Jeanne d'Arc, 92130 Issy-les-Moulineaux (FR).(72) Inventors: LYONS, Kent; 612 Sierra Vista Avenue, Unit
J, Mountain View, CA 94043 (US). BOLOT, Jean, C.;
656 Giralda Drive, Los Altos, CA 94024 (US). GOELA,Naveen; 2430 Dwight Way, Apt. 202, Berkeley, CA 94704
(US). HAMIDI-RAD, Shahab; 969 Durlane Court, Sunny-
vale, CA 94087 (US).(74) Agent: DORINI, Brian, J. et al.; c/o Thomson Licensing
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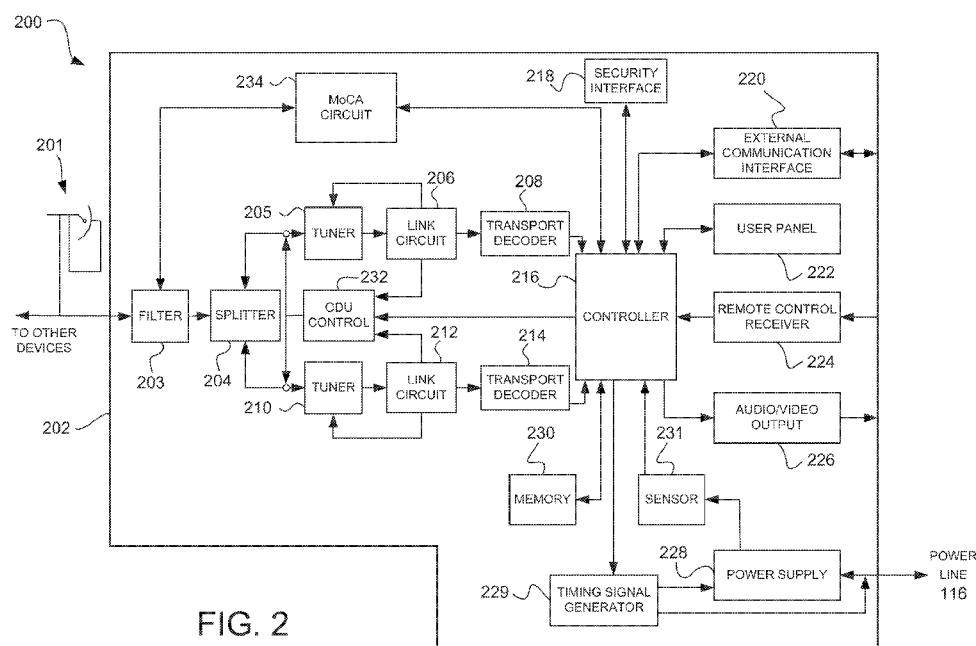


FIG. 2

(57) **Abstract:** The present disclosure is directed to devices, systems and methods for power line endpoint identification. The present disclosure provides for determining a location of one or more devices coupled to a power line within a power distribution system. In one aspect, a timing signal is inserted by a source from a single point on the power line. Due to variations in the distances between the point where the source is coupled to the power line and the location of the devices coupled to the power line, the timing signal has a different arrival time for each device. This different arrival time for each device may be used to determine a unique timing value, or unique identifier, for each device coupled to the power line. The unique timing value may then be used to determine the location of the device coupled to the power line.



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DEVICES, SYSTEMS AND METHODS FOR POWER LINE ENDPOINT IDENTIFICATION

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of U.S. Provisional Patent Application Serial No. 62/408,296, filed October 14, 2016, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

 The present disclosure generally relates to power distribution and communication systems.
10 More particularly, the present disclosure is related to devices, systems and methods for power line endpoint identification.

BACKGROUND

 Any background information described herein is intended to introduce the reader to various
15 aspects of art, which may be related to the present embodiments that are described below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light.

 In recent times, there has been an increase in the number of devices that are present in a
20 dwelling or building. Some or all of these devices may be coupled to the electrical wiring system of the dwelling via an outlet or light socket. With the increasing number of devices that are present in dwellings, it may be difficult to keep track of which outlets, light sockets, or other connection points to the electrical wiring system of a dwelling that each device is coupled to.

 Current techniques for keeping track of devices that are coupled to the electrical wiring
25 system of a dwelling may include manually labeling and tracking each device that is coupled to the electrical wiring system or using an indoor position system to locate each device coupled to the electrical wiring system. However, these techniques may require significant manual effort or changes to the existing infrastructure of an electrical wiring system. Furthermore, these techniques may produce coarse or imprecise location estimates.

SUMMARY

In one aspect of the present disclosure, a method is provided including: receiving, by a processor, a timing signal on a power line of a power distribution system; determining, by the processor, a timing value of the timing signal with respect to a reference signal; and determining,
5 by the processor, a location of a connection to the power line based on the timing value.

In another aspect of the present disclosure, a method is provided including: transmitting, by a processor, a timing signal on a power line of a power distribution system; receiving, by the processor, a timing value from at least one device that is coupled to the power line, the timing value based on the transmitted timing signal; and determining, by the processor, a location of a
10 connection to the power line of the at least one device based on the timing value.

In another aspect of the present disclosure, a device is provided including: a power supply interface that receives a timing signal on a power line of a power distribution system; and a processor coupled to the power supply interface that receives the timing signal, determines a timing value of the timing signal with respect to a reference signal, and determines a location of a
15 connection to the power line based on the timing value.

In another aspect of the present disclosure, a device is provided including: a signal generator that generates a timing signal to be transmitted on a power line of a power distribution system; and a processor that receives a timing value from at least one device that is coupled to the power line, the timing value based on the transmitted timing signal, wherein the processor
20 determines a location of a connection to the power line of the at least one device based on the timing value.

In accordance with another aspect of the present disclosure, an embodiment of a method comprises: receiving, by a processor, a timing signal on a power line of a power distribution system; determining, by the processor, a timing value of the timing signal with respect to a
25 reference signal; and determining, by the processor, a location of a connection to the power line based on the timing value. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise reference signal being used by the processor to synchronize a clock that is maintained by the processor. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise determining the
30 timing value may include determining a propagation delay of the timing signal from a source to the processor, wherein the reference signal includes a time the timing signal was originally sent by

the source. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise receiving the reference signal by the processor via the power line. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise the timing signal and the reference signal being encoded into a power mains
5 signal distributed on the power line via the power distribution system. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise receiving, by the processor, the reference signal via a channel external to the power distribution system. In accordance with another aspect, one or more embodiments of a method as described herein including a channel may further include the channel comprising a wireless communication. In
10 accordance with another aspect, one or more embodiments of a method as described herein may further include the timing signal comprising a fluctuation of a power mains signal distributed by the power distribution system on the power line and caused by a power usage variation of a device receiving power from the power line. In accordance with another aspect, one or more
15 embodiments of a method as described herein may further comprise the timing signal being received by the processor at periodic intervals and the determining of the timing value being based on the periodic intervals. In accordance with another aspect, one or more embodiments of a method as described herein may further include the power distribution system distributing power to a plurality of power outlets in a building that are coupled to the power line, and the processor is
20 included in a device coupled to one of the plurality of power outlets, and the location comprises a position of the one of the plurality of power outlets in the building. In accordance with another aspect, one or more embodiments of a method as described herein may further include the timing signal being received in response to a query transmitted, by the processor, via at least one of the power line and a wireless communication. In accordance with another aspect, one or more
25 embodiments of a method as described herein may further
comprise transmitting, by the processor, the determined location to at least one other device via at least one of the power line and a wireless communication. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise: receiving, by the processor, a second timing signal on the power line of the power distribution system; determining,
30 by the processor, a timing value of the second timing signal with respect to the reference signal;

and wherein, the determining the location of the connection to the power line (116) is also based on the timing value of the second timing signal.

In accordance with another aspect of the present disclosure, an embodiment of a method comprises: transmitting, by a processor, a timing signal on a power line of a power distribution system; receiving, by the processor, a timing value from at least one device that is coupled to the power line, the timing value based on the transmitted timing signal; and determining (506), by the processor, a location of a connection to the power line of the at least one device based on the timing value. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise transmitting, by the processor, a signal indicating a time the timing signal was sent. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise receiving, by the processor, a plurality of timing values from a plurality of devices, each device coupled to the power line; determining, by the processor, the location that each of the plurality of devices are coupled to the power line based on the plurality of timing values; and generating, by the processor, a visual representation including the location of each of the plurality of devices within a building based on the determined location of each of the plurality of devices. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise outputting for display, by the processor, the visual representation. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise the timing signal being transmitted in response to a query from the at least one device. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise the timing value being received via the power line. In accordance with another aspect, one or more embodiments of a method as described herein may further comprise the timing value being received via a wireless communication.

In accordance with another aspect of the present disclosure, an embodiment of a device comprises: a power supply interface that receives a timing signal on a power line of a power distribution system; and a processor coupled to the power supply interface that receives the timing signal, determines a timing value of the timing signal with respect to a reference signal, and determines a location of a connection to the power line based on the timing value. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the reference signal being used by the processor to synchronize a clock that is maintained by the processor. In accordance with another aspect, one or more embodiments of a

device as described herein may further comprise the processor determining the timing value by determining a propagation delay of the timing signal from a source to the processor, wherein the reference signal includes a time the timing signal was originally sent by the source. In accordance with another aspect, one or more embodiments of a device as described herein may

5 further comprise the power supply interface receiving the reference signal via the power line and providing the reference signal to the processor. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the timing signal and the reference signal being encoded into a power mains signal distributed on the power line via the power distribution system. In accordance with another aspect, one or more embodiments of a

10 device as described herein may further comprise a communication interface that receives the reference signal via a channel external to the power distribution system. In accordance with another aspect, one or more embodiments of a device as described herein may further include the channel comprising a wireless communication. In accordance with another aspect, one or more embodiments of a device as described herein may further include the timing signal

15 comprising a fluctuation of a power mains signal distributed by the power distribution system on the power line and caused by a power usage variation of a device receiving power from the power line. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the timing signal being received by the processor at periodic intervals and the timing value being based on the periodic intervals. In accordance with

20 another aspect, one or more embodiments of a device as described herein may further comprise the power distribution system distributing power to a plurality of power outlets in a building that are coupled to the power line, and the processor is included in a device coupled to one of the plurality of power outlets, and the location comprises a position of the one of the plurality of power outlets in the building. In accordance with another aspect, one or more embodiments of a

25 device as described herein may further comprise the timing signal being received in response to a query transmitted, by the processor, via at least one of the power line and a wireless communication. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the processor transmitting the determined location to at least one other device via at least one of the power line and a wireless communication. In

30 accordance with another aspect, one or more embodiments of a device as described herein may further comprise the processor receiving a second timing signal on the power line of the power

distribution system and determining a timing value of the second timing signal with respect to the reference signal, wherein the location of the connection to the power line is also based on the timing value of the second timing signal.

In accordance with another aspect of the present disclosure, an embodiment of a device
5 comprises: a signal generator that generates a timing signal to be transmitted on a power line of a power distribution system; and a processor that receives a timing value from at least one device that is coupled to the power line, the timing value based on the transmitted timing signal, wherein the processor determines a location of a connection to the power line of the at least one device based on the timing value. In accordance with another aspect, one or more embodiments
10 of a device as described herein may further comprise the processor transmitting a signal indicating a time the timing signal was sent. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the processor receiving a plurality of timing values from a plurality of devices, each device coupled to the power line, the processor determining the location that each of the plurality of devices are coupled to the power
15 line based on the plurality of timing values, and generating a visual representation including the location of each of the plurality of devices within a building based on the determined location of each of the plurality of devices. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise an audio/visual output that outputs for display the visual representation. In accordance with another aspect, one or more embodiments of a
20 device as described herein may further comprise the timing signal being transmitted in response to a query from the at least one device. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the timing value being received via the power line. In accordance with another aspect, one or more embodiments of a device as described herein may further comprise the timing value being received via a wireless
25 communication. In accordance with another aspect of the present disclosure, an embodiment comprises a computer program product stored in a non-transitory computer-readable storage medium comprising computer-executable instructions for performing any of the methods in accordance with the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a block diagram of an exemplary electrical wiring system for a dwelling or building in accordance with an embodiment of the present disclosure;

FIG. 2 is a block diagram of an exemplary source device in accordance with an embodiment of the present disclosure;

FIG. 3 is a block diagram of an exemplary device coupled to a power line in accordance with an embodiment of the present disclosure;

FIG. 4 is a flowchart illustrating an exemplary method for determining a timing value associated to a device in accordance with an embodiment of the present disclosure; and

FIG. 5 is a flowchart illustrating an exemplary method for determining a location of a device connected to a power line in accordance with an embodiment of the present disclosure.

It should be understood that the drawing(s) are for purposes of illustrating the concepts of the disclosure and is not necessarily the only possible configuration for illustrating the disclosure.

DETAILED DESCRIPTION

It also should be understood that the elements shown in the figures may be implemented in various forms of hardware, software or combinations thereof. Preferably, these elements are implemented in a combination of hardware and software on one or more appropriately programmed general-purpose devices, which may include a processor, memory and input/output interfaces. Herein, the phrase "coupled" is defined to mean directly connected to or indirectly connected with through one or more intermediate components. Such intermediate components may include both hardware and software based components.

The present description illustrates the principles of the present disclosure. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the disclosure and are included within its scope.

All examples and conditional language recited herein are intended for educational purposes to aid the reader in understanding the principles of the disclosure and the concepts contributed by

the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions.

Moreover, all statements herein reciting principles, aspects, and embodiments of the disclosure, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both
5 currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented herein represent conceptual views of illustrative circuitry embodying the principles of
10 the disclosure. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudocode, and the like represent various processes which may be substantially represented in computer readable media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

The functions of the various elements shown in the figures may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with
15 appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term “processor” or “controller” should not be construed to refer exclusively to hardware capable of executing software, and may implicitly
20 include, without limitation, digital signal processor (DSP) hardware, read only memory (ROM) for storing software, random access memory (RAM), and nonvolatile storage.

Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control
25 and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

In the claims hereof, any element expressed as a means for performing a specified function is intended to encompass any way of performing that function including, for example, a) a combination of circuit elements that performs that function or b) software in any form, including,
30 therefore, firmware, microcode or the like, combined with appropriate circuitry for executing that software to perform the function. The disclosure as defined by such claims resides in the fact that

the functionalities provided by the various recited means are combined and brought together in the manner which the claims call for. It is thus regarded that any means that can provide those functionalities are equivalent to those shown herein.

The present disclosure is directed to devices, systems and methods for power line endpoint
5 identification. The present disclosure provides devices, systems and methods for determining a location of one or more devices coupled to a power line within a dwelling or building by using the existing infrastructure of the dwelling or building's electrical wiring system. In one aspect of the present disclosure, a timing signal is inserted by a source from a single point on a power line of an electrical wiring system. Due to variations in the distances between the point where the source is
10 coupled to the power line and the location of the devices coupled to the power line, the timing signal has a different arrival time for each device. This different arrival time for each device may be used to determine a unique timing value for each device coupled to the power line.

Referring to FIG. 1, an exemplary electrical wiring system for a dwelling or building 100 is shown in accordance with the present disclosure. As shown in FIG. 1, in one embodiment, the
15 wiring system of dwelling 100 may include one or more outlets 104, 106, 108, 110 and one or more light sockets or fixtures 112, 114 that are each coupled to a power line 116. The power line 116 may be embedded within an interior portion of a wall 118 of dwelling 100 and power line 116 may be further coupled to a circuit breaker panel 102, where circuit breaker panel 102 is coupled to a power distribution system supplied by a utility. A power mains signal is provided to each of
20 outlets 104, 106, 108, 110 and light sockets or fixtures 112, 114 via power line 116. One or more end devices 105, 107, 109, 111, 113, 115 may be coupled to one of outlets 104, 106, 108, 110 or one of light sockets 112, 114 to receive the power mains signal via power line 116.

It is to be appreciated that each end device coupled to power line 116 may be a smart device, i.e., an electronic device generally connected to other devices or networks via different
25 wireless protocols such as Wi-Fi, Bluetooth, Near Field Communications (NFC), 3G, etc. For example, each of end devices 105, 107, 109, 111 coupled to outlets 104, 106, 108, 110 may be a smart appliance, such as, but not limited to, a smart stove, smart thermostat, smart refrigerator, smart washing machine, smart television, smart phone, smart gateway, smart set top box, etc. Furthermore, end devices 113, 115, coupled to light sockets 112, 114, may be smart light bulbs,
30 smart fans, or other smart lighting devices. Additionally, one or more of outlets 104, 106, 108, 110 may be a smart outlet or smart switch. It is to be appreciated that one or more of the smart

end devices described above may be coupled directly to power line 116 (i.e., not via an outlet or light socket).

It is to be appreciated that the devices (e.g., outlets, light sockets, and/or end devices) coupled to power line 116 may be configured to communicate with each other in a variety of ways.

5 For example, in some embodiments, each of the devices (e.g., outlets, light sockets, and/or end device) may be configured to communicate via wireless and/or radio frequency communication, such as, but not limited to, Wi-Fi, Bluetooth, Transmission Control Protocol/Internet Protocol, Secure Shell, File Transfer Protocol, ZigBee, Z-Wave, Mobile Communication Protocols (e.g., 2G, 3G, 4G, LTE, etc.), NFC, Radio Frequency Identification (RFID), and any other protocols
10 suitable to support the Internet of Things. Furthermore, each device (e.g., outlets, light sockets, and end devices) coupled to power line 116 may be configured to communicate via power line 116 using one or more narrowband and/or broadband power line communication protocols, such as, but not limited to, Universal Powerline Bus, X10, Ethernet Over Power (e.g., HomePlug AV, Powerline AV, etc.), and any other protocols suitable to support power line communication.

15 In one embodiment, the wiring system of dwelling or building 100 may be configured, such that, a timing signal is inserted onto power line 116 from a source that is coupled to a single point on power line 116. The timing signal is then received by each of outlets 104, 106, 108, 110 and light sockets 112, 114. In one embodiment, each of outlets 104, 106, 108, 110 and light sockets
20 112, 114 may be configured to determine a timing value associated with the reception of the timing signal by each outlet 104, 106, 108, 110 and light socket 112, 114, where the timing value is a propagation delay of the timing signal from a source (i.e., of the timing signal) to the receiving outlet or light socket. In another embodiment, the timing signal received by each of outlets 104, 106, 108, 110 and light sockets 112, 114 is further provided to an end device coupled to the outlet or light socket, such as, one of end devices 105, 107, 109, 111, 113, 115. In either case, the timing
25 signal is used by a device coupled to power line 116 (e.g., outlet, light socket, and/or end device) to determine a timing value or propagation delay of the timing signal from the source to the receiving outlet, light socket, and/or end device.

In one embodiment, circuit breaker panel 102 may be configured as a source capable of inserting a timing signal onto power line 116. In another embodiment, any one of outlets 104, 106,
30 108, 110 may be configured as the source. In yet another embodiment, any one of end devices 105, 107, 109, 111, 113, or 115 may be configured as the source, e.g., a power strip, a wall wart,

etc. It is to be appreciated that although the source is described above as being one of circuit breaker panel 102, outlets 104, 106, 108, 110, or end devices 105, 107, 109, 111, 113, 115, any device that is coupled to power line 116 and is capable of inserting a signal on power line 116 may be the source.

5 Regardless of which device coupled to power line 116 (e.g., outlet, light socket, panel, or end device) is configured as the source, the source is configured to insert a timing signal onto power line 116, where the timing signal is distinguishable by a receiving device coupled to power line 116 (e.g., an outlet, light socket, or end device) from the conventional power mains signal received via power line 116. For example, in one embodiment, the timing signal is a pulse, or
10 spike, in voltage in the power mains signal provided on power line 116 that is inserted into the power line 116 by the source. The pulse is distinguishable from the power mains signal (e.g., an appreciably higher voltage than the power signal) that is provided to each outlet or light socket coupled to power line 116 via the power distribution system. In this way, the timing signal may be encoded into the power mains signal distributed on power line 116 via the power distribution
15 system. It is to be appreciated that the timing signal may be any type of variation or modulation of the power mains signal distributed on power line 116. For example, the timing signal may be a pulse of a frequency variation inserted into the power signal on power line 116, e.g., a frequency variation or modulation injected onto the base 60/50 Hz carrier of the power distribution system.

 As shown in FIG. 1, each outlet 104, 106, 108, 110 and light socket 112, 114 (and,
20 therefore, the end devices coupled to each outlet or light socket) is coupled to a different location on power line 116. Therefore, if a source inserts a timing signal (e.g., a pulse or voltage spike of the power mains signal) onto power line 116, the timing signal arrives at different times to each outlet 104, 106, 108, 110 and light socket 112, 114 (and, therefore, the end devices coupled to each outlet or light socket). In one embodiment, each device (e.g., outlet, light socket, end device, etc.)
25 coupled to power line 116 may be configured to determine the unique timing value associated with the amount of time it takes the timing signal to propagate from the source to the receiving device.

 For example, in one embodiment, end device 111 may operate as the source. In this embodiment, end device 111 inserts a timing signal onto power line 116 (through outlet 110). The timing signal is originally inserted by end device 111 at a time t_0 . The timing signal then
30 propagates on power line 116 to each end device coupled to power line 116. Due to the differing distances along power line 116 between each of end devices 105, 107, 109, 113, and 115 from end

device 111, the timing signal is received by each end device at a different time. For example, the timing signal may reach end device 113 at time t_1 , end device 109 at time t_2 , end device 115 at time t_3 , end device 107 at time t_4 , and end device 105 at time t_5 . Each end device receiving the timing signal may then determine the amount of time (i.e., the timing value) the timing signal took to travel from the source to the receiving device, where the timing value for each end device receiving the timing signal is unique (i.e., since the distance between each end device and the source is different).

To determine the amount of time the timing signal took to propagate from the source to a receiving device, each receiving device in dwelling or building 100 is configured to evaluate the received timing signal with respect to a reference signal. In one embodiment, the reference signal is a clock signal provided to each end device, outlet, and/or light socket coupled to power line 116. The reference signal may also represent a signal used to synchronize an internal clock disposed in each device coupled to power line 116. The reference signal may be received over power line 116 (e.g., encoded into the power mains signal distributed on power line 116), or alternatively, via a channel external to power line 116 (e.g., external to the power distribution system), such as, a wireless communication.

For example, in one embodiment, each outlet, light socket, and/or end device coupled to power line 116 may be configured to communicate over power line 116 using a power line communication protocol. In this embodiment, the reference signal may be provided by any of the devices coupled to power line 116, or alternatively, may be encoded into the power mains signal by the utility maintaining the power distribution system that provides power to the power line 116.

In another embodiment, as stated above, each device coupled to power line 116 may be a smart device configured for wireless communication (e.g., Wi-Fi, ZigBee, Z-Wave, Bluetooth, etc.) over a network. The reference signal may be received as part of a time synchronization protocol via a wireless communication. For example, the internal clocks of each device coupled to power line 116 may be synchronized using a protocol, such as, but not limited to, Network Time Protocol, Clock Sampling Mutual Network Synchronization, Precision Time Protocol, Reference Broadcast Synchronization, Reference Broadcast Infrastructure Synchronization, etc. It is to be appreciated that the above described synchronization protocols are merely exemplary and that the usage of other synchronization protocols to synchronize the internal clocks of any device coupled to power line 116 may be used in accordance with the present disclosure.

In another embodiment, the reference signal may also include a time the timing signal was originally sent by the source. In this embodiment, in addition to using a common clock signal to determine the unique timing value for each device, each device coupled to power line 116 is configured to determine the original time the timing signal was sent from the source. In one
5 embodiment, where the source is a smart device (e.g., a set top box), either before or after the timing signal is inserted onto power line 116, the source acting as the smart device may also communicate the time t_0 to each device coupled to power line 116 (where time t_0 is based on the synchronized common clock of each device coupled to power line 116). It is to be appreciated that the original time t_0 may be communicated by the source to the other devices coupled to power
10 line 116 either via a power line communication over power line 116 or via a wireless communication, as described above. In this way, when the timing signal is received by each device coupled to power line 116, each receiving device may compare the time the timing signal was received by the receiving device (as measured using the synchronized internal clock of the receiving device) to the time t_0 that the timing signal was originally sent by the source to determine
15 the timing value for that receiving device (i.e., the time it took for the timing signal to propagate from the source to the receiving device).

In another embodiment, the source is configured to periodically transmit the timing signal according to a time interval, for example, at the beginning of each minute. This periodic time interval (e.g., the beginning of every minute) used by the source to insert the timing signal onto
20 power line 116 is known by each receiving device coupled to power line 116 (e.g., outlets, light sockets, and/or end devices) prior to receiving the timing signal. In this way, when the timing signal is received by a receiving device coupled to power line 116, the receiving device is configured to calculate the difference in time between the beginning of the known periodic time interval and the time the timing signal was received by the receiving device to determine the timing
25 value for that receiving device.

In another embodiment, a receiving device coupled to power line 116 may transmit a query to the device acting as the source to receive a timing signal from the source. It is to be appreciated that the query may be transmitted by the receiving device either via a power line communication over power line 116 or via a wireless communication, as described above. In response to receiving
30 the query from the receiving device, the source inserts a timing signal onto power line 116 to be received by the receiving device.

In another embodiment, the timing signal may be a fluctuation of the power mains signal distributed by the power distribution system over power line 116 that is caused by a power usage variation of a device receiving power from power line 116. For example, in one embodiment, an end device coupled to power line 116, such as end device 107, may be a refrigerator. As part of the normal operation of the refrigerator, the refrigerator's compressor motor may turn on and cause a fluctuation in the amount of power drawn by the refrigerator from the power distribution system (via power line 116). The additional power drawn by the refrigerator because of the compressor motor turning on results in a fluctuation of the power mains signal on power line 116. The fluctuations to the power mains signal may be distinguishable by the other devices coupled to power line 116. For example, the fluctuation may have certain signal characteristics (e.g., frequency, phase, etc.) known by each device coupled to power line 116.

In this embodiment, the fluctuations to the power mains signal created by the power usage of the refrigerator may be used as the timing signal (e.g., the refrigerator 107 is the source of the timing signal). When the fluctuation created by the source (e.g., the refrigerator or end device 107) is received by an end device, the end device determines the time (based on the synchronized clock signal shared by all devices coupled to power line 116) that the fluctuation to the power mains signal created by the power usage of the refrigerator is received. Each end device receiving the fluctuation may then share (e.g., via wireless or power line communication) the arrival time of the fluctuation with the other end devices coupled to power line 116 that have received the fluctuation. Since each of the end devices coupled to power line 116 are a different distance from end device 107, the arrival time of the fluctuation for each end device is different or unique. In one embodiment, the unique arrival time of the fluctuation to an end device may be the unique timing value for that end device. In another embodiment, each end device may compare differences in the arrival time of the fluctuation of other end devices with its own arrival time to determine the order with which the fluctuation was received by each of the end devices, where the order that a device receives the fluctuation is the timing value for that end device.

In yet another embodiment, a second device acting as a second source may insert a second timing signal into the power mains signal on power line 116. In this embodiment, the second source is coupled to a different location on power line 116 than the first source and the timing signal inserted by the second source includes different signal characteristics (i.e., voltage level, frequency, etc.) than the timing signal inserted by the first source. In this way, the first timing

signal inserted by the first source is distinguishable by receiving devices coupled to the power line 116 from the second timing signal inserted by the second source. Since each device acting as a source is a different distance along power line 116 from each other receiving device, the first timing signal and the second timing signal will arrive at each receiving device at different times.

5 In this embodiment, each receiving device is configured to determine the timing value of the first timing signal and the second timing signal.

The first and second timing values (i.e., propagation delays) for each receiving device coupled to power line 116 may be shared on a network (e.g., via wireless or power line communication) with all other receiving devices. The first and second timing values of each
10 receiving device may be used to resolve any discrepancies that result from devices that are similar distances from a source. For example, referring again to FIG. 1, in one embodiment, end device 111 may be a first source that inserts a first timing signal onto power line 116 that is received by the other end devices coupled to power line 116. The timing values (i.e., propagation delays) calculated by end devices 107 and 115 may be similar since source 111 is a similar distance from
15 both of end devices 107 and 115. However, it may be undesirable for two different devices to have similar timing values, where, for example, the timing value of a device is used to determine a location of that device, as will be described in greater detail below.

To differentiate similar timing values of two different devices, such as end devices 107 and 115 in the example above, a second end device may act as a second source and insert a second
20 timing signal onto power line 116. For example, end device 105 may act as a source for a second timing signal. Since end devices 107 and 115 are different distances from end device 105, the second timing value (i.e., propagation delay) calculated by each of end devices 107 and 115 is different and may be used to differentiate the similar first timing values of end devices 107 and 115.

25 In another embodiment, the first and second timing signals can be sent at different times, but having the synchronized clock means the propagation time from each can be calculated. Additionally, the first and second timing signals may be differentiated so the end device knows which is which (e.g., a sender identification may be encoded into the signal), or the first and second timing signals may be coordinated out of band (e.g., on an external channel such as a wireless
30 communication). With multiple senders (i.e., multiple sources), the devices can start to do a form of triangulation so not only is the “distance” from the one sender or source determined, but the

relative distances can be determined. For example, it is possible that three devices look very close together (i.e., have similar propagation delays or timing values) from a source, e.g., a set top box. But from a different source (e.g. a gateway), the signals travel the power lines from different directions and it can be determined with the second timing signal that two of the devices still seem
5 close (i.e., similar delays) while the third device has a different delay. Therefore, the system knows the third device is in a different spot than the first two devices. It is to be appreciated that the first two devices may still be in different locations but having more senders/sources would increase the ability to differentiate these devices. In one embodiment, any receiver (or end device) may take on sender/source role forming a full star topology.

10 It is to be appreciated that any number of devices coupled to power line 116 may concurrently act as a source and insert a different timing signal onto power line 116 so that all similar timing signals of different end devices may be differentiated.

In the embodiments described above, the unique timing value (i.e. the propagation delay from the source to a receiving device coupled to power line 116) determined by each device
15 coupled to power line 116 may be used to achieve many purposes. For example, the timing value determined by each receiving device may be used to generate a unique identifier for each receiving device. In one embodiment, the timing value is a unique identifier associated to the particular device. In another embodiment, the timing value may be combined with other data to create the unique identifier for the particular device, e.g., a name of the dwelling's network, an address of
20 the dwelling's network, etc. Furthermore, the timing value of each receiving device may be shared (e.g., via power line communication or wireless communication) with each other receiving device coupled to power line 116. In this way, each device coupled to power line 116 is aware of the other devices coupled to power line 116.

In one embodiment, the propagation delay (i.e., the timing value) to each outlet, light
25 socket, and/or end device coupled to the power line 116 may be associated to each outlet, light socket, and/or end device, and stored in one or more of the devices coupled to power line 116. In this embodiment, a receiving device may determine a location of the receiving device's connection (e.g., to an outlet or light socket, or a direct connection to power line 116) on power line 116, or alternatively, the location of another receiving device's connection on power line 116, based on
30 the determined unique timing value.

For example, referring to FIG. 1 again, end device 111 may act as the source and insert a timing signal on power line 116. In this embodiment, the propagation delay from end device 111 to each of outlets 104, 106, 108, 110 and light sockets 112, 114 may be predetermined and associated to each outlet and light socket. These predetermined values may be stored in a memory
5 of one or more of the devices coupled to power line 116. When, end device 113 receives the timing signal sent by source 111, end device 113 may determine the unique timing value (i.e., propagation delay) associated with its connection point to power line 116, and thus, its location. End device 113 may then determine if its unique timing value matches the timing value associated with one of outlets 104, 106, 108, 110 or light sockets 112, 113. End device 113 may then determine that
10 its timing value matches the stored timing value for light socket 112. In this way, end device 113 may determine that it is coupled to light socket 112.

This process may be repeated by each receiving device coupled to power line 116 to determine which outlet or light socket the device is currently coupled to. After each device determines which outlet or light socket it is coupled to, this information may be shared with each
15 other device either via a wireless communication or via a power line communication. In one embodiment, a single device, such as the source device (e.g., end device 111), receives the unique timing signals determined and shared by each receiving device coupled to power line 116 (along with other identifying information for such device) and the source device determines which outlet or light socket each device is coupled to based on the predetermined associations of timing value
20 to outlet or socket.

It is to be appreciated that the above described process may alternatively (or additionally) be performed by each outlet 104, 106, 108, 110 and light socket 112, 114 of dwelling or building. In this embodiment, each outlet and light socket is configured to determine if power is being drawn from the outlet or light socket, indicating an end device is coupled the outlet or light socket. If the
25 outlet or light socket determines that power is being drawn from it, the outlet or light socket may then determine the unique timing value in response to receiving a timing signal via power line 116. The unique timing value may then be shared with other devices coupled to power line 116 via a wireless or power line communication.

In another embodiment, the physical location of each outlet and light socket within
30 dwelling or building 100 (e.g., an x/y/z coordinate location) may be mapped and represented in a visual representation of dwelling or building 100, e.g., a two-dimensional or three-dimensional

representation. The physical location of each outlet and light socket in the visual representation of dwelling or building 100 is also associated to the unique timing value of each outlet and light socket. In this embodiment, after each receiving device has determined its unique timing value, the unique timing value of each receiving device may be shared via wireless or power line communication and collected by a single device, for example, the source device. The source device may then determine the physical location of each device within dwelling or building 100 based on the timing value of each device, since, as described above, the timing value of each device is mapped to a physical location. After the physical location is determined, the source device may generate a visual representation including which devices are coupled to particular outlets or light sockets on the visual representation of dwelling or building 100. The visual representation may then be outputted for display to a display device (e.g., a television or monitor) by the source (or other device generating the visual representation).

It is to be appreciated that each device may share information about itself (e.g., identifying information) with the source device to further enrich the information available in the visual representation, e.g., each device may share information such as, but not limited to, the type of device it is (e.g., a smart TV), the name assigned to the device (e.g., John Doe's Smart TV), etc.

As stated above, a source device may be coupled to power line 116. Referring to FIG. 2, a block diagram of an exemplary source device 202 is shown in accordance with the present disclosure. The source device 202 may be included as part of a gateway device, modem, set top box, or other similar communications device. It is to be appreciated that, in one embodiment, source device 202 is configured to act as either a source or a receiving device that is coupled to power line 116, as will be described in greater detail below.

Referring to FIG. 2, the source device 202 will be described as a set top box that is part of a signal receiving system 200. The signal receiving system 200 receives signals, e.g., media content, Internet communications, etc., over one of several possible networks including, but not limited to, over the air, cable, satellite, Ethernet, fiber and phone line networks. In the embodiment shown in FIG. 2, system 200 primarily receives signals from one or more satellites as well as multiple television broadcast transmission sites. The signals are provided by one or more service providers and represent broadcast audio and video programs and content. System 200 is described as including components that reside both inside and outside a user's premises. It is important to note that one or more components in system 200 may be moved from inside to outside a premises,

such as, dwelling or building 100. Further, one or more components may be integrated with a display device, such as a television or display monitor (not shown). In either case, several components and interconnections necessary for complete operation of system 200 are not shown in the interest of conciseness, as the components not shown are well known to those skilled in the art.

An outdoor unit (ODU) 201 receives signals from satellites and from terrestrial transmission towers through an over the air and/or near earth orbit communications link. ODU 201 is connected to set top box 202. In one embodiment, ODU 201 may further be coupled to dwelling or building 100. Within set top box 202, the input is connected to filter 203. Optionally, filter 203 can be connected to splitter 204. Filter 203 is coupled to three signal processing paths, optionally via splitter 204 which may be used to produce signals provided to the various signal paths. A first path includes tuner 205, link circuit 206, and transport decoder 208 connected together serially. A second path includes tuner 210, link circuit 212, and transport decoder 214 connected together serially. A third path includes MoCA (Multimedia over Coax Alliance) circuit 234 which further connects to controller 216. The outputs of transport decoder 208 and transport decoder 214 each connect to controller or processor 216. Controller 216 connects to security interface 218, external communication interface 220, user panel 222, remote control receiver 224, audio/video output 226, power supply 228, memory 230, and ODU control 232. External communication interface 220, remote control receiver 224, audio/video output 226, and power supply 228 provide external interfaces for the set top box 202. ODU control 232 also connects to the filter 203.

Satellite signal streams, each containing a plurality of channels, are received by ODU 201. ODU 201 includes a dish for capturing and focusing the propagated radio wave from the atmosphere onto one or more antennas contained within a structure known as a low noise block converter (LNB). ODU 201 may be configured to receive the signal streams from satellite transponders located on one or more satellites. In one embodiment, two sets of sixteen channels are received by ODU 201, and converted, using one or more LNBs to a frequency range of 950 Megahertz (MHz) to 2,150 MHz, referred to as L-band. ODU 201 also includes a terrestrial antenna for receiving over the air broadcasts. In one embodiment, ODU 201 includes a multiple element antenna array for receiving ISDB-T signals in the frequency range from 170 MHz to 800 MHz.

ODU 201 provides a converted signal stream to the set top box 202 through radio frequency (RF) co-axial cable. The converted signal stream is provided to filter 203. In one embodiment, filter 203 operates as a multiplex filter with up to three separate filter sections or interfaces. The frequency response properties of filter 203 may include a separate highpass filter and lowpass filter such that the frequency passbands of each do not overlap. The arrangement, often referred to as a diplexer or duplex filter, allows for a separation, through signal filtering, of the incoming satellite signal and/or MoCA signal from the terrestrial signal and/or MoCA signal. In one embodiment, the low pass filter frequency response pass band ends at a frequency below 900 MHz. The low pass filter portion allows a MoCA signal in a frequency range from 475 MHz to 625 MHz as well as a terrestrial signal in the frequency range from 170 MHz to 800 MHz to pass through to subsequent blocks while attenuating, or not passing through, a satellite signal in a frequency range from 950 MHz to 2,150 MHz. The high pass filter portion operates in an opposite manner passing the MoCA signal, in the frequency range around 1100 MHz, along with the satellite signal through and attenuating cable or terrestrial broadcast signal. The high pass filter portion may also filter any electrical supply or communication signals provided to the ODU 201. An additional bandpass filter circuit may be provided to further process MoCA signals and provide the signals as an output to a home MoCA network or for processing in set top box 202. Other embodiments may be possible and some of these embodiments are described in further detail below. Filter 203 may also include surge or transient voltage protection devices.

The output signal from the high pass filter portion of filter 203 is provided to a first signal path containing a tuner 205, a link circuit 206, and a transport decoder 208 connected in a serial fashion. The output signal from the low pass filter portion of the filter 203 is provided to a second signal path. The second signal path also contains a tuner 210, a link circuit 212, and a transport decoder 214 connected in a serial fashion. Each processing path may perform similar processing on the filtered signal streams, the processing being specific to the transmission protocol used.

Tuner 205 processes the split signal stream by selecting or tuning one of the channels provided from a satellite service provider in the highpass filtered signal stream to produce one or more baseband signals. Tuner 205 contains circuits (e.g., amplifiers, filters, mixers, and oscillators) for amplifying, filtering and frequency converting the satellite signal stream. Tuner 205 typically is controlled or adjusted by link circuit 206. Alternately, tuner 205 may be controlled by another controller, such as controller 216, which will be described later. The control commands

include commands for changing the frequency of an oscillator used with a mixer in tuner 205 to perform the frequency conversion.

5 Tuner 210 processes the lowpass filtered signal stream by selecting or tuning one of the terrestrial or cable broadcast channels in the split signal stream to produce one or more baseband signals. Tuner 210 contains circuits (e.g., amplifiers, filters, mixers, and oscillators) for amplifying, filtering and frequency converting the signal stream. Tuner 210 may be controlled or adjusted in a manner similar to that described earlier for tuner 205.

10 Typically, the baseband signals at the output of tuner 205 or tuner 210 may collectively be referred to as the desired received signal and represent one satellite channel selected out of a group of channels that were received as the input signal stream. Although the signal is described as a baseband signal, this signal may actually be positioned at a frequency that is only near to baseband.

15 The one or more baseband signals from the satellite service provider are provided to link circuit 206 through tuner 205. Link circuit 206 typically contains the processing circuits needed to convert the one or more baseband signals into a digital signal for demodulation by the remaining circuitry of link circuit 206. In one embodiment, the digital signal may represent a digital version of the one or more baseband signals. In another embodiment, the digital signal may represent the vector form of the one or more baseband signals. Link circuit 206 also demodulates and performs error correction on the digital signal from the satellite service provider to produce a transport signal. The transport signal may represent a data stream for one program, often referred to as a single program transport streams (SPTS), or it may represent multiple program streams multiplexed together, referred to as a multiple program transport stream (MPTS).

25 The one or more baseband signals from the broadcast service provider are provided to link circuit 212 through tuner 210. Link circuit 212 typically contains the processing circuits needed to convert the one or more baseband signals into a digital signal for demodulation by the remaining circuitry of link circuit 212 in a manner similar to link circuit 206 described earlier. Link circuit 212 also demodulates, performs broadcast channel equalization error correction on the digital signal from the broadcast service provider to produce a transport signal. As described earlier, the transport signal may represent a data stream for one program or it may represent multiple program streams multiplexed together.

30 The transport signal from link circuit 206 is provided to transport decoder 208. Transport decoder 208 typically separates the transport signal, which is provided as either a SPTS or MPTS,

into individual program streams and control signals. Transport decoder 208 also decodes the program streams, and creates audio and video signals from these decoded program streams. In one embodiment, transport decoder 208 is directed by user inputs or through a controller such as controller 216 to decode only the one program stream that has been selected by a user and create
5 only one audio and video signal corresponding to this one decoded program stream. In another embodiment, transport decoder 208 may be directed to decode all of the available program streams and then create one more audio and video signals depending on user request.

The transport signal from link circuit 212 is similarly provided to transport decoder 214. Transport decoder 214 decodes the program streams, and creates audio and video signals from
10 these decoded program streams as directed by user inputs or a controller in a manner similar to that described earlier for transport decoder 208.

The audio and video signals, along with any necessary control signals, from both transport decoder 208 and transport decoder 214 are provided to controller 216. Controller 216 manages the routing and interfacing of the audio, video, and control signals and, further, controls various
15 functions within set top box 202. For example, the audio and video signals from transport decoder 208 may be routed through controller 216 to an audio/video (A/V) output 226. A/V output 226 supplies the audio and video signals from set top box 202 for use by external devices (e.g., televisions, display monitors, and computers). Also, the audio and video signals from transport decoder 214 may be routed through controller 216 to memory block 230 for recording and storage.

Memory block 230 may contain several forms of memory including one or more large
20 capacity integrated electronic memories, such as static random access memory (SRAM), dynamic RAM (DRAM), or hard storage media, such as a hard disk drive or an interchangeable optical disk storage system (e.g., compact disk drive or digital video disk drive). Memory block 230 may include a memory section for storage of instructions and data used by controller 216 as well as a
25 memory section for audio and video signal storage. Controller 216 may also allow storage of signals in memory block 230 in an alternate form (e.g., an MPTS or SPTS from transport decoder 208 or transport decoder 214).

Controller 216 is also connected to an external communications interface 220. External communication interface 220 may provide signals for establishing billing and use of the service
30 provider content. External communications interface 220 may include a phone modem for providing phone connection to a service provider. External communications interface 220 may

also include an interface for connection to an Ethernet network and/or to home wireless communications network. The Ethernet network and/or home wireless network may be used for communication data, audio, and/or video signals and content to and from other devices connected to the Ethernet network and/or home wireless network (e.g., other media devices in a home). In one embodiment, external communications interface 220 may be used to communicate with some or all of the devices coupled to power line 116 of dwelling or building 100 via the home wireless network of dwelling or building 100 using one or more of the wireless communication protocols described above (e.g., Wi-Fi, Bluetooth, ZigBee, Z-Wave, etc.)

Controller 216 also connects to a security interface 218 for communicating signals that manage and authorize use of the audio/video signals and for preventing unauthorized use. Security interface 218 may include a removable security device, such as a smart card. User control is accomplished through user panel 222, for providing a direct input of user commands to control the set top box and remote control receiver 224, for receiving commands from an external remote control device. Although not shown, controller 216 may also connect to the tuners 205, 210, link circuits 206, 212, and transport decoders 208, 214 to provide initialization and set-up information in addition to passing control information between the blocks.

Finally, power supply 228 typically connects to all of the blocks in set top box 202 and supplies the power to those blocks as well as providing power to any of the elements needing power externally, such as the ODU 201. In one embodiment, power supply 228 is coupled to power line 116 of dwelling or building 100, via, for example, a multi-conductor cord and plug. Power supply 228 may also be coupled to a timing signal generator 229 and a sensor 231, where timing signal generator 229 and sensor 231 may each be further coupled to controller 216. The timing signal generator 229 and sensor 231 will be described in greater detail below.

Controller 216 also controls ODU control 232. ODU control 232 provides signaling and power supply electrical power back to the ODU 201 through filter 203. ODU control 232 provides these signals and power onto the co-axial cable(s) running between ODU 201 and set top box 202. In one embodiment, the ODU control 232 receives input control signals from controller 216 and provides different DC voltage levels to specific portions of the ODU 201 to provide a certain signal stream containing a set of programs or content to filter 203 and further to tuner 205 and tuner 210. In another embodiment, the ODU control 232 receives inputs from controller 216 and also from link circuit 206 and link circuit 212 and provides DC voltage levels and a separate tuning control

signal to ODU 201 using low frequency carrier based frequency shift keying modulation or using SWM format. Controller 216 also may send control commands to disable ODU controller 230 from providing either direct current (DC) voltages or control signals to ODU 201.

MoCA circuit 234 amplifies and processes the MoCA signal both for reception and
5 transmission. As described above the MoCA interface permits communications of audio and video signals in a home network and may operate bi-directionally. MoCA circuit 234 includes a low noise amplifier for improving reception performance of a MoCA signal received by signal receiving device 200 from another network connected device. The received and amplified signal is tuned, demodulated, and decoded. The decoded signal may be provided to a number of other
10 circuits, including audio and video outputs as well as a mass storage device (e.g., hard disk drive, optical drive, and the like), not shown. Additionally, MoCA circuit 234 generates and formats the MoCA transmit signal using audio and video content available in signal receiving device, including content received from the input (e.g., satellite signal) and content from the mass storage device. MoCA circuit 234 also includes a power amplifier for increasing the transmitted signal
15 level of the MoCA signal sent by system 200 to another network connected device. Adjustment of the receive signal amplification as well as the transmit signal amplification in MoCA circuit 234 may be controlled by controller 216.

It should be appreciated by one skilled in the art that the blocks described inside set top box 202 have important interrelations, and some blocks may be combined and/or rearranged and
20 still provide the same basic overall functionality. For example, transport decoder 208 and transport decoder 214 may be combined and further integrated along with some or all of the functions of controller 216 into a System on a Chip (SoC) that operates as the main controller for set top box 202. Further, control of various functions may be distributed or allocated based on specific design applications and requirements. As an example, link circuit 206 may provide control signals to
25 ODU control 232 and no connection may exist between link circuit 212 and ODU control 232.

Further, it should be appreciated although ODU 201 includes both a dish and LNB for use with satellite signals and a terrestrial antenna, other embodiments may use separate structures. In some embodiments, the satellite dish and LNB and included in one structure and the terrestrial antenna is part of a second structure. The outputs of both satellite dish/LNB structure and
30 terrestrial antenna are combined using a signal combining circuit and provided to set top box 202.

Although set top box 202 is described above as receiving a single converted signal stream, set top box 202 may also be configured to receive two or more separate converted signal streams supplied by ODU 201 in some modes of operation. Operation in these modes may include additional components including switches and/or further tuning and signal receiving components, not shown. Further, set top box 202 may be designed to operate only on a home network using the Ethernet or home wireless network interfaces described above. In this case, the elements associated with operation in a MoCA network may be removed from set top box 202.

It is to be appreciated that, in some embodiments, set top box 202 may be one of end devices 105, 107, 109, 111 coupled to the power line 116 of dwelling or building 100 via one of outlets 104, 106, 108, 110.

As shown in FIG. 2, power supply 228 is coupled to power line 116, timing signal generator 229, and sensor 231. Power supply 228 receives the power mains signal from power line 116 (e.g., via an outlet, such as one of outlets 104, 106, 108, 110) and provides the power mains signal to sensor 231. Sensor 231 is configured to measure one or more electrical parameters (e.g., voltage, current, frequency, etc.) associated with the power mains signal. In one embodiment, sensor 231 includes an analog to digital converter to convert the measured electrical parameters associated with the power mains signal into a digital signal that is provided to controller or processor 216. It is to be appreciated that, in some embodiments, sensor 231 may be directly coupled to power line 116 instead of being coupled to power supply 228.

In one embodiment, set top box 202 is configured to send and receive power line communication signals to and from other devices coupled to power line 116. For example, power line communication signals may be received by set top box 202 via power supply 228 and provided to sensor 231, where sensor 231 is configured to measure, or sense, the power line communication signals and convert them to digital signals that are provided to controller 216. Controller 216 is further configured to process and read the digital power line communication signals. Furthermore, controller 216 may generate and transmit power line communication signals via timing signal generator 229. In one embodiment, timing signal generator 229 is configured to generate power signals in response to a control signal from controller 216, and timing signal generator 229 is configured to provide the generated power signals to power line 116 (either directly or via power supply 228). The generated power signals may then be received by one or more of the devices coupled to power line 116.

In one embodiment, set top box 202 may act as a receiving device in dwelling or building 100 that is configured to receive a timing signal from a source via power line 116. In this embodiment, a timing signal is inserted onto power line 116 and provided to sensor 231 via power supply 228 and power line 116. When the timing signal is received by sensor 231, sensor 231
5 measures the discernable variation in the power mains signal that is associated with the timing signal (e.g., a pulse or voltage spike, as described above), and provides this measurement to controller or processor 216 as a digital signal. After controller 216 receives the measured timing signal from sensor 231, controller 216 is configured to detect the timing signal based on the variation in the power mains signal that is associated with the timing signal (e.g., the pulse or
10 voltage spike, as described above). In one embodiment, controller 216 may be configured to determine if the measurement of the power mains signal varies (e.g., in voltage level, frequency, etc.) above a predetermined threshold, where the variation above the predetermined threshold is associated with the timing signal.

Furthermore, controller 216 is configured to determine a unique timing value of the timing
15 signal for set top box 202 with respect to a reference signal. As described above, the reference signal may be provided to a common clock (not shown), where the common clock is maintained by controller 216. The reference signal may be a synchronization signal received via external communication interface 220 (e.g., via a wireless communication) or via power line 116 (e.g., via a power line communication). Furthermore, the reference signal may be an initial time the timing
20 signal was sent from the source. Based on the timing value, set top box 202 may determine the location that set top box 202 is coupled to power line 116. Furthermore, set top box 202, may share its unique timing value with the other devices coupled to power line 116 (e.g., end devices 105, 107, 109, 111, 113, and/or 115).

In one embodiment, set top box 202 may be configured as the source that inserts a timing
25 signal onto power line 116. In this embodiment, timing signal generator 229 is configured to generate a timing signal based on a control signal received from controller 216. The timing signal generated by timing signal generator 229 is then transmitted via power line 116 to the other devices coupled to power line 116. Once the other devices receiving the timing signal transmitted by set top box 202 have determined each of their unique timing values, each receiving device may
30 transmit the unique timing value to set top box 202 (or any other device coupled to power line 116) via a power line communication or a wireless communication.

In one embodiment, the unique timing values (e.g., the propagation delay) for each connection point to power line 116 (e.g., outlets 104, 106, 108, 110, light sockets 112, 114, or other direct connection points) relative to set top box 202 are saved in a memory of set top box 202, such as memory 230. In other words, the propagation delay of the timing signal inserted by set top box 202 to each device coupled to power line 116 is saved in memory 230 of set top box 202. Furthermore, each unique timing value, or propagation delay, of each connection point to power line 116 may be mapped to a location within building or dwelling 100 (e.g., to a particular outlet, light socket, or physical connection point to power line 116), as described above. This mapping may also be stored in memory 230 of set top box 202.

In this way, when controller 216 receives a unique timing value from a receiving device coupled to power line 116, controller 216 may determine the location of the receiving device within building 100. The timing values of each of the devices may be transmitted to set top box 202 via external communication interface 220 (e.g., a wireless communication) or power line 116 (e.g., a power line communication) and saved in memory 230 or provided to controller 216. Controller 216 may then determine the physical location of each device coupled to power line 116 and generate a visual representation of each devices physical position (e.g., connection point to particular outlet, socket, or direct connection point to power line 116) in building 100, as described above. Controller 216 may then output the generated map for display via audio/video output 226 on a display device coupled to set top box 202.

As described above, many different types of devices may be coupled to power line 116. Referring to FIG. 3, an exemplary device 300 is shown that is configured to act as a source or a receiving device in accordance with the present disclosure. It is to be appreciated that, in one embodiment, device 300 may be any one of outlets 104, 106, 108, 110 or light sockets 112, 114. In another embodiment, device 300 may be any one of end devices 105, 107, 109, 111, 113, 115.

As seen in FIG. 3, device 300 includes a sensor 302, communication interface 304, power supply interface 306, processor 308, timing signal generator 310, and memory 312. Sensor 302, communication interface 304, power supply interface 306, timing signal generator 310, and memory 312 are each coupled to processor 308. Power supply interface 306 is further coupled to sensor 302, timing signal generator 310, and power line 116.

In one embodiment, power supply interface 306 receives the power mains signal via power line 116 to power the various components of device 300. It is to be appreciated that the power

supply interface 306 may be coupled to the power line 116 via a multi-conductor cord and plug. The power mains signal may further be provided to or sampled by sensor 302. Sensor 302 is configured to measure one or more electrical parameters (e.g., voltage, current, frequency, power, etc.) associated with the power signal being received by power supply interface 306 and provide
5 the measurements to processor 308. It is to be appreciated that sensor 302 may include an analog-to-digital converter to convert any analog measurements of signals received by power supply interface 306 to digital measurements that are provided to and read by processor 308.

It is to be appreciated that device 300 is configured for wireless communication. For example, device 300 includes communication interface 304. Communication interface 304 is
10 configured to communicate with any of the devices coupled to power line 116 via a suitable wireless communication protocol (e.g., Wi-Fi, ZigBee, Z-Wave, 2G, 3G, 4G, or any of the other wireless communication protocols described above). In one embodiment, communication interface may further be configured to communicate using Ethernet communication protocols.

Device 300 is also configured to send and receive power line communication signals to
15 and from other devices coupled to power line 116. For example, power line communication signals may be received by device 300 via power supply interface 306 and provided to sensor 302, where sensor 302 is configured to measure the power line communication signals and convert them to digital signals that are provided to processor 308. Processor 308 is further configured to process and read the digital power line communication signals. Furthermore, processor 308 may transmit
20 power line communication signals via timing signal generator 310. In one embodiment, timing signal generator 310 is configured to generate power signals in response to a control signal from processor 308, and timing signal generator 310 is configured to provide the generated power signals to power line 116 (either directly or via power supply interface 306). The generated power signals may then be received by one or more of the devices coupled to power line 116.

When device 300 is acting as a receiving device, a timing signal may be received by power
25 supply interface 306 via power line 116 from a source that is coupled to power line 116. As stated above, the timing signal may be a pulse or voltage spike, or any other variation, in the power mains signal received by power supply interface 306. The power mains signal (including the timing signal) is provided to sensor 302, where the signal is measured (as described above), and further
30 provided to processor 308

After processor 308 receives the measurements of the power mains signal including the timing signal, processor 308 is configured to determine if the measurement of the power mains signal varies (e.g., in voltage level, frequency, etc.) above a predetermined threshold, where the variation above the predetermined threshold is associated with the timing signal. If processor 308 determines that the measurement of the power mains signal includes a variation above a predetermined threshold, processor 308 determines that a timing signal has been received and records the time (according to a clock maintained by processor 308 that is synchronized with the clocks of other devices coupled to power line 116). Processor 308 further determines a timing value (e.g., a propagation delay) of the timing signal with respect to a reference signal. As described above, the reference signal may be a common clock signal, where the common clock is maintained by processor 308. The reference signal may be a synchronization signal received via communication interface 304 (e.g., via a wireless communication) or via power line 116 (e.g., via a power line communication). Furthermore, the reference signal may be an initial time the timing signal was sent from the source. Processor 308 may then store this timing value in memory 312 or use the information in any one of the ways described above (e.g., to determine the location of device 300 on power line 116). Processor 308 may also share the timing value with other devices coupled to power line 116 via communication interface 304 or power line 116.

It is to be appreciated that power supply interface 306 may be any type of interface that couples a device 300 to power line 116. For example, if device 300 is a smart lightbulb, interface 306 may be a lightbulb contact configured to be coupled to a light socket, such as light socket 112, 114. If device 300 is a smart TV, interface 306 may be a power cable, e.g., a multi-conductor cord and plug, configured to be coupled to an outlet, such as outlet 104, 106, 108, 110. If device 300 is a light socket or outlet, interface 306 may be a cable directly coupled the light socket or outlet to power line 116.

Referring to FIG. 4, a flowchart of an exemplary method 400 for determining a timing value associated to a device is shown in accordance with the present disclosure. It is to be appreciated that the method 400 may be used with any one of outlets 104, 106, 108, 110, light sockets 112, 114, set top box 202, and/or device 300, described above.

In step 402, a timing signal is received on a power line of a power distribution system. For example, the timing signal may be received via power line 116 by one of the devices described above, such as, outlets 104, 106, 108, 110, light sockets 112, 114, set top box 202, and/or device

300, described above. In the example of the set top box 202, the timing signal may be received via the power supply 228, detected by the sensor 231 and provided to controller 216. In the example of the device 300, the timing signal may be received via the power supply interface 306, detected by the sensor 302 and provided to processor 308.

5 In step 404, a timing value of the timing signal is determined with respect to a reference signal. For example, a processor, such as processor 216 or 308 may determine a timing value (e.g., a propagation delay of the timing signal from a source to the receiving device along power line 116) of the timing signal with respect to a reference signal. As stated above, the reference signal may be a common clock signal, a synchronization signal, and/or an initial time the timing signal
10 was sent from the source. In step 406, a location of a connection to a power distribution system is determined based on the timing value. For example, processor 216 or 318 may determine the physical location that a device is connected to (e.g., an outlet, light socket, or direct connection point to power line 116) based on the timing value, where the timing value has been mapped or associated to the location, as described above. In one embodiment, these mapped or associated
15 locations may be stored in memory 230 or memory 312. The processor 216 or 318 may then access the appropriate memory with the timing value to determine the mapped or associated location.

 Referring to FIG. 5, an exemplary flowchart of a method 500 for determining a location of a device connected to a power line is shown in accordance with the present disclosure. It is to be appreciated that the method 500 may be used with any one of outlets 104, 106, 108, 110, light
20 sockets 112, 114, set top box 202, and/or device 300, described above.

 In step 502, a timing signal is transmitted on power line of a power distribution system. For example, the timing signal may be transmitted by a device (such as one of outlets 104, 106, 108, 110, light sockets 112, 114, set top box 202, and/or device 300) acting as a source, where the timing signal may be a variation (such as a pulse or voltage spike) in the power mains signal on a
25 power line, such as power line 116. In the example of the set top box 202, the timing signal may be generated by the timing signal generator 229 and inserted onto the power line directly or via the power supply 228. In the example of the device 300, the timing signal may be generated by the timing signal generator 310 and inserted onto the power line 116 directly or via the power supply interface 306.

30 In step 504, a timing value is receiving from at least one device that is coupled to the power line. For example, the source device may receive a unique timing value (i.e., the propagation delay

of the timing signal from the source to a receiving device) from a receiving device (such as one of outlets 104, 106, 108, 110, light sockets 112, 114, set top box 202, and/or device 300). The source may receive the timing value via a power line communication or a wireless communication. In step 506, a location of a connection to the power line of the at least one device based on the timing value is determined. For example, a processor 216 or 308 (where the source is set top box 202 or device 300) may determine, based on the timing value of a receiving device, the physical location of the receiving device or which outlet or light socket the receiving device is coupled to, as described above. In the example of the set top box, the controller 216 may determine the physical location of each device coupled to power line 116 by accessing memory 230 to determine the associated location for each timing value and the controller 216 may then generate a visual representation of each devices physical position (e.g., connection point to particular outlet, socket, or direct connection point to power line 116) in building 100, as described above. The controller 216 may then output the generated map for display via audio/video output 226 on a display device coupled to set top box 202.

It is to be appreciated that the various features shown and described are interchangeable, that is a feature shown in one embodiment may be incorporated into another embodiment.

Although embodiments which incorporate the teachings of the present disclosure have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings. Having described embodiments of methods and apparatuses for power line endpoint identification, it is noted that modifications and variations can be made by persons skilled in the art in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the disclosure disclosed which are within the scope of the disclosure as outlined by the appended claims.

CLAIMS

1. A method comprising:
receiving, by a processor, a timing signal on a power line of a power distribution system;
5 determining, by the processor, a timing value of the timing signal with respect to a
reference signal; and
determining, by the processor, a location of a connection to the power line based on the
timing value.

10 2. The method of claim 1, wherein the reference signal is used by the processor to
synchronize a clock that is maintained by the processor.

3. The method of claim 1, wherein determining the timing value includes determining
a propagation delay of the timing signal from a source to the processor, wherein the reference
15 signal includes a time the timing signal was originally sent by the source.

4. The method of claim 1, wherein the timing signal and the reference signal are
encoded into a power mains signal distributed on a power line via the power distribution system;
and further comprising receiving the reference signal by the processor via the power line.

20

5. The method of claim 4, wherein the timing signal comprises a fluctuation of the
power mains signal distributed by the power distribution system on the power line and caused by
a power usage variation of a device receiving power from the power line.

25 6. The method of claim 1, wherein the power distribution system distributes power to
a plurality of power outlets in a building that are coupled to the power line, and the processor is
included in a device coupled to one of the plurality of power outlets, and the location comprises a
position of the one of the plurality of power outlets in the building.

30 7. The method of claim 1, wherein the timing signal is received in response to a query
transmitted, by the processor, via at least one of the power line and a wireless communication.

8. The method of claim 1, further comprising transmitting, by the processor, the determined location to at least one other device via at least one of the power line and a wireless communication.

5

9. The method of claim 1, further comprising:
receiving, by the processor, a second timing signal on the power line of the power distribution system;

10 determining, by the processor, a timing value of the second timing signal with respect to the reference signal; and

wherein, the determining the location of the connection to the power line is also based on the timing value of the second timing signal.

10. A device comprising:

15 a power supply interface that receives a timing signal on a power line of a power distribution system; and

a processor coupled to the power supply interface that receives the timing signal, determines a timing value of the timing signal with respect to a reference signal, and determines a location of a connection to the power line based on the timing value.

20

11. The device of claim 10, wherein the reference signal is used by the processor to synchronize a clock that is maintained by the processor.

25 12. The device of claim 10, wherein the processor determines the timing value by determining a propagation delay of the timing signal from a source to the processor, and wherein the reference signal includes a time the timing signal was originally sent by the source.

13. The device of claim 10, wherein the power supply interface receives the reference signal via the power line and provides the reference signal to the processor.

30

14. The device of claim 13, wherein the timing signal and the reference signal are encoded into a power mains signal distributed on the power line via the power distribution system.

15. The device of claim 10, further comprising a communication interface that receives
5 the reference signal via a channel external to the power distribution system.

16. The device of claim 10, wherein the timing signal comprises a fluctuation of a power mains signal distributed by the power distribution system on the power line and caused by a power usage variation of a device receiving power from the power line.
10

17. The device of claim 10, wherein the timing signal is received by the processor at periodic intervals and the timing value is based on the periodic intervals.

18. The device of claim 10, wherein the power distribution system distributes power to
15 a plurality of power outlets in a building that are coupled to the power line, and the processor is included in a device coupled to one of the plurality of power outlets, and the location comprises a position of the one of the plurality of power outlets in the building.

19. The device of claim 10, wherein the timing signal is received in response to a query
20 transmitted, by the processor, via at least one of the power line and a wireless communication.

20. A computer program product stored in a non-transitory computer-readable storage medium comprising computer-executable instructions for performing the method of claim 1.

25

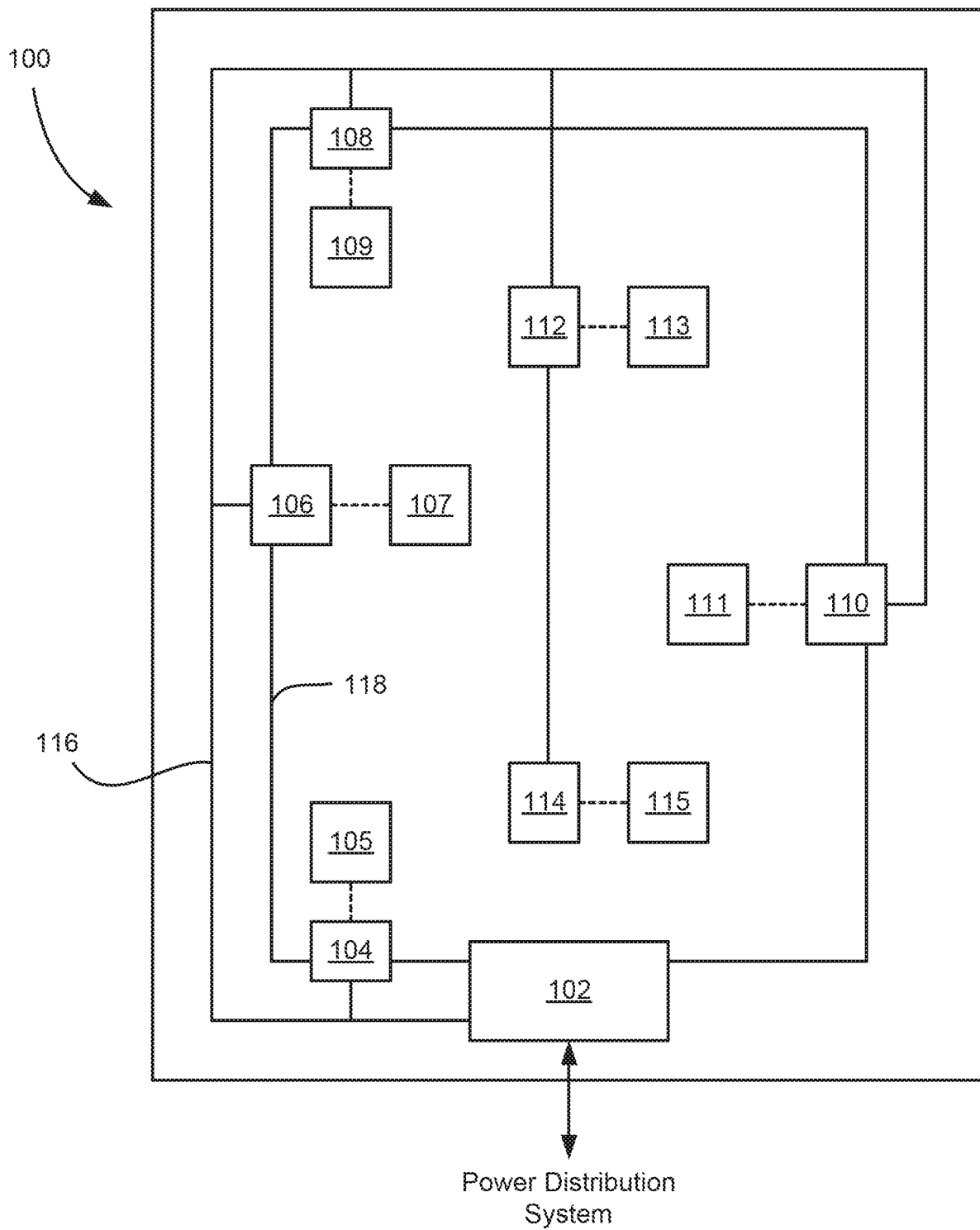


FIG. 1

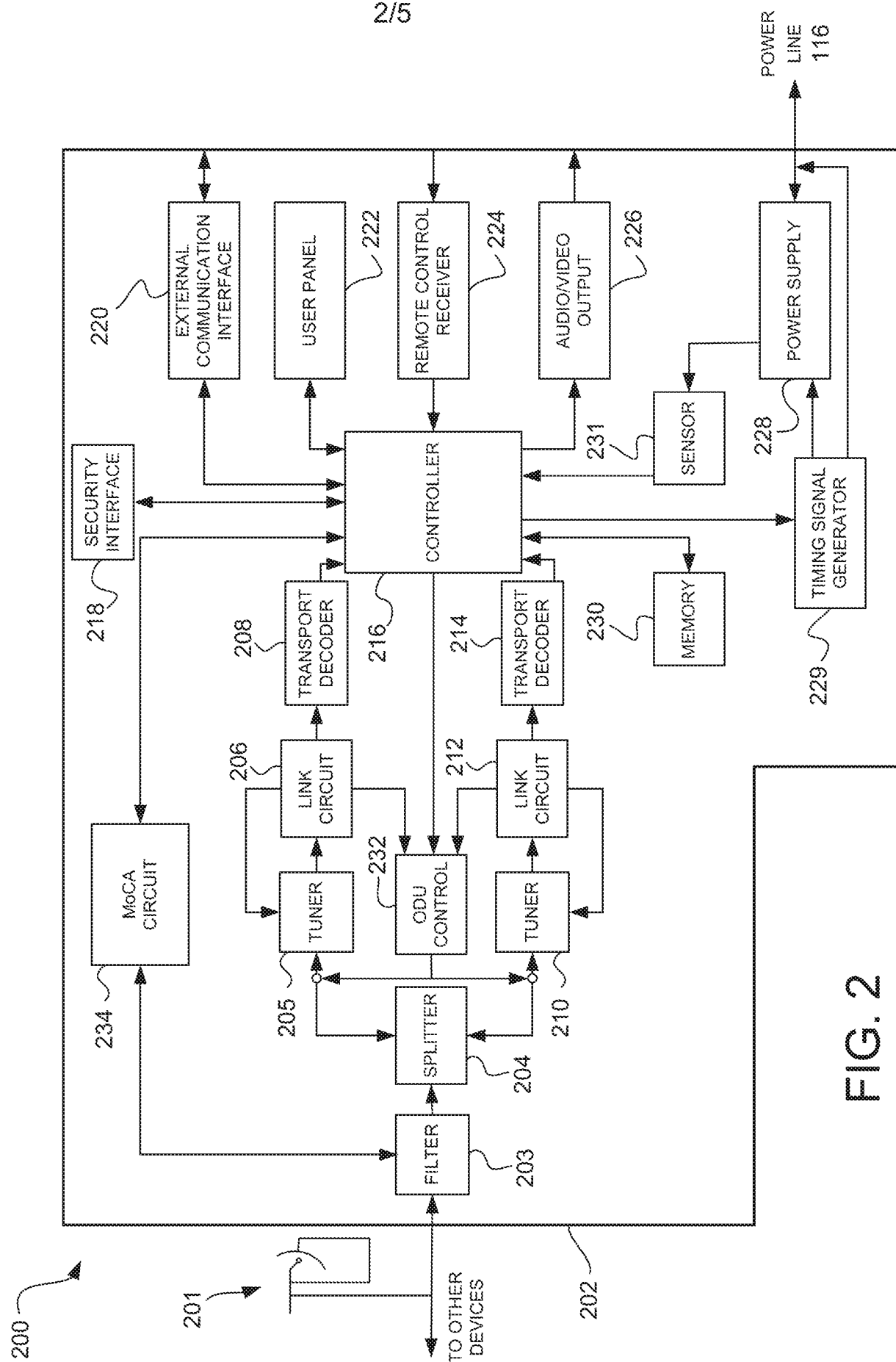


FIG. 2

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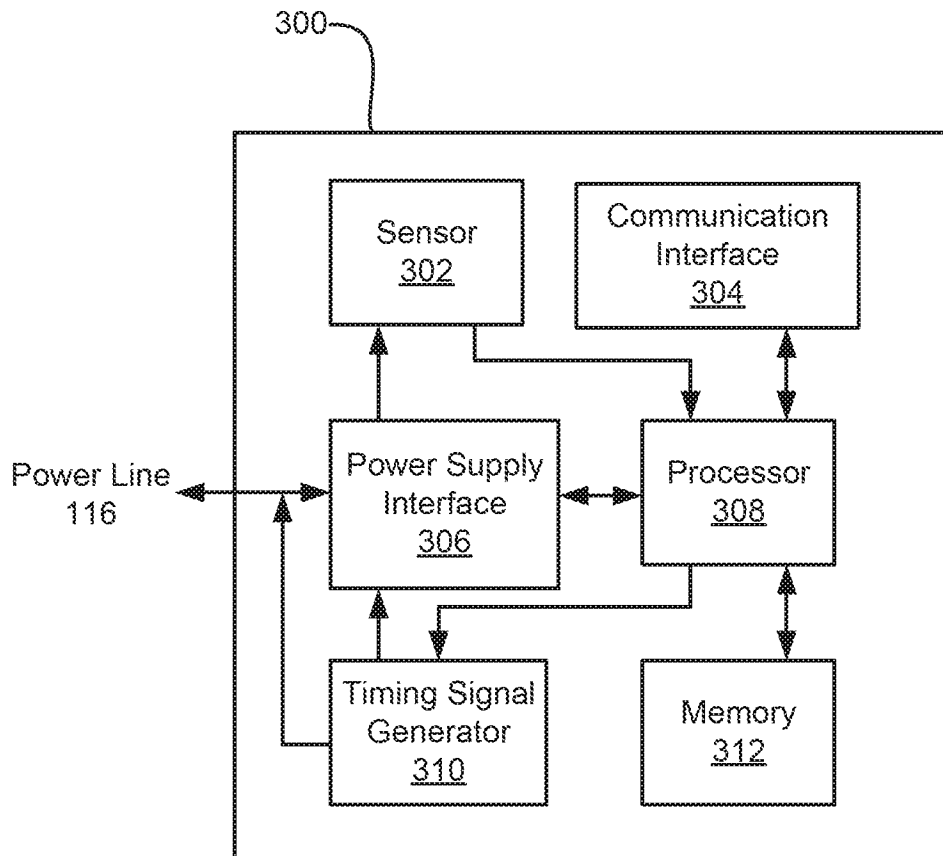


FIG. 3

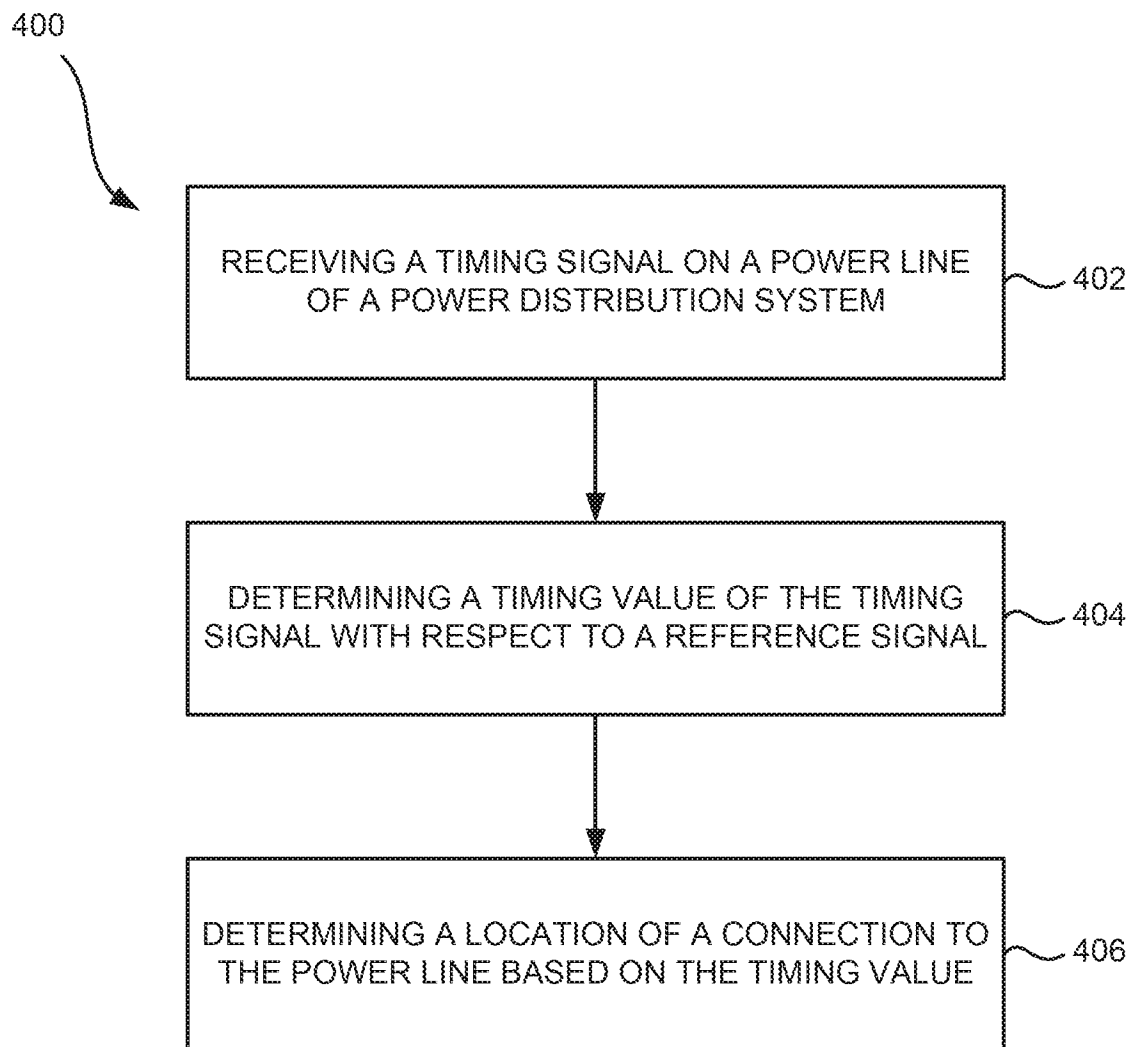


FIG. 4

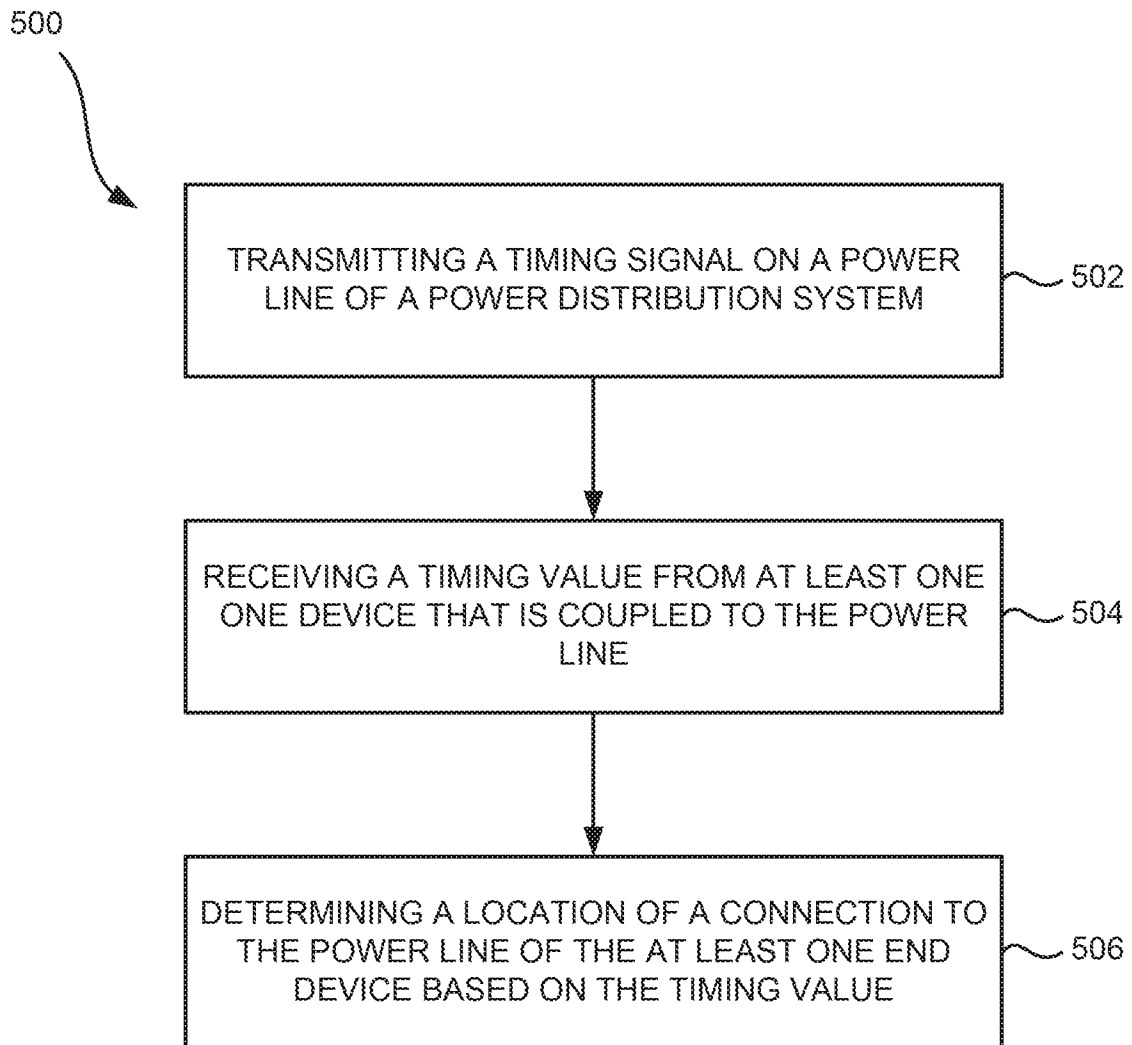


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/055025

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J13/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02J G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

11 January 2018

Date of mailing of the international search report

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Ramcke, Ties

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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