

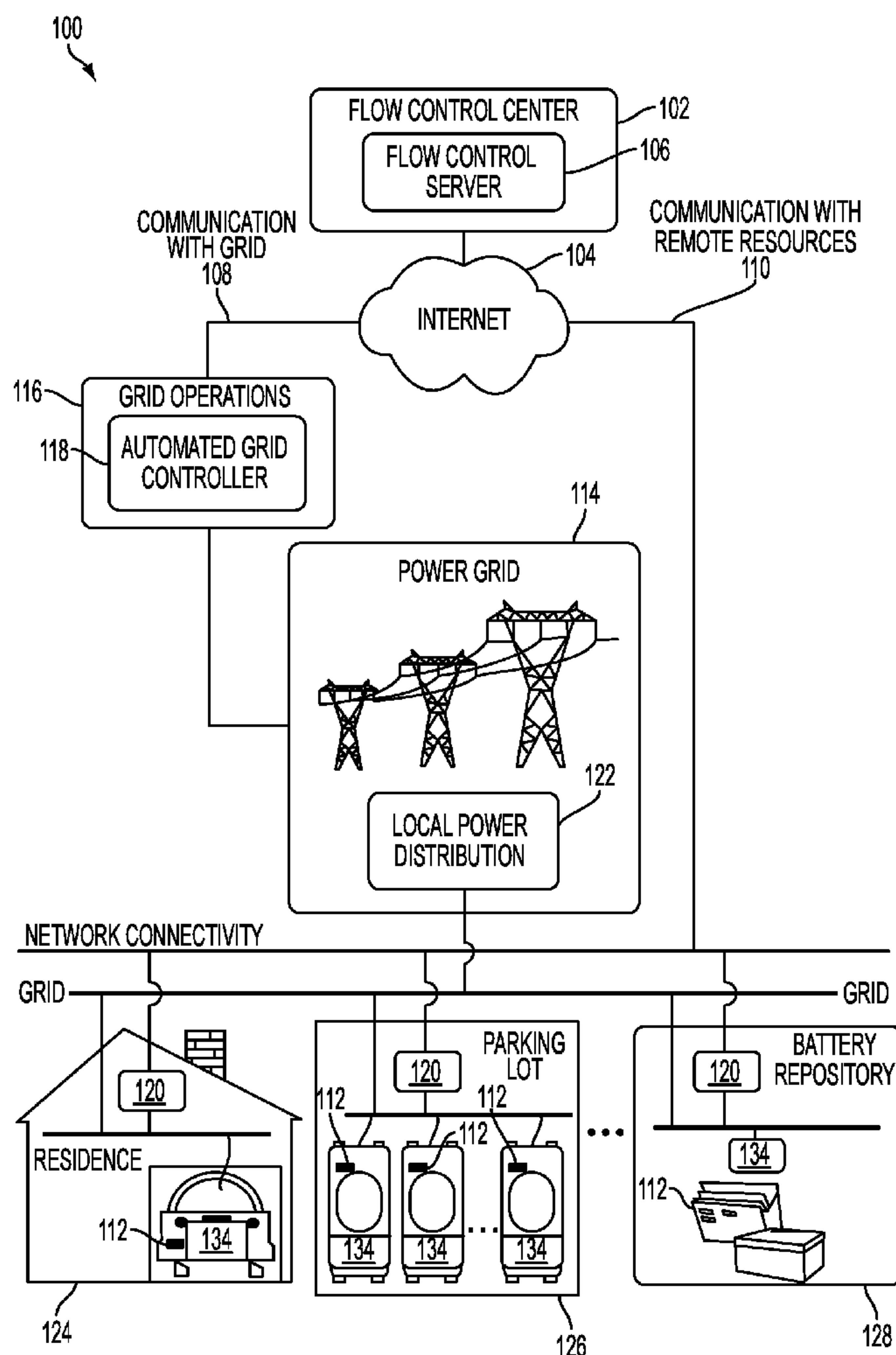
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Bridges et al.(10) **Pub. No.: US 2011/0007824 A1**(43) **Pub. Date: Jan. 13, 2011**(54) **SYSTEM COMMUNICATION SYSTEMS AND
METHODS FOR ELECTRIC VEHICLE
POWER MANAGEMENT****Publication Classification**(51) **Int. Cl.**
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H02J 3/14 (2006.01)(75) Inventors: **Seth W. Bridges**, Seattle, WA (US);
Joby Lafky, Seattle, WA (US)(52) **U.S. Cl.** **375/257; 307/40**(57) **ABSTRACT**

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Washington, DC 20037 (US)(73) Assignee: **GridPoint, Inc.**, Arlington, VA
(US)(21) Appl. No.: **12/751,853**(22) Filed: **Mar. 31, 2010****Related U.S. Application Data**(60) Provisional application No. 61/165,344, filed on Mar.
31, 2009.

A system and method that minimizes network traffic consumption in a power flow management system is described. A minimization system may include a network to communicate device information and power flow information between the power flow management system and the devices. The power flow management system reduces consumption of the traffic traversing the network via a network traffic consumption reduction technique. In addition, this application discloses a system and method for communications protocol translation in a power flow management system that includes networks which connect electric devices and electric power supplies. One network utilizes a communications protocol that is different from the communications protocol utilized by another network. A communications protocol translation device communicates with the networks, and formulates messages from one communications protocol to the other communications protocol. The reformulated messages pass from one network to another network.



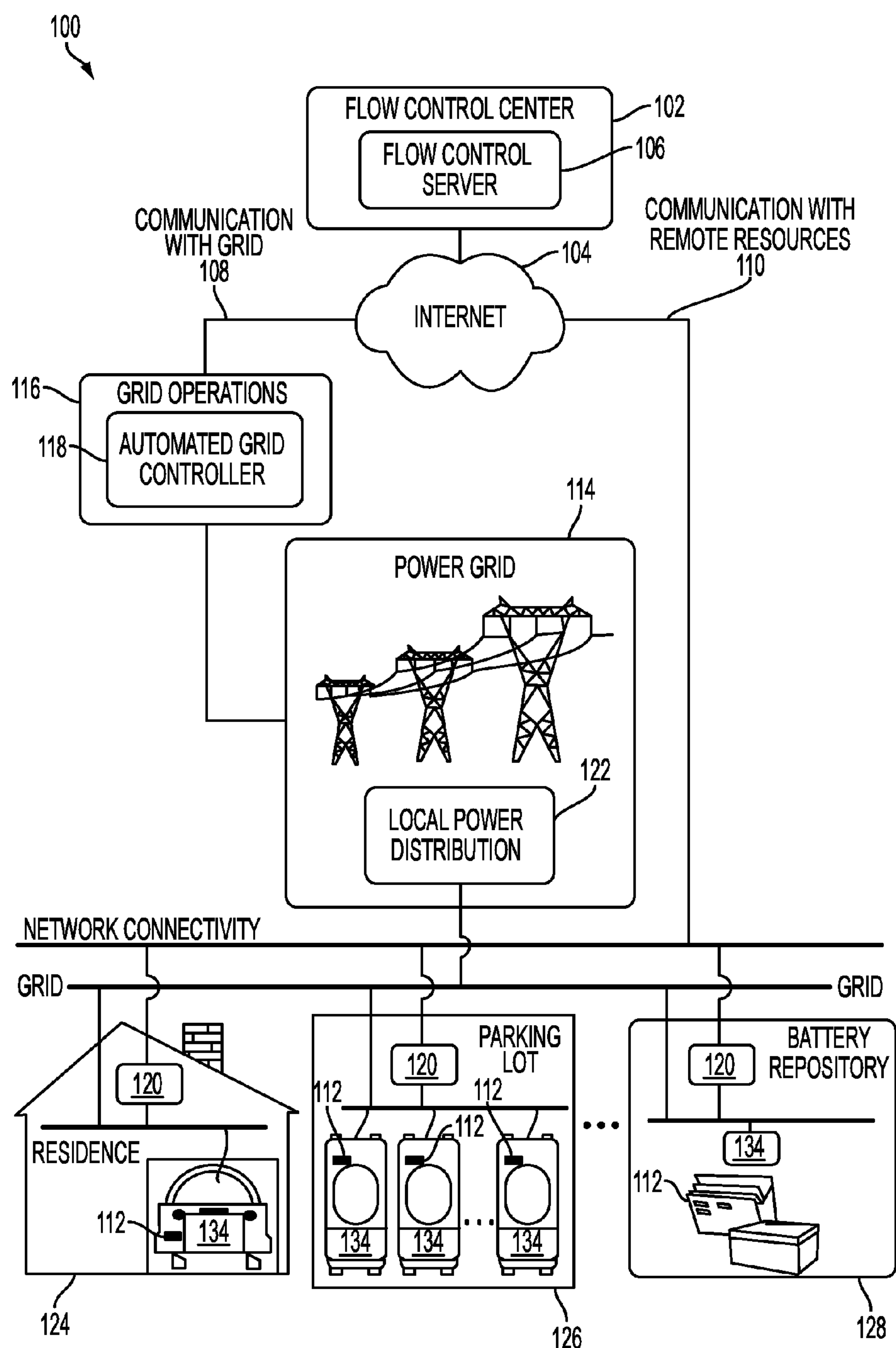


FIG. 1

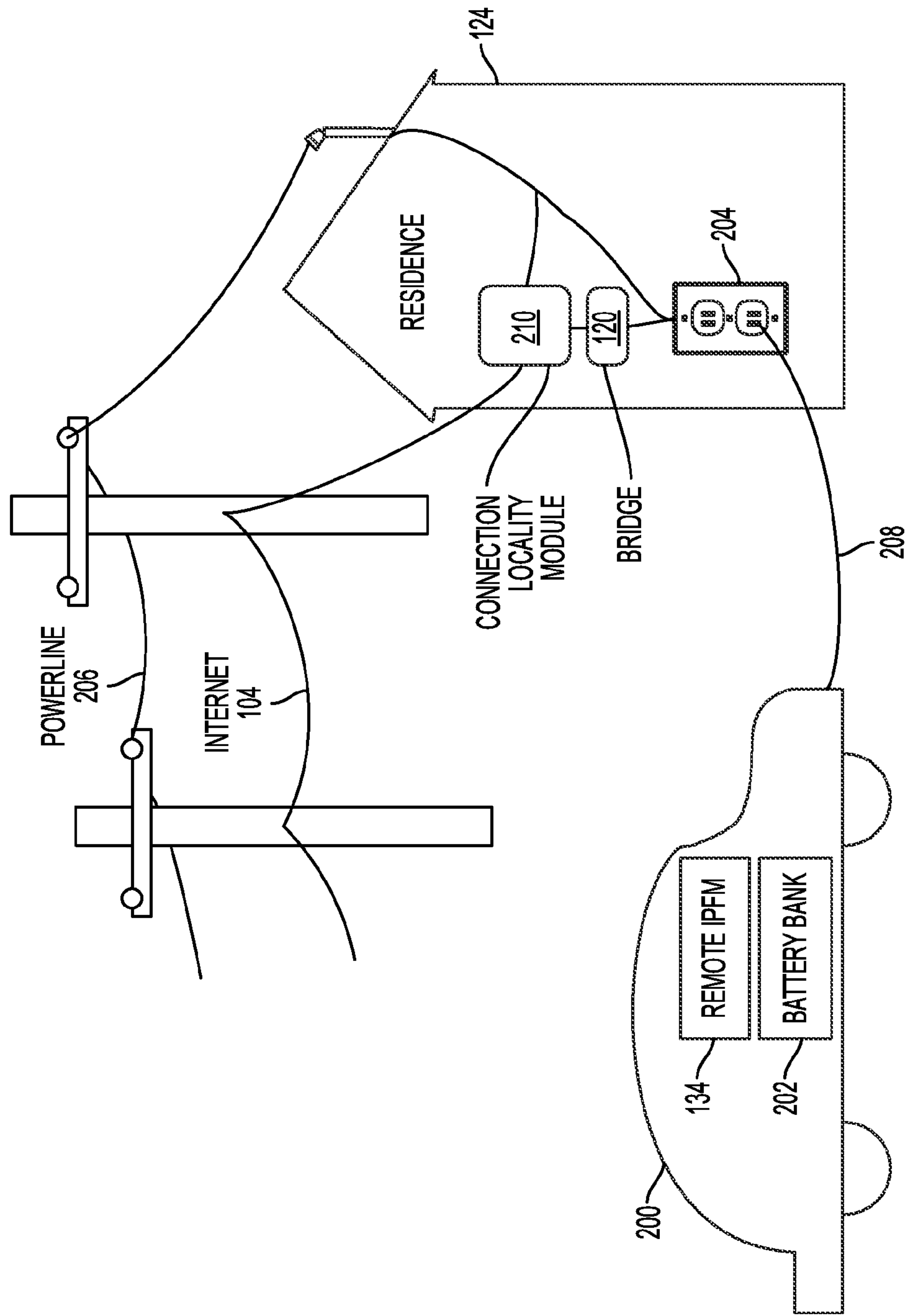


FIG. 2A

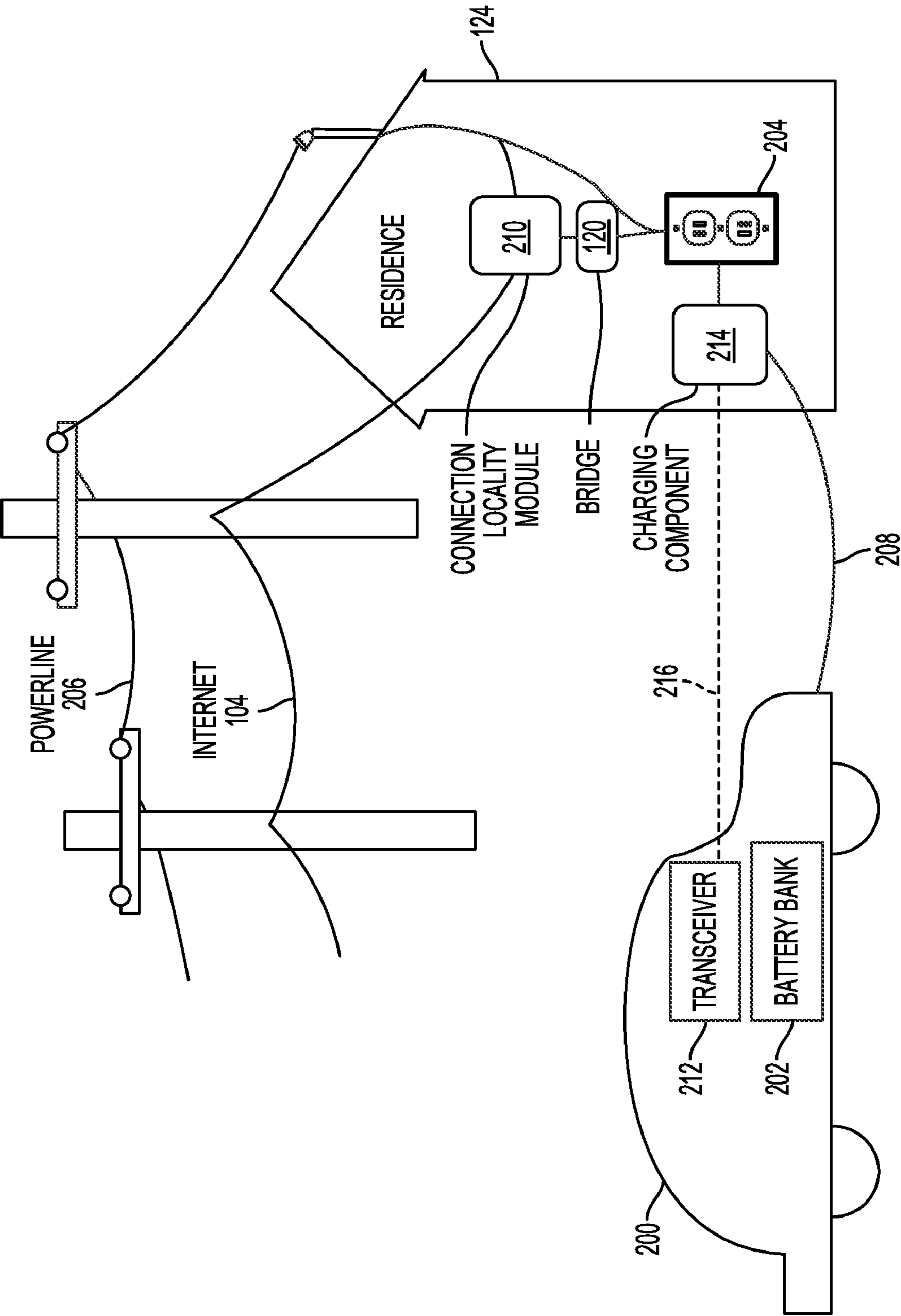


FIG. 2B

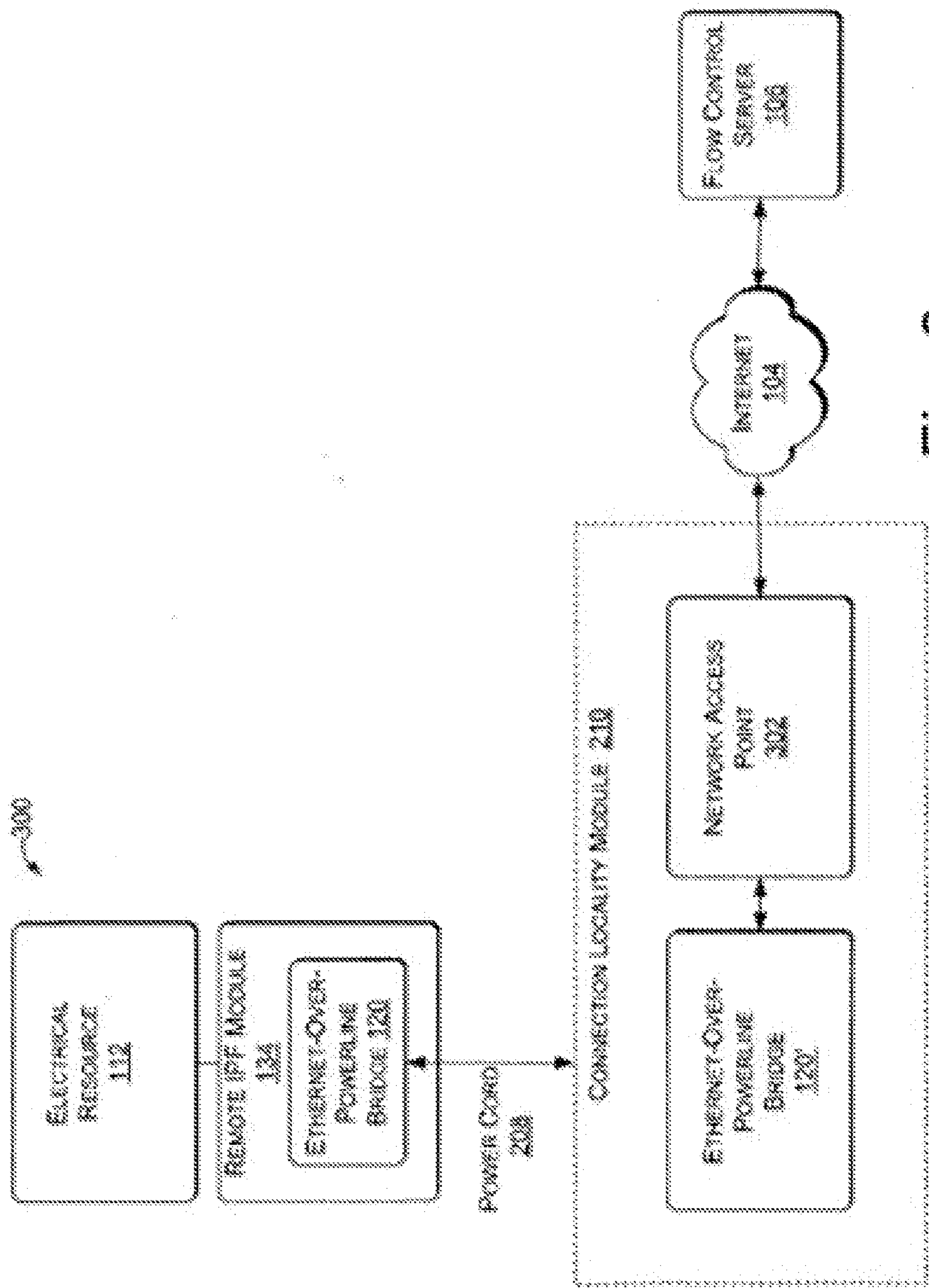


Fig. 3

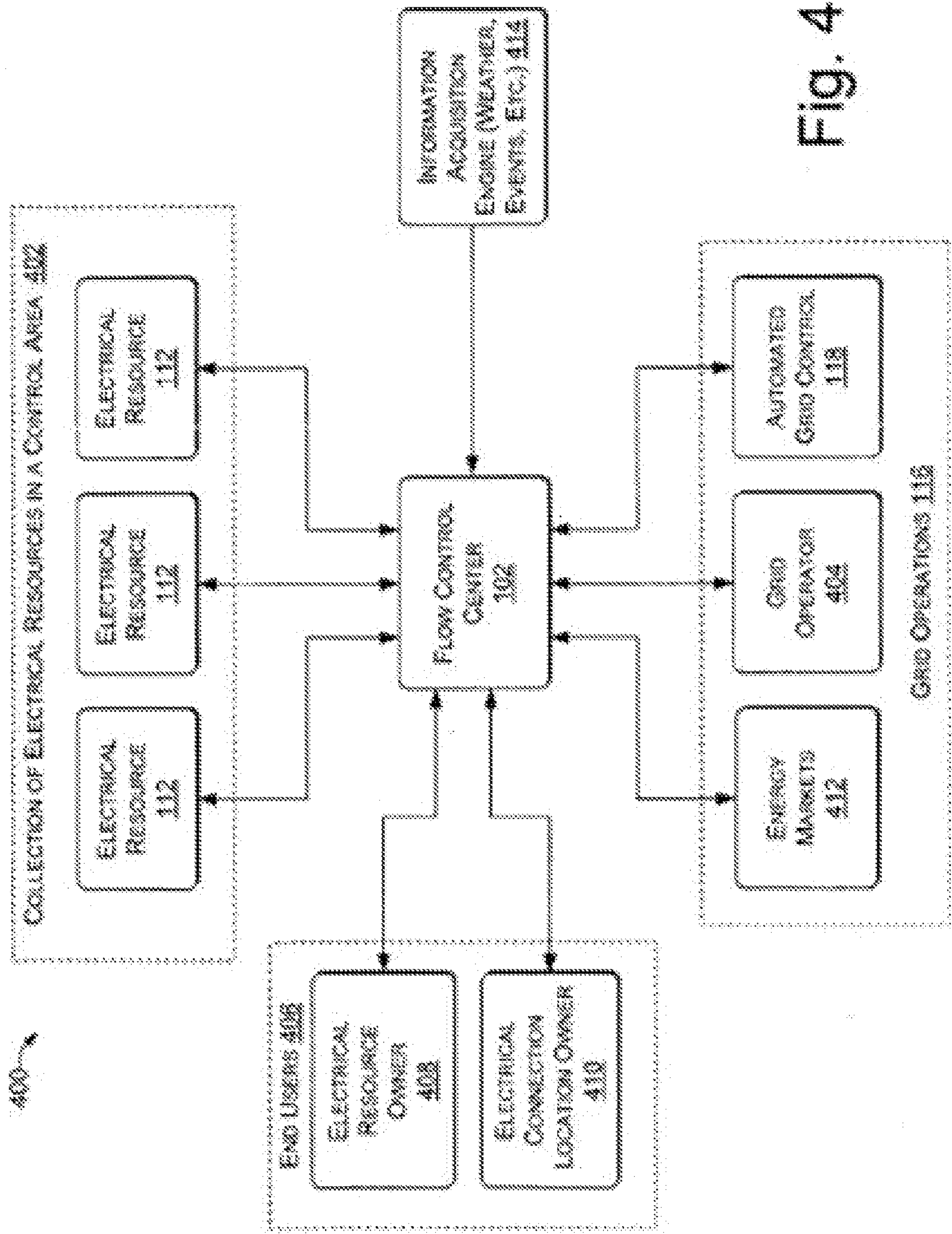


Fig. 4

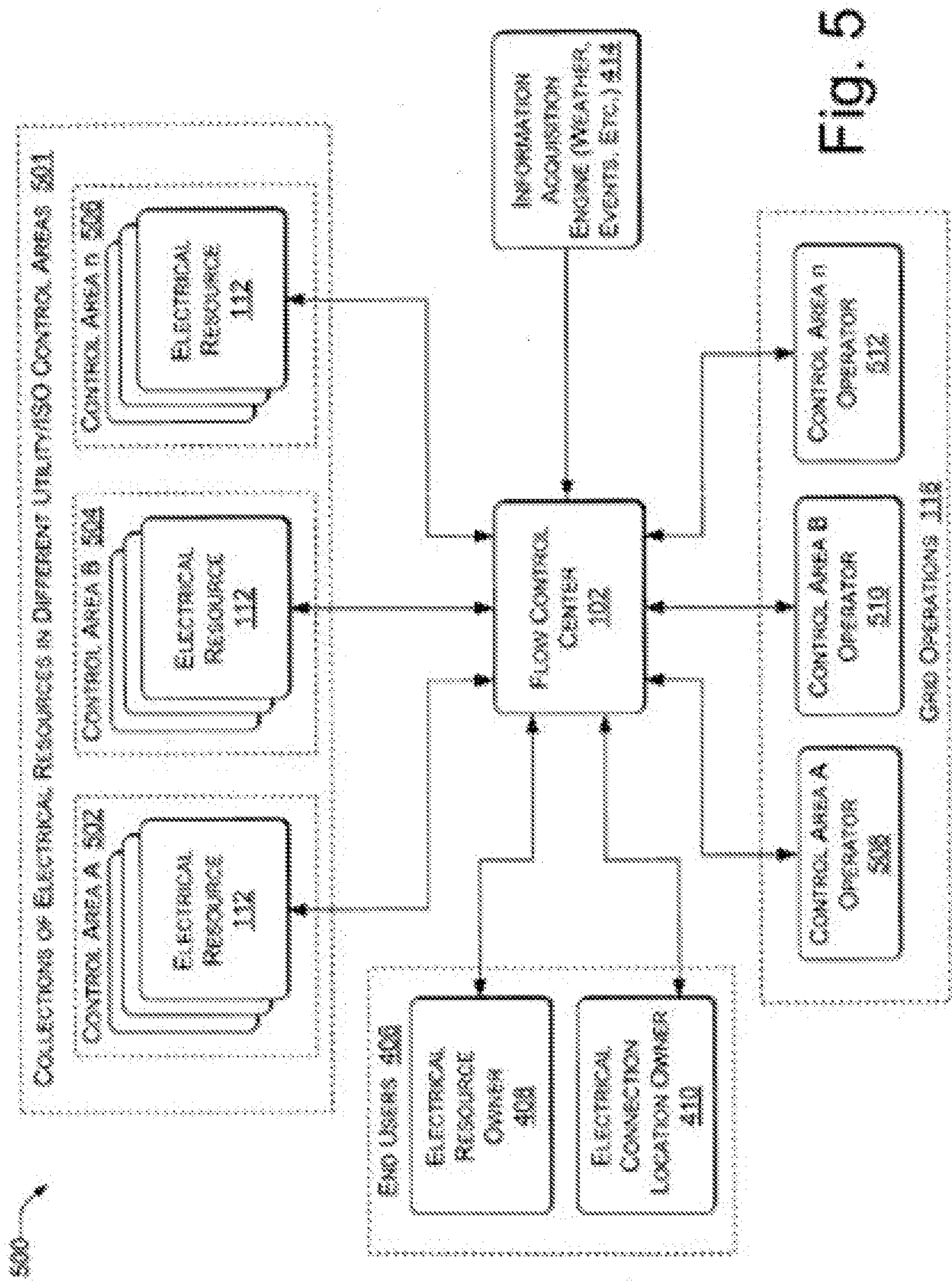


Fig. 5

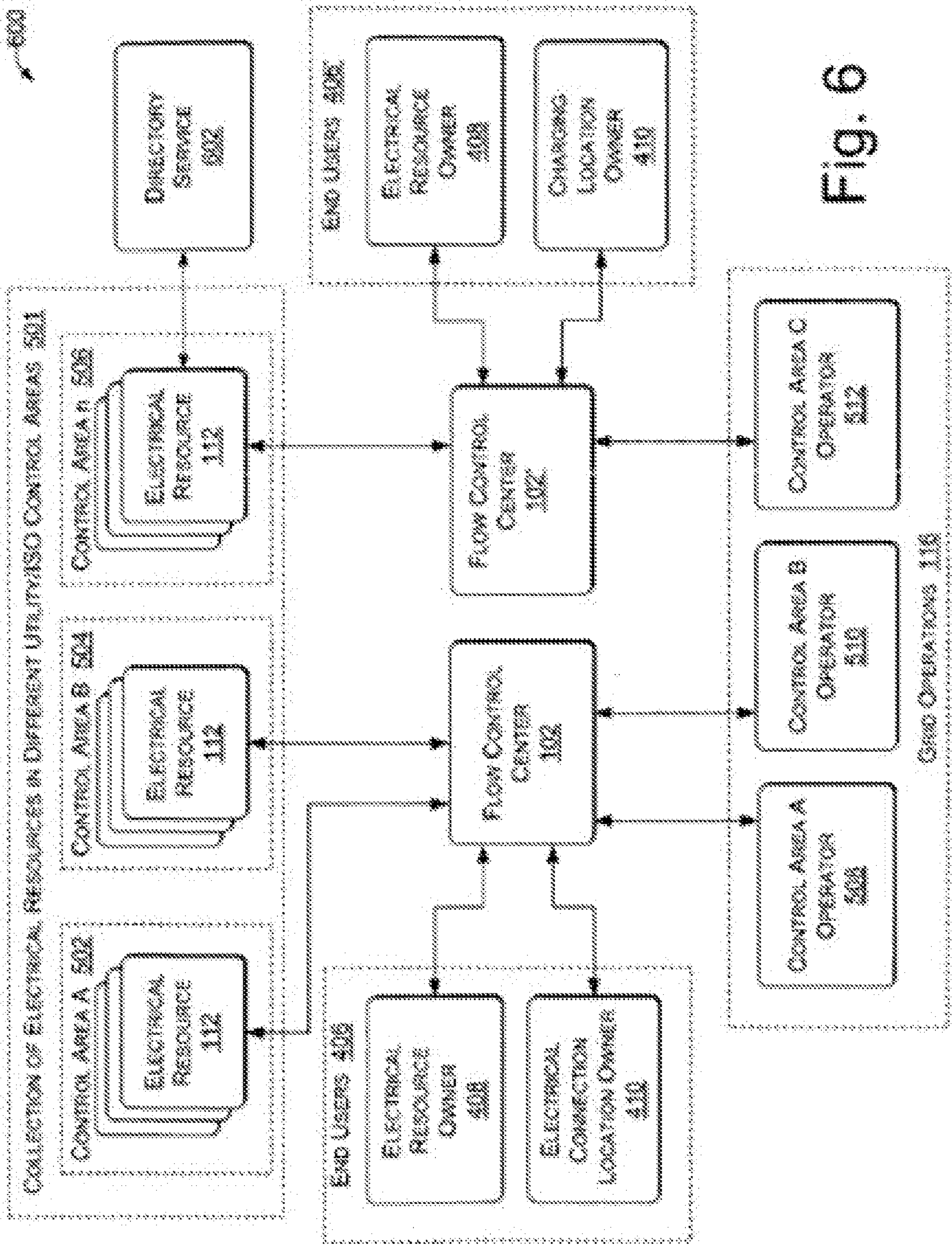


Fig. 6

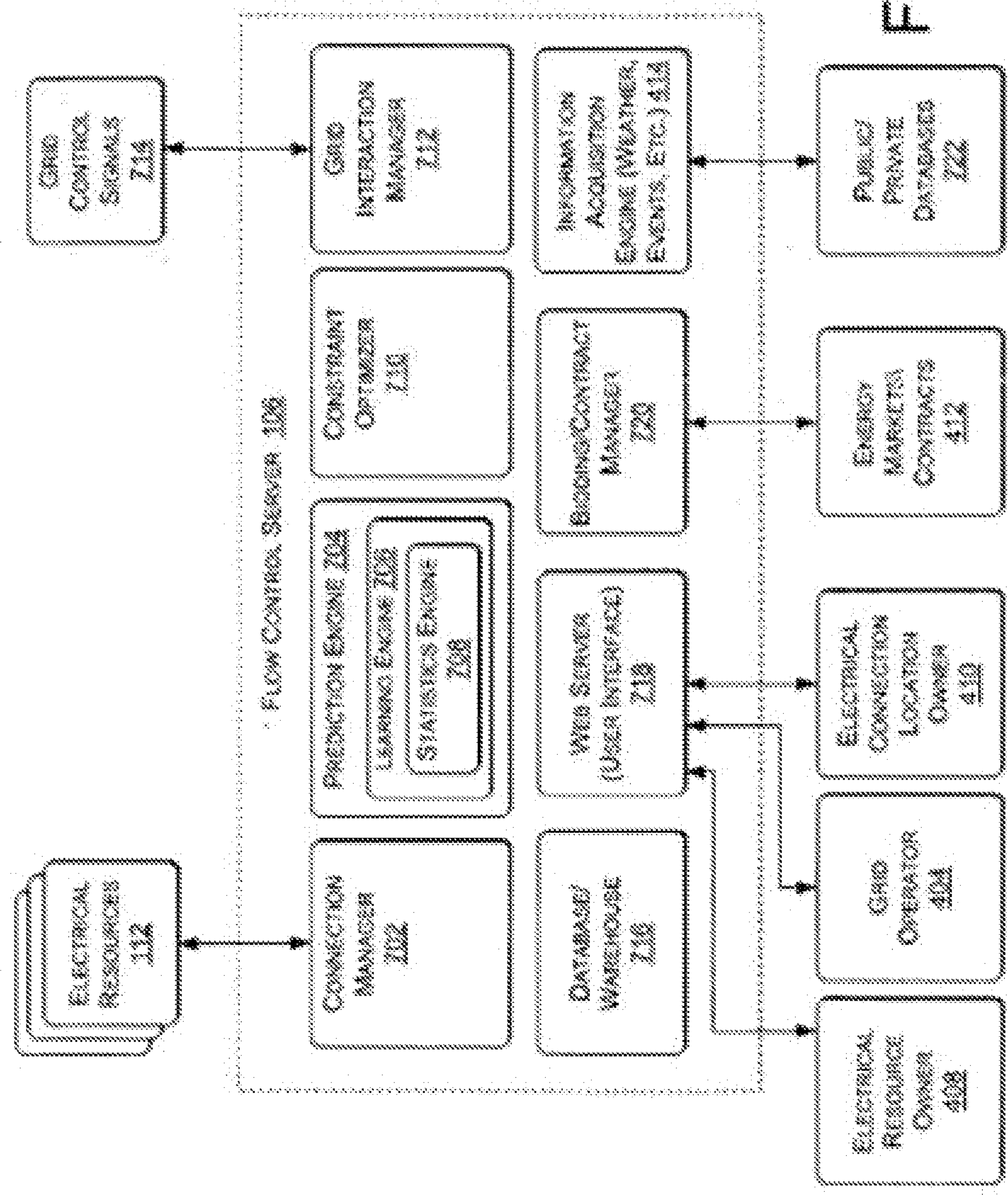
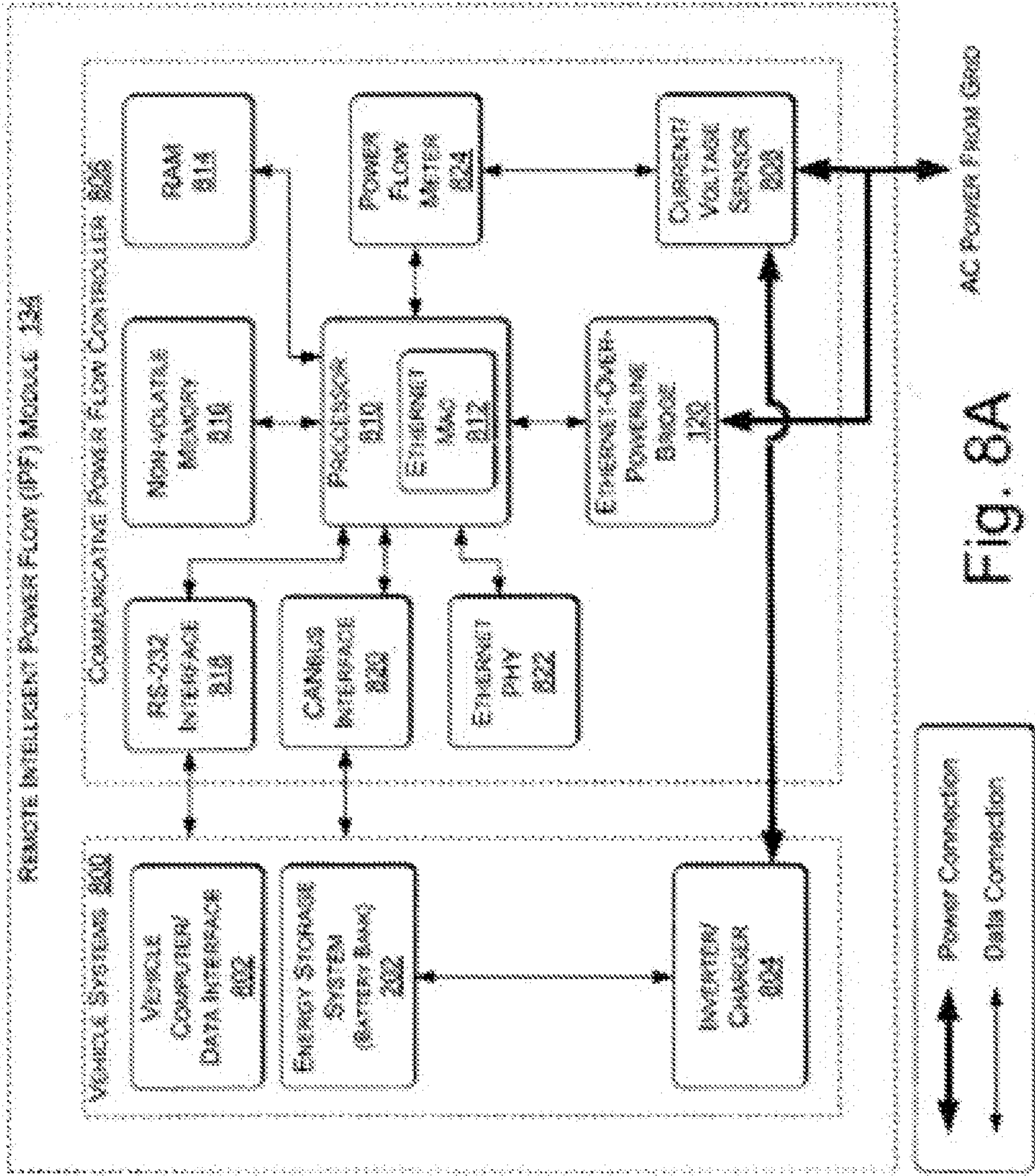
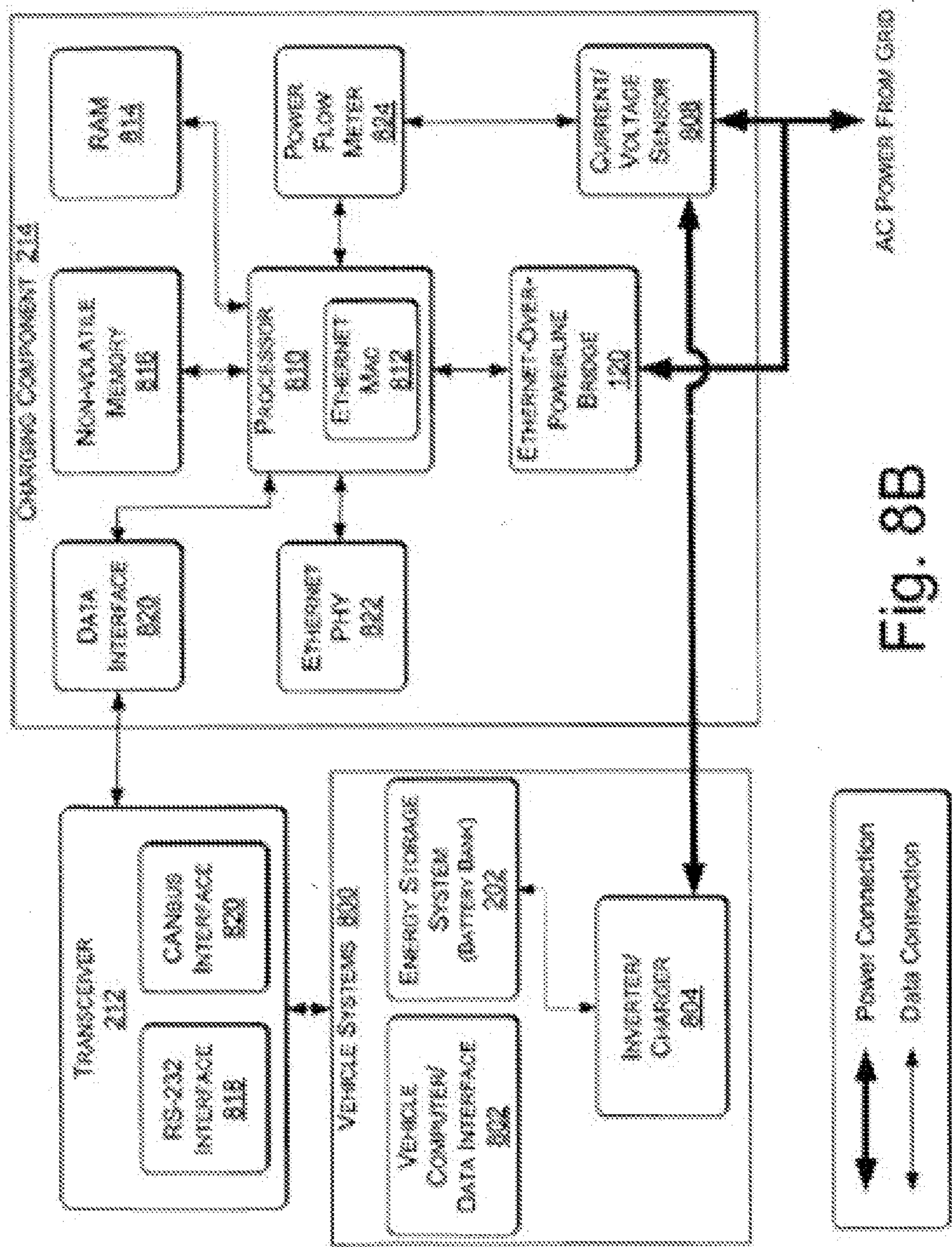


Fig. 7





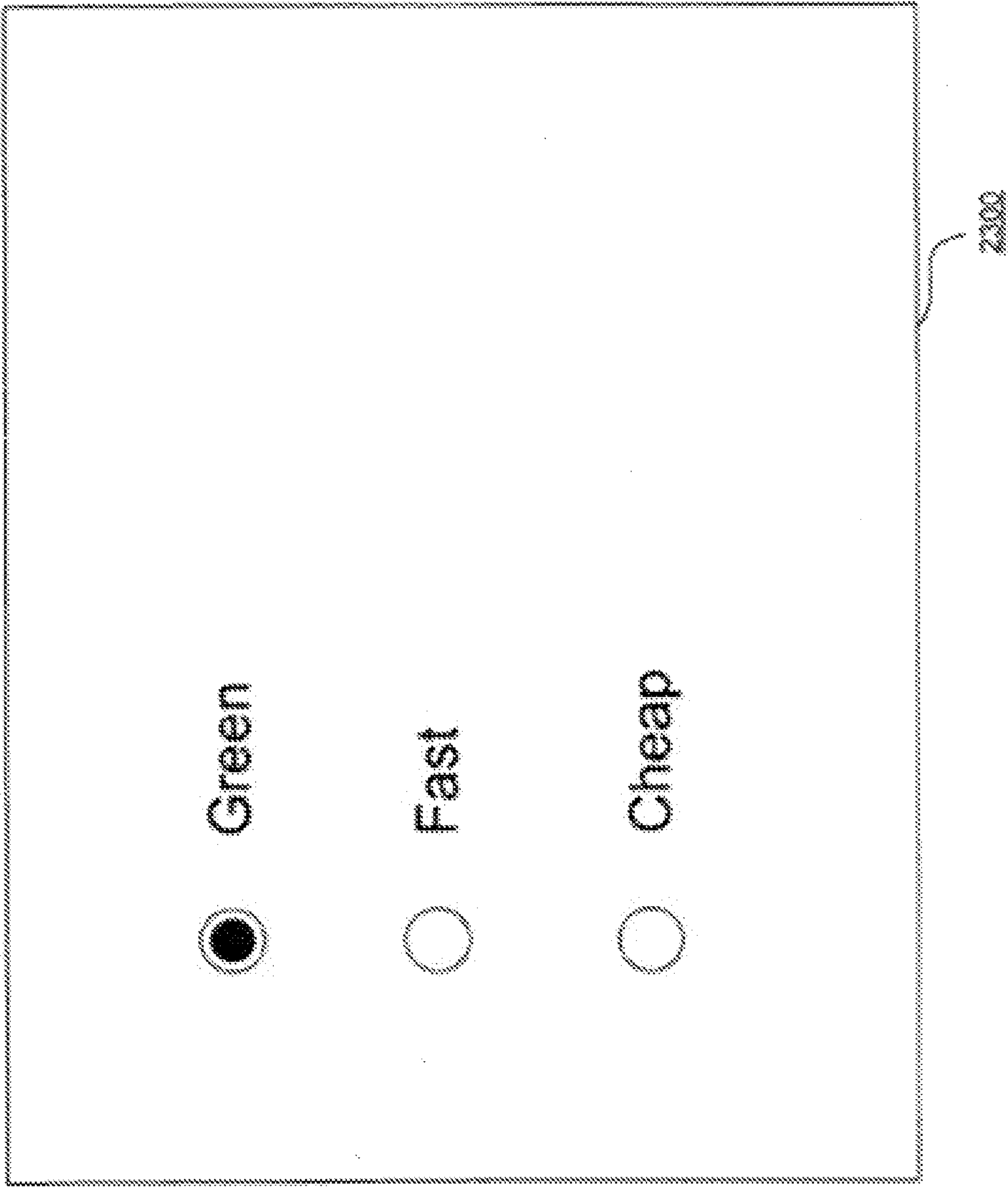


Fig. 8C

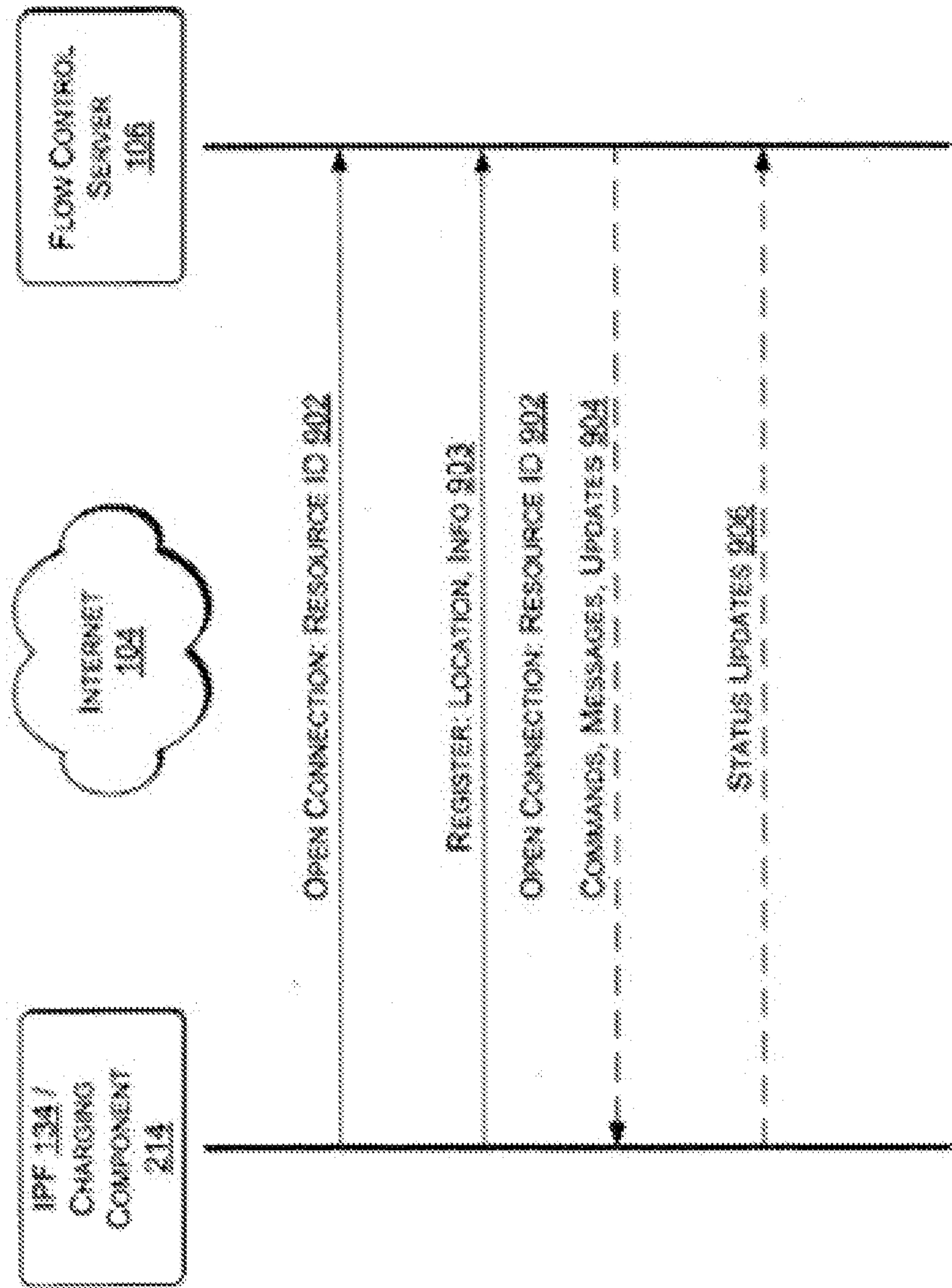


Fig. 9

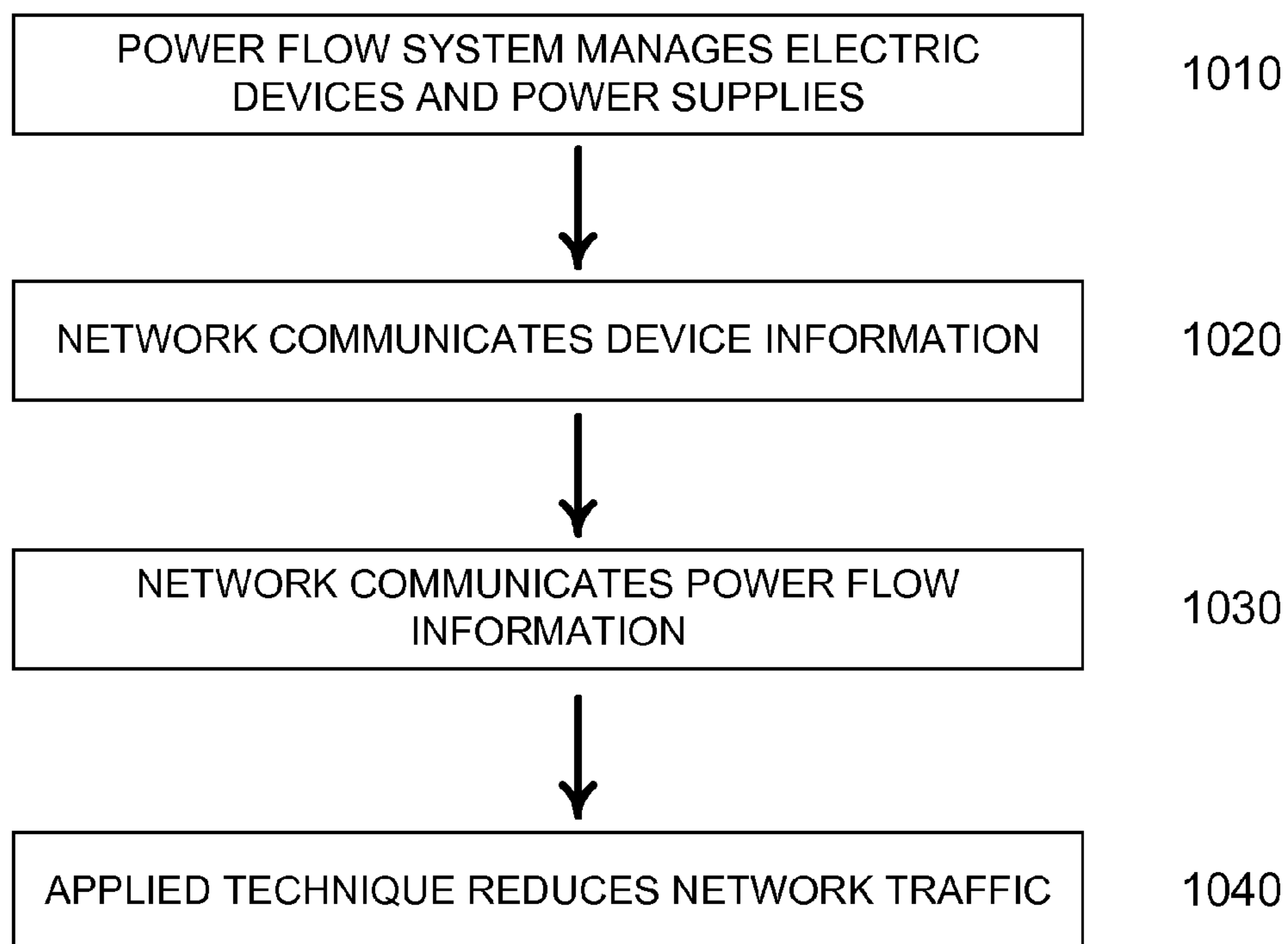


FIG. 10

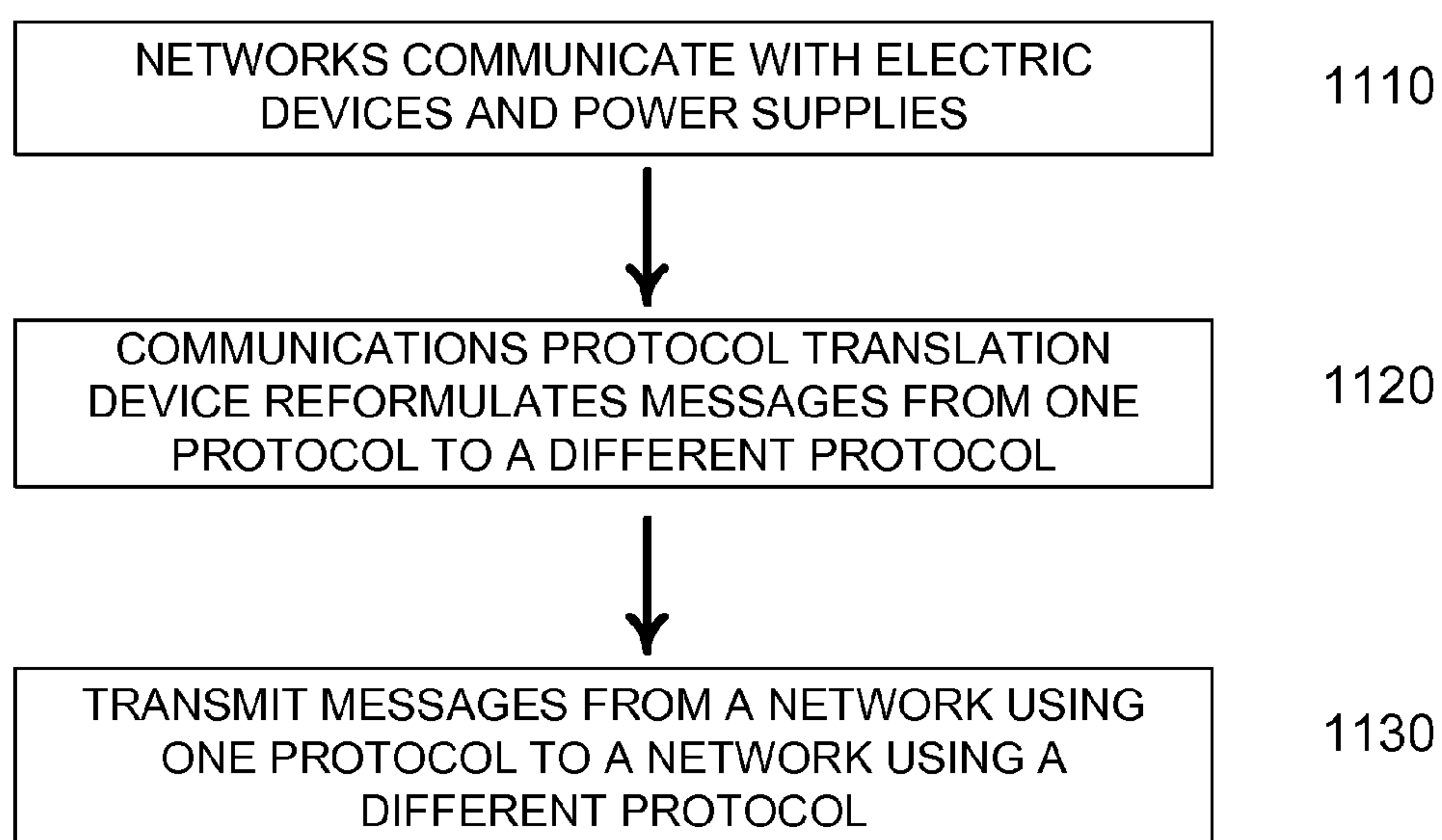


FIG. 11

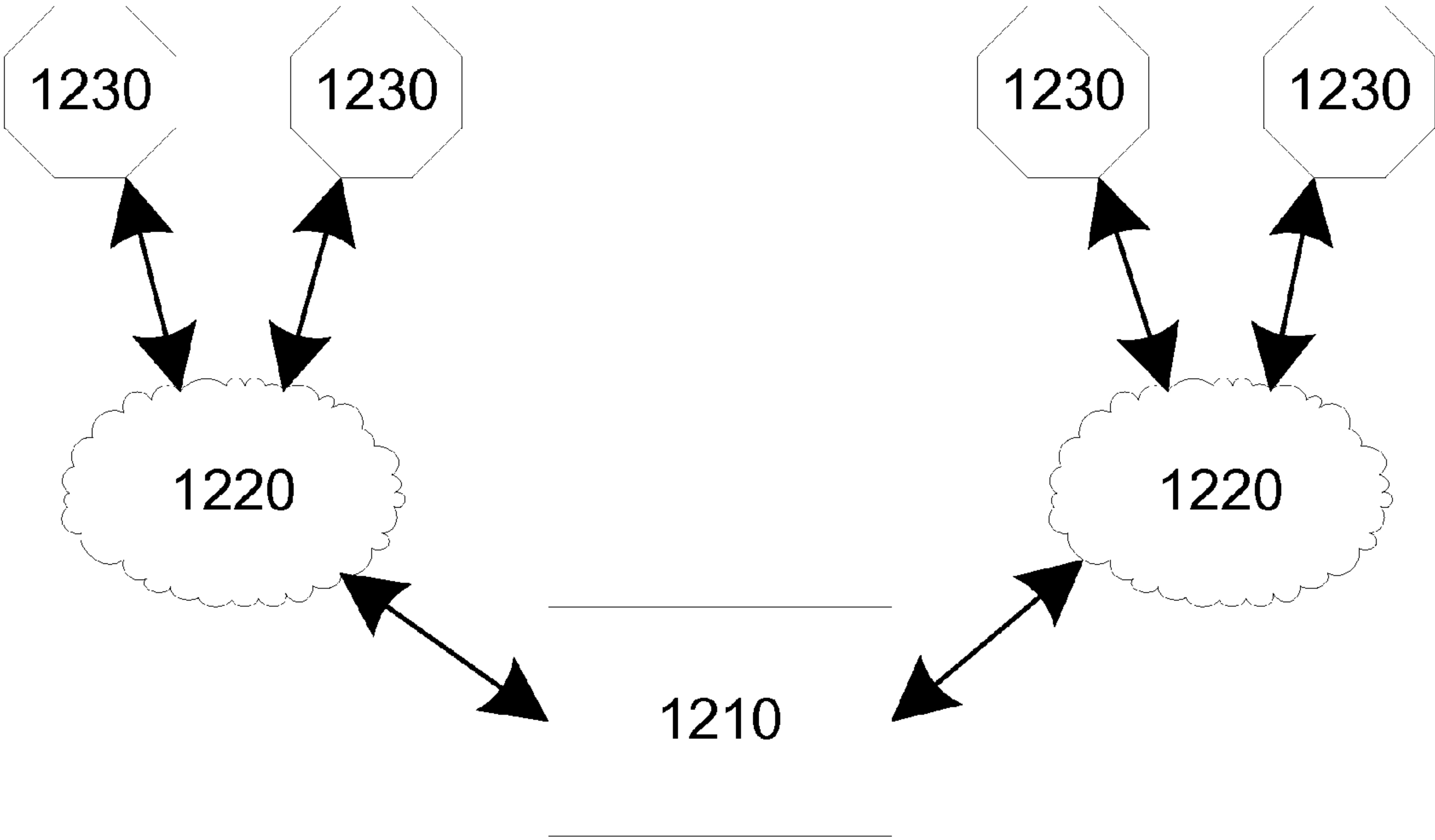


FIG. 12

SYSTEM COMMUNICATION SYSTEMS AND METHODS FOR ELECTRIC VEHICLE POWER MANAGEMENT

[0001] This non-provisional patent application claims priority to, and incorporates herein by reference, U.S. Provisional Patent Application No. 61/165,344 filed on Mar. 31, 2009. This application also incorporates herein by reference the following: U.S. patent application Ser. No. 12/252,657 filed Oct. 16, 2008; U.S. patent application Ser. No. 12/252,209 filed Oct. 15, 2008; U.S. patent application Ser. No. 12/252,803 filed Oct. 16, 2008; and U.S. patent application Ser. No. 12/252,950 filed Oct. 16, 2008.

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FIELD OF THE INVENTION

[0003] The present invention relates in general to the field of electric vehicles, and in particular to novel systems and methods for system communication and interaction between electric vehicles and the electrical grid.

BACKGROUND OF THE INVENTION

[0004] Low-level electrical and communication interfaces to enable charging and discharging of electric vehicles with respect to the grid is described in U.S. Pat. No. 5,642,270 to Green et al., entitled, "Battery powered electric vehicle and electrical supply system," incorporated herein by reference. The Green reference describes a bi-directional charging and communication system for grid-connected electric vehicles.

[0005] Modern vehicles contain a variety of subsystems that may benefit from communications with various off-vehicle entities. As the smart energy marketplace evolves, multiple application-level protocols may further develop for the control of power flow for electric vehicles and within the home. For example, energy management protocols are being developed for both Zigbee and Homeplug. A vehicle manufacturer may need to support multiple physical communications mediums. For example, ZigBee is used in some installations while PLC is used in others. Considering the very long service life of items such as utility meters and automobiles, the use of multiple incompatible protocols may pose an barrier to deployment. For example, if a homeowner buys a car that utilizes one protocol and receives a utility meter that uses another protocol, it is unlikely that either device will quickly replace other device.

[0006] Significant opportunities for improvement exist with respect to communications between power grids and electric vehicles. What is needed are systems and methods that provide for the complexity of translating information among various protocols. In addition to cost of translating messages, there is a cost associated with transmitting messages across networks. As such, there is also a need for novel communication techniques that provide for bandwidth minimization.

SUMMARY OF THE INVENTION

[0007] In one embodiment, a system for minimizing network traffic consumption in a power flow management sys-

tem includes devices operable to generate, consume, or store electric energy, and a power flow management system, which manages power flow transferred between the plurality of devices and a power grid. This minimization system also includes a network to communicate device information and power flow information between the power flow management system and the devices. The device information is received by the power flow management system. The power flow information is transmitted by the power flow management system, and includes an energy rate command received by a devices. The power flow management system reduces consumption of the traffic traversing the network via a network traffic consumption reduction technique.

[0008] In one embodiment of a system for communications protocol translation in a power flow management system, the system includes networks that connect electric devices and electric power supplies. One network utilizes a communications protocol that is different from the communications protocol utilized by another network. A communications protocol translation device communicates with the networks, and formulates messages from one communications protocol to the other communications protocol. The reformulated messages pass from one network to another network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of embodiments as illustrated in the accompanying drawings, in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating principles of the invention.

[0010] FIG. 1 is a diagram of an example of a power aggregation system.

[0011] FIGS. 2A-2B are diagrams of an example of connections between an electric vehicle, the power grid, and the Internet.

[0012] FIG. 3 is a block diagram of an example of connections between an electric resource and a flow control server of the power aggregation system.

[0013] FIG. 4 is a diagram of an example of a layout of the power aggregation system.

[0014] FIG. 5 is a diagram of an example of control areas in the power aggregation system.

[0015] FIG. 6 is a diagram of multiple flow control centers in the power aggregation system and a directory server for determining a flow control center.

[0016] FIG. 7 is a block diagram of an example of flow control server.

[0017] FIG. 8A is a block diagram of an example of remote intelligent power flow module.

[0018] FIG. 8B is a block diagram of an example of transceiver and charging component combination.

[0019] FIG. 8C is an illustration of an example of simple user interface for facilitating user controlled charging.

[0020] FIG. 9 is a diagram of an example of resource communication protocol.

[0021] FIG. 10 is a flow chart of an example of a bandwidth minimization technique.

[0022] FIG. 11 is a flow chart of an example of a protocol translation system.

[0023] FIG. 12 is a block diagram of an example of a communications protocol translation device.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0024] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0025] Overview

[0026] Described herein is a power aggregation system for distributed electric resources, and associated methods. In one implementation, a system communicates over the Internet and/or some other public or private networks with numerous individual electric resources connected to a power grid (hereinafter, “grid”). By communicating, the system can dynamically aggregate these electric resources to provide power services to grid operators (e.g. utilities, Independent System Operators (ISO), etc.).

[0027] “Power services” as used herein, refers to energy delivery as well as other ancillary services including demand response, regulation, spinning reserves, non-spinning reserves, energy imbalance, reactive power, and similar products.

[0028] “Aggregation” as used herein refers to the ability to control power flows into and out of a set of spatially distributed electric resources with the purpose of providing a power service of larger magnitude.

[0029] “Charge Control Management” as used herein refers to enabling or performing the starting, stopping, or level-setting of a flow of power between a power grid and an electric resource.

[0030] “Power grid operator” as used herein, refers to the entity that is responsible for maintaining the operation and stability of the power grid within or across an electric control area. The power grid operator may constitute some combination of manual/human action/intervention and automated processes controlling generation signals in response to system sensors. A “control area operator” is one example of a power grid operator.

[0031] “Control area” as used herein, refers to a contained portion of the electrical grid with defined input and output ports. The net flow of power into this area must equal (within some error tolerance) the sum of the power consumption within the area and power outflow from the area.

[0032] “Power grid” as used herein means a power distribution system/network that connects producers of power with consumers of power. The network may include generators, transformers, interconnects, switching stations, and safety equipment as part of either/both the transmission system (i.e., bulk power) or the distribution system (i.e. retail power). The power aggregation system is vertically scalable for use within a neighborhood, a city, a sector, a control area, or (for example) one of the eight large-scale Interconnects in the North American Electric Reliability Council (NERC). Moreover, the system is horizontally scalable for use in providing power services to multiple grid areas simultaneously.

[0033] “Grid conditions” as used herein, refers to the need for more or less power flowing in or out of a section of the electric power grid, in response to one of a number of conditions, for example supply changes, demand changes, contingencies and failures, ramping events, etc. These grid conditions typically manifest themselves as power quality events such as under- or over-voltage events or under- or over-frequency events.

[0034] “Power quality events” as used herein typically refers to manifestations of power grid instability including voltage deviations and frequency deviations; additionally, power quality events as used herein also includes other disturbances in the quality of the power delivered by the power grid such as sub-cycle voltage spikes and harmonics.

[0035] “Electric resource” as used herein typically refers to electrical entities that can be commanded to do some or all of these three things: take power (act as load), provide power (act as power generation or source), and store energy. Examples may include battery/charger/inverter systems for electric or hybrid-electric vehicles, repositories of used-but-serviceable electric vehicle batteries, fixed energy storage, fuel cell generators, emergency generators, controllable loads, etc.

[0036] “Electric vehicle” is used broadly herein to refer to pure electric and hybrid electric vehicles, such as plug-in hybrid electric vehicles (PHEVs), especially vehicles that have significant storage battery capacity and that connect to the power grid for recharging the battery. More specifically, electric vehicle means a vehicle that gets some or all of its energy for motion and other purposes from the power grid. Moreover, an electric vehicle has an energy storage system, which may consist of batteries, capacitors, etc., or some combination thereof. An electric vehicle may or may not have the capability to provide power back to the electric grid.

[0037] Electric vehicle “energy storage systems” (batteries, super capacitors, and/or other energy storage devices) are used herein as a representative example of electric resources intermittently or permanently connected to the grid that can have dynamic input and output of power. Such batteries can function as a power source or a power load. A collection of aggregated electric vehicle batteries can become a statistically stable resource across numerous batteries, despite recognizable tidal connection trends (e.g., an increase in the total number of vehicles connected to the grid at night; a downswing in the collective number of connected batteries as the morning commute begins, etc.) Across vast numbers of electric vehicle batteries, connection trends are predictable and such batteries become a stable and reliable resource to call upon, should the grid or a part of the grid (such as a person’s home in a blackout) experience a need for increased or decreased power. Data collection and storage also enable the power aggregation system to predict connection behavior on a per-user basis.

[0038] An Example of the Presently Disclosed System

[0039] FIG. 1 shows a power aggregation system 100. A flow control center 102 is communicatively coupled with a network, such as a public/private mix that includes the Internet 104, and includes one or more servers 106 providing a centralized power aggregation service. “Internet” 104 will be used herein as representative of many different types of communicative networks and network mixtures (e.g., one or more wide area networks—public or private—and/or one or more local area networks). Via a network, such as the Internet 104, the flow control center 102 maintains communication 108 with operators of power grid(s), and communication 110 with remote resources, i.e., communication with peripheral electric resources 112 (“end” or “terminal” nodes/devices of a power network) that are connected to the power grid 114. In one implementation, power line communicators (PLCs), such as those that include or consist of Ethernet-over-power line bridges 120 are implemented at connection locations so that the “last mile” (in this case, last feet—e.g., in a residence 124)

of Internet communication with remote resources is implemented over the same wire that connects each electric resource **112** to the power grid **114**. Thus, each physical location of each electric resource **112** may be associated with a corresponding Ethernet-over-power line bridge **120** (hereinafter, “bridge”) at or near the same location as the electric resource **112**. Each bridge **120** is typically connected to an Internet access point of a location owner, as will be described in greater detail below. The communication medium from flow control center **102** to the connection location, such as residence **124**, can take many forms, such as cable modem, DSL, satellite, fiber, WiMax, etc. In a variation, electric resources **112** may connect with the Internet by a different medium than the same power wire that connects them to the power grid **114**. For example, a given electric resource **112** may have its own wireless capability to connect directly with the Internet **104** or an Internet access point and thereby with the flow control center **102**.

[0040] Electric resources **112** of the power aggregation system **100** may include the batteries of electric vehicles connected to the power grid **114** at residences **124**, parking lots **126** etc.; batteries in a repository **128**, fuel cell generators, private dams, conventional power plants, and other resources that produce electricity and/or store electricity physically or electrically.

[0041] In one implementation, each participating electric resource **112** or group of local resources has a corresponding remote intelligent power flow (IPF) module **134** (hereinafter, “remote IPF module” **134**). The centralized flow control center **102** administers the power aggregation system **100** by communicating with the remote IPF modules **134** distributed peripherally among the electric resources **112**. The remote IPF modules **134** perform several different functions, including, but not limited to, providing the flow control center **102** with the statuses of remote resources; controlling the amount, direction, and timing of power being transferred into or out of a remote electric resource **112**; providing metering of power being transferred into or out of a remote electric resource **112**; providing safety measures during power transfer and changes of conditions in the power grid **114**; logging activities; and providing self-contained control of power transfer and safety measures when communication with the flow control center **102** is interrupted. The remote IPF modules **134** will be described in greater detail below.

[0042] In another implementation, instead of having an IPF module **134**, each electric resource **112** may have a corresponding transceiver (not shown) to communicate with a local charging component (not shown). The transceiver and charging component, in combination, may communicate with flow control center **102** to perform some or all of the above mentioned functions of IPF module **134**. A transceiver and charging component are shown in FIG. 2B and are described in greater detail herein.

[0043] FIG. 2A shows another view of electrical and communicative connections to an electric resource **112**. In this example, an electric vehicle **200** includes a battery bank **202** and a remote IPF module **134**. The electric vehicle **200** may connect to a conventional wall receptacle (wall outlet) **204** of a residence **124**, the wall receptacle **204** representing the peripheral edge of the power grid **114** connected via a residential powerline **206**.

[0044] In one implementation, the power cord **208** between the electric vehicle **200** and the wall outlet **204** can be composed of only conventional wire and insulation for conduct-

ing alternating current (AC) power to and from the electric vehicle **200**. In FIG. 2A, a location-specific connection locality module **210** performs the function of network access point—in this case, the Internet access point. A bridge **120** intervenes between the receptacle **204** and the network access point so that the power cord **208** can also carry network communications between the electric vehicle **200** and the receptacle **204**. With such a bridge **120** and connection locality module **210** in place in a connection location, no other special wiring or physical medium is needed to communicate with the remote IPF module **134** of the electric vehicle **200** other than a conventional power cord **208** for providing residential line current at any conventional voltage. Upstream of the connection locality module **210**, power and communication with the electric vehicle **200** are resolved into the powerline **206** and an Internet cable **104**.

[0045] Alternatively, the power cord **208** may include safety features not found in conventional power and extension cords. For example, an electrical plug **212** of the power cord **208** may include electrical and/or mechanical safeguard components to prevent the remote IPF module **134** from electrifying or exposing the male conductors of the power cord **208** when the conductors are exposed to a human user.

[0046] In some embodiments, a radio frequency (RF) bridge (not shown) may assist the remote IPF module **134** in communicating with a foreign system, such as a utility smart meter (not shown) and/or a connection locality module **210**. For example, the remote IPF module **134** may be equipped to communicate over power cord **208** or to engage in some form of RF communication, such as Zigbee or Bluetooth™, and the foreign system may be able to engage in a different form of RF communication. In such an implementation, the RF bridge may be equipped to communicate with both the foreign system and remote IPF module **134** and to translate communications from one to a form the other may understand, and to relay those messages. In various embodiments, the RF bridge may be integrated into the remote IPF module **134** or foreign system, or may be external to both. The communicative associations between the RF bridge and remote IPF module **134** and between the RF bridge and foreign system may be via wired or wireless communication.

[0047] FIG. 2B shows a further view of electrical and communicative connections to an electric resource **112**. In this example, the electric vehicle **200** may include a transceiver **212** rather than a remote IPF module **134**. The transceiver **212** may be communicatively coupled to a charging component **214** through a connection **216**, and the charging component itself may be coupled to a conventional wall receptacle (wall outlet) **204** of a residence **124** and to electric vehicle **200** through a power cord **208**. The other components shown in FIG. 2B may have the couplings and functions discussed with regard to FIG. 2A.

[0048] In various embodiments, transceiver **212** and charging component **214** may, in combination, perform the same functions as the remote IPF module **134**. Transceiver **212** may interface with computer systems of electric vehicle **200** and communicate with charging component **214**, providing charging component **214** with information about electric vehicle **200**, such as its vehicle identifier, a location identifier, and a state of charge. In response, transceiver **212** may receive requests and commands which transceiver **212** may relay to vehicle **200**'s computer systems.

[0049] Charging component **214**, being coupled to both electric vehicle **200** and wall outlet **204**, may effectuate

charge control of the electric vehicle **200**. If the electric vehicle **200** is not capable of charge control management, charging component **214** may directly manage the charging of electric vehicle **200** by stopping and starting a flow of power between the electric vehicle **200** and a power grid **114** in response to commands received from a flow control server **106**. If, on the other hand, the electric vehicle **200** is capable of charge control management, charging component **214** may effectuate charge control by sending commands to the electric vehicle **200** through the transceiver **212**.

[0050] In some embodiments, the transceiver **212** may be physically coupled to the electric vehicle **200** through a data port, such as an OBD-II connector. In other embodiments, other couplings may be used. The connection **216** between transceiver **212** and charging component **214** may be a wireless signal, such as a radio frequency (RF), such as a Zigbee, or Bluetooth™ signal. And charging component **214** may include a receiver socket to couple with power cord **208** and a plug to couple with wall outlet **204**. In one embodiment, charging component **214** may be coupled to connection locality module **210** in either a wired or wireless fashion. For example, charging component **214** may have a data interface for communicating wirelessly with both the transceiver **212** and locality module **210**. In such an embodiment, the bridge **120** may not be required.

[0051] Further details about the transceiver **212** and charging component **214** are illustrated by FIG. 8B and described in greater detail herein.

[0052] FIG. 3 shows another implementation of the connection locality module **210** of FIG. 2, in greater detail. In FIG. 3, an electric resource **112** has an associated remote IPF module **134**, including a bridge **120**. The power cord **208** connects the electric resource **112** to the power grid **114** and also to the connection locality module **210** in order to communicate with the flow control server **106**.

[0053] The connection locality module **210** includes another instance of a bridge **120**, connected to a network access point **302**, which may include such components as a router, switch, and/or modem, to establish a hardwired or wireless connection with, in this case, the Internet **104**. In one implementation, the power cord **208** between the two bridges **120** and **120'** is replaced by a wireless Internet link, such as a wireless transceiver in the remote IPF module **134** and a wireless router in the connection locality module **210**.

[0054] In other embodiments, a transceiver **212** and charging component **214** may be used instead of a remote IPF module **134**. In such an embodiment, the charging component **214** may include or be coupled to a bridge **120**, and the connection locality module **210** may also include a bridge **120'**, as shown. In yet other embodiments, not shown, charging component **214** and connection locality module **210** may communicate in a wired or wireless fashion, as mentioned previously, without bridges **120** and **120'**. The wired or wireless communication may utilize any sort of connection technology known in the art, such as Ethernet or RF communication, such as Zigbee, or Bluetooth.

[0055] System Layouts

[0056] FIG. 4 shows a layout **400** of the power aggregation system **100**. The flow control center **102** can be connected to many different entities, e.g., via the Internet **104**, for communicating and receiving information. The layout **400** includes electric resources **112**, such as plug-in electric vehicles **200**, physically connected to the grid within a single control area

402. The electric resources **112** become an energy resource for grid operators **404** to utilize.

[0057] The layout **400** also includes end users **406** classified into electric resource owners **408** and electrical connection location owners **410**, who may or may not be one and the same. In fact, the stakeholders in a power aggregation system **100** include the system operator at the flow control center **102**, the grid operator **404**, the resource owner **408**, and the owner of the location **410** at which the electric resource **112** is connected to the power grid **114**.

[0058] Electrical connection location owners **410** can include:

[0059] Rental car lots—rental car companies often have a large portion of their fleet parked in the lot. They can purchase fleets of electric vehicles **200** and, participating in a power aggregation system **100**, generate revenue from idle fleet vehicles.

[0060] Public parking lots—parking lot owners can participate in the power aggregation system **100** to generate revenue from parked electric vehicles **200**. Vehicle owners can be offered free parking, or additional incentives, in exchange for providing power services.

[0061] Workplace parking—employers can participate in a power aggregation system **100** to generate revenue from parked employee electric vehicles **200**. Employees can be offered incentives in exchange for providing power services.

[0062] Residences—a home garage can merely be equipped with a connection locality module **210** to enable the homeowner to participate in the power aggregation system **100** and generate revenue from a parked car. Also, the vehicle battery **202** and associated power electronics within the vehicle can provide local power backup power during times of peak load or power outages.

[0063] Residential neighborhoods—neighborhoods can participate in a power aggregation system **100** and be equipped with power-delivery devices (deployed, for example, by homeowner cooperative groups) that generate revenue from parked electric vehicles **200**.

[0064] The grid operations **116** of FIG. 4 collectively include interactions with energy markets **412**, the interactions of grid operators **404**, and the interactions of automated grid controllers **118** that perform automatic physical control of the power grid **114**.

[0065] The flow control center **102** may also be coupled with information sources **414** for input of weather reports, events, price feeds, etc. Other data sources **414** include the system stakeholders, public databases, and historical system data, which may be used to optimize system performance and to satisfy constraints on the power aggregation system **100**.

[0066] Thus, a power aggregation system **100** may consist of components that:

[0067] communicate with the electric resources **112** to gather data and actuate charging/discharging of the electric resources **112**;

[0068] gather real-time energy prices;

[0069] gather real-time resource statistics;

[0070] predict behavior of electric resources **112** (connectedness, location, state (such as battery State-Of-Charge) at a given time of interest, such as a time of connect/disconnect);

[0071] predict behavior of the power grid **114**/load;

[0072] encrypt communications for privacy and data security;

[0073] actuate charging of electric vehicles **200** to optimize some figure(s) of merit;

[0074] offer guidelines or guarantees about load availability for various points in the future, etc.

[0075] These components can be running on a single computing resource (computer, etc.), or on a distributed set of resources (either physically co-located or not).

[0076] Power aggregation systems **100** in such a layout **400** can provide many benefits: for example, lower-cost ancillary services (i.e., power services), fine-grained (both temporal and spatial) control over resource scheduling, guaranteed reliability and service levels, increased service levels via intelligent resource scheduling, and/or firming of intermittent generation sources such as wind and solar power generation.

[0077] The power aggregation system **100** enables a grid operator **404** to control the aggregated electric resources **112** connected to the power grid **114**. An electric resource **112** can act as a power source, load, or storage, and the resource **112** may exhibit combinations of these properties. Control of a set of electric resources **112** is the ability to actuate power consumption, generation, or energy storage from an aggregate of these electric resources **112**.

[0078] FIG. 5 shows the role of multiple control areas **402** in the power aggregation system **100**. Each electric resource **112** can be connected to the power aggregation system **100** within a specific electrical control area. A single instance of the flow control center **102** can administer electric resources **112** from multiple distinct control areas **501** (e.g., control areas **502**, **504**, and **506**). In one implementation, this functionality is achieved by logically partitioning resources within the power aggregation system **100**. For example, when the control areas **402** include an arbitrary number of control areas, control area "A" **502**, control area "B" **504**, . . . , control area "n" **506**, then grid operations **116** can include corresponding control area operators **508**, **510**, . . . , and **512**. Further division into a control hierarchy that includes control division groupings above and below the illustrated control areas **402** allows the power aggregation system **100** to scale to power grids **114** of different magnitudes and/or to varying numbers of electric resources **112** connected with a power grid **114**.

[0079] FIG. 6 shows a layout **600** of a power aggregation system **100** that uses multiple centralized flow control centers **102** and **102'** and a directory server **602** for determining a flow control center. Each flow control center **102** and **102'** has its own respective end users **406** and **406'**. Control areas **402** to be administered by each specific instance of a flow control center **102** can be assigned dynamically. For example, a first flow control center **102** may administer control area A **502** and control area B **504**, while a second flow control center **102'** administers control area n **506**. Likewise, corresponding control area operators (**508**, **510**, and **512**) are served by the same flow control center **102** that serves their respective different control areas.

[0080] In various embodiments, an electric resource may determine which flow control center **102/102'** administers its control area **502/504/506** by communicating with a directory server **602**. The address of the directory server **602** may be known to electric resource **112** or its associated IPF module **134** or charging component **214**. Upon plugging in, the electric resource **112** may communicate with the directory server **602**, providing the directory server **112** with a resource identifier and/or a location identifier. Based on this information, the directory server **602** may respond, identifying which flow control center **102/102'** to use.

[0081] In another embodiment, directory server **602** may be integrated with a flow control server **106** of a flow control center **102/102'**. In such an embodiment, the electric resource **112** may contact the server **106**. In response, the server **106** may either interact with the electric resource **112** itself or forward the connection to another flow control center **102/102'** responsible for the location identifier provided by the electric resource **112**.

[0082] In some embodiments, whether integrated with a flow control server **106** or not, directory server **602** may include a publicly accessible database for mapping locations to flow control centers **102/102'**.

[0083] Flow Control Server

[0084] FIG. 7 shows a server **106** of the flow control center **102**. The illustrated implementation in FIG. 7 is only one example configuration, for descriptive purposes. Many other arrangements of the illustrated components or even different components constituting a server **106** of the flow control center **102** are possible within the scope of the subject matter. Such a server **106** and flow control center **102** can be executed in hardware, software, or combinations of hardware, software, firmware, etc.

[0085] The flow control server **106** includes a connection manager **702** to communicate with electric resources **112**, a prediction engine **704** that may include a learning engine **706** and a statistics engine **708**, a constraint optimizer **710**, and a grid interaction manager **712** to receive grid control signals **714**. Grid control signals **714** are sometimes referred to as generation control signals, such as automated generation control (AGC) signals. The flow control server **106** may further include a database/information warehouse **716**, a web server **718** to present a user interface to electric resource owners **408**, grid operators **404**, and electrical connection location owners **410**; a contract manager **720** to negotiate contract terms with energy markets **412**, and an information acquisition engine **414** to track weather, relevant news events, etc., and download information from public and private databases **722** for predicting behavior of large groups of the electric resources **112**, monitoring energy prices, negotiating contracts, etc.

[0086] Remote IPF Module

[0087] FIG. 8A shows the remote IPF module **134** of FIGS. 1 and 2 in greater detail. The illustrated remote IPF module **134** is only one example configuration, for descriptive purposes. Many other arrangements of the illustrated components or even different components constituting a remote IPF module **134** are possible within the scope of the subject matter. Such a remote IPF module **134** has some hardware components and some components that can be executed in hardware, software, or combinations of hardware, software, firmware, etc. In other embodiments, executable instructions configured to perform some or all of the operations of remote IPF module **134** may be added to hardware of an electric resource **112** such as an electric vehicle that, when combined with the executable instructions, provides equivalent functionality to remote IPF module **134**. References to remote IPF module **134** as used herein include such executable instructions.

[0088] The illustrated example of a remote IPF module **134** is represented by an implementation suited for an electric vehicle **200**. Thus, some vehicle systems **800** are included as part of the remote IPF module **134** for the sake of description. However, in other implementations, the remote IPF module **134** may exclude some or all of the vehicles systems **800** from being counted as components of the remote IPF module **134**.

[0089] The depicted vehicle systems **800** include a vehicle computer and data interface **802**, an energy storage system, such as a battery bank **202**, and an inverter/charger **804**. Besides vehicle systems **800**, the remote IPF module **134** also includes a communicative power flow controller **806**. The communicative power flow controller **806** in turn includes some components that interface with AC power from the grid **114**, such as a powerline communicator, for example an Ethernet-over-powerline bridge **120**, and a current or current/voltage (power) sensor **808**, such as a current sensing transformer.

[0090] The communicative power flow controller **806** also includes Ethernet and information processing components, such as a processor **810** or microcontroller and an associated Ethernet media access control (MAC) address **812**; volatile random access memory **814**, nonvolatile memory **816** or data storage, an interface such as an RS-232 interface **818** or a CAN-bus interface **820**; an Ethernet physical layer interface **822**, which enables wiring and signaling according to Ethernet standards for the physical layer through means of network access at the MAC/Data Link Layer and a common addressing format. The Ethernet physical layer interface **822** provides electrical, mechanical, and procedural interface to the transmission medium—i.e., in one implementation, using the Ethernet-over-powerline bridge **120**. In a variation, wireless or other communication channels with the Internet **104** are used in place of the Ethernet-over-powerline bridge **120**.

[0091] The communicative power flow controller **806** also includes a bidirectional power flow meter **824** that tracks power transfer to and from each electric resource **112**, in this case the battery bank **202** of an electric vehicle **200**.

[0092] The communicative power flow controller **806** operates either within, or connected to an electric vehicle **200** or other electric resource **112** to enable the aggregation of electric resources **112** introduced above (e.g., via a wired or wireless communication interface). These above-listed components may vary among different implementations of the communicative power flow controller **806**, but implementations typically include:

[0093] an intra-vehicle communications mechanism that enables communication with other vehicle components;

[0094] a mechanism to communicate with the flow control center **102**;

[0095] a processing element;

[0096] a data storage element;

[0097] a power meter; and

[0098] optionally, a user interface.

[0099] Implementations of the communicative power flow controller **806** can enable functionality including:

[0100] executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);

[0101] storing locally-cached behavior profiles for “roaming” connectivity (what to do when charging on a foreign system, i.e., when charging in the same utility territory on a foreign meter or in a separate utility territory, or in disconnected operation, i.e., when there is no network connectivity);

[0102] allowing the user to override current system behavior; and

[0103] metering power-flow information and caching meter data during offline operation for later transaction.

[0104] Thus, the communicative power flow controller **806** includes a central processor **810**, interfaces **818** and **820** for communication within the electric vehicle **200**, a powerline

communicator, such as an Ethernet-over-powerline bridge **120** for communication external to the electric vehicle **200**, and a power flow meter **824** for measuring energy flow to and from the electric vehicle **200** via a connected AC powerline **208**.

[0105] Power Flow Meter

[0106] Power is the rate of energy consumption per interval of time. Power indicates the quantity of energy transferred during a certain period of time, thus the units of power are quantities of energy per unit of time. The power flow meter **824** measures power for a given electric resource **112** across a bidirectional flow—e.g., power from grid **114** to electric vehicle **200** or from electric vehicle **200** to the grid **114**. In one implementation, the remote IPF module **134** can locally cache readings from the power flow meter **824** to ensure accurate transactions with the central flow control server **106**, even if the connection to the server is down temporarily, or if the server itself is unavailable.

[0107] Transceiver and Charging Component

[0108] FIG. 8B shows the transceiver **212** and charging component **214** of FIG. 2B in greater detail. The illustrated transceiver **212** and charging component **214** is only one example configuration, for descriptive purposes. Many other arrangements of the illustrated components or even different components constituting the transceiver **212** and charging component **214** are possible within the scope of the subject matter. Such a transceiver **212** and charging component **214** have some hardware components and some components that can be executed in hardware, software, or combinations of hardware, software, firmware, etc.

[0109] The illustrated example of the transceiver **212** and charging component **214** is represented by an implementation suited for an electric vehicle **200**. Thus, some vehicle systems **800** are illustrated to provide context to the transceiver **212** and charging component **214** components.

[0110] The depicted vehicle systems **800** include a vehicle computer and data interface **802**, an energy storage system, such as a battery bank **202**, and an inverter/charger **804**. In some embodiments, vehicle systems **800** may include a data port, such as an OBD-II port, that is capable of physically coupling with the transceiver **212**. The transceiver **212** may then communicate with the vehicle computer and data interface **802** through the data port, receiving information from electric resource **112** comprised by vehicle systems **800** and, in some embodiments, providing commands to the vehicle computer and data interface **802**. In one implementation, the vehicle computer and data interface **802** may be capable of charge control management. In such an embodiment, the vehicle computer and data interface **802** may perform some or all of the charging component **214** operations discussed below. In other embodiments, executable instructions configured to perform some or all of the operations of the vehicle computer and data interface **802** may be added to hardware of an electric resource **112** such as an electric vehicle that, when combined with the executable instructions, provides equivalent functionality to the vehicle computer and data interface **802**. References to the vehicle computer and data interface **802** as used herein include such executable instructions.

[0111] In various embodiments, the transceiver **212** may have a physical form that is capable of coupling to a data port of vehicle systems **800**. Such a transceiver **212** may also include a plurality of interfaces, such as an RS-232 interface **818** and/or a CAN-bus interface **820**. In various embodiments, the RS-232 interface **818** or CAN-bus interface **820**

may enable the transceiver **212** to communicate with the vehicle computer and data interface **802** through the data port. Also, the transceiver may be or comprise an additional interface (not shown) capable of engaging in wireless communication with a data interface **820** of the charging component **214**. The wireless communication may be of any form known in the art, such as radio frequency (RF) communication (e.g., Zigbee, and/or Bluetooth™ communication). In other embodiments, the transceiver may comprise a separate conductor or may be configured to utilize a powerline **208** to communicate with charging component **214**. In yet other embodiments, not shown, transceiver **212** may simply be a radio frequency identification (RFID) tag capable of storing minimal information about the electric resource **112**, such as a resource identifier, and of being read by a corresponding RFID reader of charging component **214**. In such other embodiments, the RFID tag may not couple with a data port or communicate with the vehicle computer and data interface **802**.

[0112] As shown, the charging component **214** may be an intelligent plug device that is physically connected to a charging medium, such as a powerline **208** (the charging medium coupling the charging component **214** to the electric resource **112**) and an outlet of a power grid (such as the wall outlet **204** shown in FIG. 2B). In other embodiments charging component **214** may be a charging station or some other external control. In some embodiments, the charging component **214** may be portable.

[0113] In various embodiments, the charging component **214** may include components that interface with AC power from the grid **114**, such as a powerline communicator, for example an Ethernet-over-powerline bridge **120**, and a current or current/voltage (power) sensor **808**, such as a current sensing transformer.

[0114] In other embodiments, the charging component **214** may include a further Ethernet plug or wireless interface in place of bridge **120**. In such an embodiment, data-over-powerline communication is not necessary, eliminating the need for a bridge **120**. The Ethernet plug or wireless interface may communicate with a local access point, and through that access point to flow control server **106**.

[0115] The charging component **214** may also include Ethernet and information processing components, such as a processor **810** or microcontroller and an associated Ethernet media access control (MAC) address **812**; volatile random access memory **814**, nonvolatile memory **816** or data storage, a data interface **826** for communicating with the transceiver **212**, and an Ethernet physical layer interface **822**, which enables wiring and signaling according to Ethernet standards for the physical layer through means of network access at the MAC/Data Link Layer and a common addressing format. The Ethernet physical layer interface **822** provides electrical, mechanical, and procedural interface to the transmission medium—i.e., in one implementation, using the Ethernet-over-powerline bridge **120**. In a variation, wireless or other communication channels with the Internet **104** are used in place of the Ethernet-over-powerline bridge **120**.

[0116] The charging component **214** may also include a bidirectional power flow meter **824** that tracks power transfer to and from each electric resource **112**, in this case the battery bank **202** of an electric vehicle **200**.

[0117] Further, in some embodiments, the charging component **214** may comprise an RFID reader to read the electric resource information from transceiver **212** when transceiver **212** is an RFID tag.

[0118] Also, in various embodiments, the charging component **214** may include a credit card reader to enable a user to identify the electric resource **112** by providing credit card information. In such an embodiment, a transceiver **212** may not be necessary.

[0119] Additionally, in one embodiment, the charging component **214** may include a user interface, such as one of the user interfaces described in greater detail below.

[0120] Implementations of the charging component **214** can enable functionality including:

[0121] executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);

[0122] storing locally-cached behavior profiles for “roaming” connectivity (what to do when charging on a foreign system or in disconnected operation, i.e., when there is no network connectivity);

[0123] allowing the user to override current system behavior; and

[0124] metering power-flow information and caching meter data during offline operation for later transaction.

[0125] User Interfaces (UI)

[0126] Charging Station UI. An electrical charging station, whether free or for pay, can be installed with a user interface that presents useful information to the user. Specifically, by collecting information about the grid **114**, the electric resource state, and the preferences of the user, the station can present information such as the current electricity price, the estimated recharge cost, the estimated time until recharge, the estimated payment for uploading power to the grid **114** (either total or per hour), etc. The information acquisition engine **414** communicates with the electric resource **112** and with public and/or private data networks **722** to acquire the data used in calculating this information.

[0127] The types of information gathered from the electric resource **112** can include an electric resource identifier (resource ID) and state information like the state of charge of the electric resource **112**. The resource ID can be used to obtain knowledge of the electric resource type and capabilities, preferences, etc. through lookup with the flow control server **106**.

[0128] In various embodiments, the charging station system including the UI may also gather grid-based information, such as current and future energy costs at the charging station.

[0129] User Charge Control UI Mechanisms. In various embodiments, by default, electric resources **112** may receive charge control management via power aggregation system **100**. In some embodiments, an override control may be provided to override charge control management and charge as soon as possible. The override control may be provided, in various embodiments, as a user interface mechanism of the remote IPF module **134**, the charging component **214**, of the electric resource (for example, if electric resource is a vehicle **200**, the user interface control may be integrated with dash controls of the vehicle **200**) or even via a web page offered by flow control server **106**. The control can be presented, for example, as a button, a touch screen option, a web page, or some other UI mechanism. In one embodiment, the UI may be the UI illustrated by FIG. 8C and discussed in greater detail below. In some embodiments, the override is a one-time override, only applying to a single plug-in session. Upon discon-

necting and reconnecting, the user may again need to interact with the UI mechanism to override the charge control management.

[0130] In some embodiments, the user may pay more to charge with the override on than under charge control management, thus providing an incentive for the user to accept charge control management. Such a cost differential may be displayed or rendered to the user in conjunction with or on the UI mechanism. This differential can take into account time-varying pricing, such as Time of Use (TOU), Critical Peak Pricing (CPP), and Real-Time Pricing (RTP) schemes, as discussed above, as well as any other incentives, discounts, or payments that may be forgone by not accepting charge control management.

[0131] UI Mechanism for Management Preferences. In various embodiments, a user interface mechanism of the remote IPF module 134, the charging component 214, of the electric resource (for example, if electric resource is a vehicle 200, the user interface control may be integrated with dash controls of the vehicle 200) or even via a web page offered by flow control server 106 may enable a user to enter and/or edit management preferences to affect charge control management of the user's electric resource 112. In some embodiments, the UI mechanism may allow the user to enter/edit general preferences, such as whether charge control management is enabled, whether vehicle-to-grid power flow is enabled or whether the electric resource 112 should only be charged with clean/green power. Also, in various embodiments, the UI mechanism may enable a user to prioritize relative desires for minimizing costs, maximizing payments (i.e., fewer charge periods for higher amounts), achieving a full state-of-charge for the electric resource 112, charging as rapidly as possible, and/or charging in as environmentally-friendly a way as possible. Additionally, the UI mechanism may enable a user to provide a default schedule for when the electric resource will be used (for example, if resource 112 is a vehicle 200, the schedule is for when the vehicle 200 should be ready to drive). Further, the UI mechanism may enable the user to add or select special rules, such as a rule not to charge if a price threshold is exceeded or a rule to only use charge control management if it will earn the user at least a specified threshold of output. Charge control management may then be effectuated based on any part or all of these user entered preferences.

[0132] Simple User Interface. FIG. 8C illustrates a simple user interface (UI) which enables a user to control charging based on selecting among a limited number of high level preferences. For example, UI 2300 includes the categories "green", "fast", and "cheap" (with what is considered "green", "fast", and "cheap" varying from embodiment to embodiment). The categories shown in UI 2300 are selected only for the sake of illustration and may instead include these and/or any other categories applicable to electric resource 112 charging known in the art. As shown, the UI 2300 may be very basic, using well known form controls such as radio buttons. In other embodiments, other graphic controls known in the art may be used. The general categories may be mapped to specific charging behaviors, such as those discussed above, by a flow control server 106.

[0133] Electric Resource Communication Protocol

[0134] FIG. 9 illustrates a resource communication protocol. As shown, a remote IPF module 134 or charging component 214 may be in communication with a flow control server 106 over the Internet 104 or another networking fabric or

combination of networking fabrics. In various embodiments, a protocol specifying an order of messages and/or a format for messages may be used to govern the communications between the remote IPF module 134 or charging component 214 and flow control server 106.

[0135] In some embodiments, the protocol may include two channels, one for messages initiated by the remote IPF module 134 or charging component 214 and for replies to those messages from the flow control server 106, and another channel for messages initiated by the flow control server 106 and for replies to those messages from the remote IPF module 134 or charging component 214. The channels may be asynchronous with respect to each other (that is, initiation of messages on one channel may be entirely independent of initiation of messages on the other channel). However, each channel may itself be synchronous (that is, once a message is sent on a channel, another message may not be sent until a reply to the first message is received).

[0136] As shown, the remote IPF module 134 or charging component 214 may initiate communication 902 with the flow control server 106. In some embodiments, communication 902 may be initiated when, for example, an electric resource 112 first plugs in/connects to the power grid 114. In other embodiments, communication 902 may be initiated at another time or times. The initial message 902 governed by the protocol may require, for example, one or more of an electric resource identifier, such as a MAC address, a protocol version used, and/or a resource identifier type.

[0137] Upon receipt of the initial message by the flow control server 106, a connection may be established between the remote IPF module 134 or charging component 214 and flow control server 106. Upon establishing a connection, the remote IPF module 134 or charging component 214 may register with flow control server 106 through a subsequent communication 903. Communication 903 may include a location identifier scheme, a latitude, a longitude, a max power value that the remote IPF module 134 or charging component 214 can draw, a max power value that the remote IPF module 134 or charging component 214 can provide, a current power value, and/or a current state of charge.

[0138] After the initial message 902, the protocol may require or allow messages 904 from the flow control server 106 to the remote IPF module 134 or charging component 214 or messages 906 from remote IPF module 134 or charging component 214 to the flow control server 106. The messages 904 may include, for example, one or more of commands, messages, and/or updates. Such messages 904 may be provided at any time after the initial message 902. In one embodiment, messages 904 may include a command setting, a power level and/or a ping to determine whether the remote IPF module 134 or charging component 214 is still connected.

[0139] The messages 906 may include, for example, status updates to the information provided in the registration message 903. Such messages 906 may be provided at any time after the initial message 902. In one embodiment, the messages 906 may be provided on a pre-determined time interval basis. In various embodiments, messages 906 may even be sent when the remote IPF module 134 or charging component 214 is connected, but not registered. Such messages 906 may include data that is stored by flow control server 106 for later processing. Also, in some embodiments, messages 904 may be provided in response to a message 902 or 906.

[0140] Bandwidth Minimization Techniques

[0141] A distributed energy management system must be in constant communication with the distributed energy resources to maintain a high level of certainty that the system is behaving as reported. Sending messages between the energy management system and the distributed energy resources is expensive because each message has a cost associated with it. Minimizing the number of bytes sent between the system and the resources will minimize the communications cost of the system. Accordingly, the consumption of network bandwidth is reduced.

[0142] Bandwidth, as used herein, can refer to network bandwidth. Bandwidth is the number of bytes per second of data traffic that flows into or out of a device or control system. Devices managed by the power flow management system can be any load, generation, or storage asset. Storage assets can comprise batteries and bi-directional power electronics such as inverters and chargers. Load assets may include water heaters, plug-in electric or plug-in hybrid electric vehicles, water heaters, generation facilities, or other controllable load, storage, or generation asset.

[0143] The disclosed system and methods can provide for the minimization of network traffic consumption in a system that manages the power flows to and from devices connected to a power grid. This power flow management system communicates with the devices, and can be centralized or decentralized. Through this communication, information about power flows is communicated to devices and information about device behavior and status is communicated to the system.

[0144] The system communicates with the devices to instruct devices as to when and at what rate energy should be taken from and delivered to the grid. These commands enable the devices to consume or produce energy when doing so is deemed optimal by the power flow management system.

[0145] The instructions that are delivered to the devices by the power flow management system can take many forms. One form of instruction is a direct command to flow power immediately at the requested level. Another form of instruction is a schedule of power flow that should be followed by the device and can take many forms. A schedule can indicate a single point in time at which a power flow level should be activated. A schedule can indicate a sequence of power flow levels that should be activated at various times in the future. The schedule can be repeating on a dynamic or fixed pattern, e.g. repeat a set of actions each day, each week, etc.

[0146] The devices also communicate information to the power flow management system about the current state of the world at the device. Information that can be transmitted for the benefit of controlling power flows includes information about how much power is currently flowing through the device and in what direction, capacity information pertaining to the resource (e.g. storage state of charge, fuel level of a generator), faults and error messages, presence of a resource (e.g.: electric vehicles come and go; is the electric vehicle currently available), scheduling constraints (e.g. how long is the resource available), energy consumption in a period (e.g. kWh consumed/produced in the last time period), etc.

[0147] Sending messages between the power flow management system and the devices requires the sending of data bytes across a network, which consumes network bandwidth. Because many communications costs can be directly measured by the number of bytes transferred to and from a device, minimizing the transfer of bytes between the device and the

power flow management system minimizes the communications costs and consumption of network bandwidth.

[0148] A power flow management system can perform in a more efficient manner when it has complete information about the state of all of the devices under its control at all times. To realize this level of information awareness requires all assets to communicate all information pertaining to the power flow management system in a timely fashion. Such a level of information communication comes with an associated cost.

[0149] There are a number of techniques that can be used to reduce the network traffic consumption in a power flow management system to reduce the cost of communicating with the distributed assets. Such techniques include the following: data compression, data overhead reduction, action/schedule pre-distribution, minimum change dispatch, communication of all status changes, configuration limits on relevant behavior, and non-time-critical information bundling. These bandwidth minimization techniques, and embodiments thereof, are further described below.

[0150] Data Compression. One of the techniques for minimizing bytes between the system and the distributed resources is data compression within a message. Compressing the data that is sent between the power flow management system and the distributed devices can reduce the total network traffic consumption.

[0151] A power flow management system that communicates with devices can send compressed messages to save on network traffic. One manner in which this works is to have both the power flow management server and the device use a compression algorithm or library (such as zlib or gzip) to compress data before transmission and to decompress data after transmission.

[0152] Reducing Data Overhead. In one technique, more bytes are included into a single message in order to reduce per-message overhead. Because each network message has some associated overhead, it is beneficial to put more data into a single message to reduce the network consumption on overhead traffic.

[0153] A device that is part of a power flow management system may collect data from its sensors and internal processes. For the bits of data that are not time critical to the system, the device can cache the data until the ratio of data to overhead is less than 5%. In the case of TCP/IP, this means waiting until the device had gathered 1280 bytes of data before sending.

[0154] Action and Schedule Pre-distribution. For complicated or long sequences of actions, these actions can be pre-distributed to the devices (or distributed one time over the network). When any of the pre-distributed actions need to be communicated, an identifier for the more complicated sequence is all that needs to be communicated. For dispatching actions or sets of actions, pre-compute large sets of actions can be directed using an action identifier. As such, the action sets are coded and only the code is transmitted. While this method consumes memory on the client and server, bandwidth consumption is reduced.

[0155] To achieve an application-level data compression, a power flow management system can define a set of compact messages that represent a pre-defined set of functionality. For example, consider a device that runs just 4 distinct schedules during its normal behavior. Rather than send the schedule that the device should run each time the behavior should begin, the power flow management system can send the device each

schedule just once. Subsequent times that each of those four schedules need to run, the power flow management system can indicate which of the four schedules to run (by name or ID), and a substantial amount of bandwidth can be saved.

[0156] Minimum Change Dispatch. Another technique for minimizing bytes between the system and the distributed resources includes dispatching resources in a way that minimizes the total state change on a per-resource basis within the system. In one example, as few resources as possible communicate in order to effect the desired change within the system. Each time that the power flow management system needs to change the state of the distributed devices (e.g. now there is a need for 15 MW of power flow in some part of the grid, where the earlier needs was for only 13 MW), it can choose to achieve the targeted power flow by looking for the minimum number of changes in the system (e.g. a device that was off needs to be on or vice versa) that satisfies the constraint. In one embodiment, techniques use a single bit to toggle from one state to another, such as from off to on and from on to off.

[0157] There are many different algorithms that a power flow management system can use to determine which of the connected devices should be at what power flow level at any point in time. Should the power flow management system need to revise the net aggregate behavior of the power flow management system, it will likely need to communicate with some subset of the connected resources to signal a change in behavior.

[0158] One measure of the quality of a particular set of device change orders is how many of the resources need to be contacted to enact the change. One algorithm for achieving the minimum change set to achieve the system-wide power flow goal is to find resource for which a power flow change in the required direction is possible, and to then sort the devices by the amount of power flow they control. Starting with the device that controls the most power, work down the list of available devices until enough power has been recruited to achieve the goal of the power flow system.

[0159] Devices should communicate all status changes. This technique does not use application level pings. In the case of any change in device status (e.g. power level change, fuel level change by some interesting quantity, resource arrived/departed where resource may be a vehicles), communicating all such status changes eliminates the need for the power flow management system to use application level pings (i.e. messages from the power flow management system, which has the purpose of asking the device "Are you there?").

[0160] In one embodiment, the implemented technique provides that resources communicate their departure from the system. This enables the removal of all application level pings from the system. This also requires that the resources have the ability to maintain power for enough time after being disconnected that they can communicate. When there is a local communications controller, the controller can indicate the disappearance of a resource to the system.

[0161] Configurable limits on interesting behavior. Another bandwidth minimization technique involves increasing the tolerance limits for state changes that require notification of the main system. Relevant information should be communicated to the power flow management system in real time. The devices should support the ability to increase and decrease the limits of interesting behavior to make the network traffic consumption be tailor-able against responsiveness (e.g. knowing each time the power flow changes by 3%

is more informative than if it changes by 10% but requires network bandwidth to communicate).

[0162] Non-time-critical information should be bundled. Techniques may minimize message overhead by saving data that is not time-sensitive for same-message transmission with data that is time sensitive, thereby saving the messaging overhead and enabling data compression on a larger message. For information that is not time critical to the operation of the power flow information system (diagnostic data, logged data, summary statistics, etc), the devices should gather this information in memory and only transmit it to the power flow management system when a sufficient amount of information is collected such that the portion of the message dedicated to overhead is small.

[0163] Various combination of the bandwidth minimization techniques may be implemented in an embodiment. For example, devices may communicate all interesting changes to the power flow management system and the limits defining interesting behavior for the device may be configurable. A power flow system that is fully informed and frequently updated about the behavior of the endpoints that are connected to it defines one endpoint on a continuum of control and flexibility. On the other end of the spectrum is a power flow management system that has little or no visibility into the behavior and status of the devices connected to it.

[0164] To enable the most flexible power flow management system while minimizing the use of network traffic, the system can establish criteria for devices that triggers an update action of status to the power flow management system. This way, only when something changes in the status of the device does communication need to be made. Such a scheme does not waste network traffic having devices inform the power flow management system that things are unchanged from the last communication.

[0165] For example, consider a battery charging device that is connected to a battery and participates in the network of the power flow management system. Once the device has connected to the power flow management system and reported its power flow (e.g. 800 W), there is no need for the device to report new information to the power flow management system unless there is a change in status. For example, if a device is reporting the amount of power flowing into a battery that is being charged and the battery fills up and does not require further charging.

[0166] FIG. 10 illustrates an embodiment of a bandwidth minimization technique. A power flow management system, which manages electric devices and electric power supplies 1010, communicates device information 1020 and power flow information 1030. Bandwidth reduction techniques described above are applied to reduce network traffic 1040.

[0167] Smart Energy Protocol Translation Device

[0168] A protocol translation device may be provided that fully participates in two or more networks using physical signaling mechanisms that are capable of communication with each network. Messages are reformulated messages such that the messages can pass from one network to another. Since two relevant protocols may not be compatible, such a device passes high-level information as opposed to binary packets. This method is distinct from the method used by Internet routers that simply forward messages from one network to another without modification.

[0169] A Power Line Communicator (PLC), such as a power line carrier, is a signaling mechanism by which a high-frequency signal is added to the AC power line in a home

or business. The high-frequency signal carries information in a variety of protocols to other devices that are able to decode these high frequency signals.

[0170] The protocol translation device may include the following: a microprocessor and power supply; physical transceivers for each supported communications protocol stack; a software stack capable of decoding messages from each of the communications protocols; and, a software/hardware layer that can translate, if necessary, and re-encode messages from one communications protocol to another communications protocol. Because modern home networking technologies can be wireless or PLC based, the protocol translation device need not be located near any device that it provides translation services for. The protocol translation device can be attached to any outlet in the home, such as wall outlet 204 illustrated in FIG. 2A. The protocol translation device can stand alone or co-reside with a device on the network.

[0171] In an embodiment, a device acts as an information bridge between two networks. An electric vehicle service equipment (EVSE), or a charge point, may communicate with an electric vehicle via the SAEJ2836 application protocol over a HomePlug AV physical communication mechanism and with a home area network (HAN) using smart energy application protocol over a ZigBee wireless physical communication mechanism. Such an EVSE or charge point can implement the message translation between the two networks. For messages that have equivalent meanings in both networks, the EVSE can reformulate the message that comes in from the ZigBee/Smart Energy network to the format of the J2836/PLC network and transmit the message from the HAN to the vehicle.

[0172] In another embodiment, the device is a member of two different networks and the device passes messages back and forth between the two networks. The networks have some incompatibility, such as a physical layer or application layer. Smart energy is an application layer protocol that is implemented for multiple physical interfaces including ZigBee and HomePlug PLC. The device can be located such that it is able to participate in both networks simultaneously. The device may contain the physical equipment to be able to send/receive messages on either network, such as ZigBee for wireless and HomePlug PLC for wired. As a message is observed on either network, the device translates the message to the other network's physical layer. When both networks implement smart energy, there is no need to translate the application layer as well.

[0173] In one embodiment, an electric vehicle service equipment (EVSE) can act as such a translation device. When a vehicle has the ability to communicate via one protocol, and an EVSE is located where access to the central charge management server is provided by a different protocol, the EVSE could act as a translator between the two protocols. Such an EVSE includes complete implementations of both the hardware and software necessary to support both protocols to fully decode each protocol to obtain the application level messages.

[0174] An EVSE can be connected to a vehicle using the SAE2836 protocol over PLC and can be connected to a home network using a wireless ZigBee protocol, according to one embodiment. The EVSE can include complete implementations of each hardware and protocol stack. As such, the EVSE can forward messages between the two stacks.

[0175] In an embodiment, the translation device could be physically distinct. For example, in an installation with a PLC

based vehicle and a wireless internet access point, the translation device can be a self-contained box plugged into a power outlet.

[0176] FIG. 11 illustrates an embodiment of a protocol translation for a power flow management system that utilizes networks to communicate between electric devices and electric power supplies 1110. A communications protocol translation device reformulates messages from one protocol to another protocol 1120 in order to transmit such messages from a network using one communications protocol to a network using a different protocol. FIG. 12 shows a communications protocol translation device 1210 implemented between two networks 1220 that are connected to electric power supplies and electric devices 1230.

CONCLUSION

[0177] Although systems and methods have been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as examples of implementations of the claimed methods, devices, systems, etc. It will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A system for minimizing network traffic consumption in a power flow management system, comprising:
 - a plurality of devices operable to generate, consume, or store electric energy;
 - a power flow management system, wherein the power flow management system manages power flow transferred between the plurality of devices and a power grid; and,
 - device information and power flow information communicated, via a network, between the power flow management system and the plurality of devices, wherein the device information is received by the power flow management system, wherein the power flow information is transmitted by the power flow management system, wherein the power flow information comprises an energy rate command received by at least one of the plurality of devices, and
 - wherein the power flow management system reduces consumption of traffic traversing the network via a network traffic consumption reduction technique.
2. The system of claim 1, wherein the power flow management system is centralized.
3. The system of claim 1, wherein the power flow management system is decentralized.
4. The system of claim 1, wherein the energy rate command provides a time and a rate of energy transfer from the at least one of the plurality of devices.
5. The system of claim 1, wherein the energy rate command provides a time and a rate of energy transfer to the at least one of the plurality of devices.
6. The system of claim 1, wherein the power flow management system determines an optimal time and rate for energy transfer.
7. The system of claim 1, wherein the energy rate command requests an immediate flow of power at a requested level.
8. The system of claim 1, wherein the energy rate command provides a schedule of power flow for the at least one of the plurality of devices.

9. The system of claim 8, wherein the schedule of power flow provides an activation time for a power flow level.

10. The system of claim 8, wherein the schedule of power flow provides a sequence of power flow levels for activating at predetermined times.

11. The system of claim 8, wherein the schedule of power flow is repeated by the at least one of the plurality of devices on a dynamic pattern or fixed pattern.

12. The system of claim 1, wherein the device information relates to a current state of at least one of the plurality of devices.

13. The system of claim 1, wherein the device information is related to at least one of the plurality of devices and is selected from a group consisting of the following: an amount and a direction of power flow associated with the at least one of the plurality of devices; a capacity relating to the at least one of the plurality of devices; faults or error messages; a device presence indicator for the at least one of the plurality of devices; a scheduling constraint; or energy consumption in a period.

14. The system of claim 1, wherein the network traffic consumption reduction technique is a technique selected from a group consisting of the following: data compression, data overhead reduction, action/schedule pre-distribution, minimum change dispatch, communication of all status changes, configurable limitations on relevant device behavior, or non-time-critical information bundling.

15. A system for communications protocol translation in a power flow management system, comprising:

electric devices and electric power supplies connected via a plurality of networks, wherein at least one network of the plurality of networks utilizes a first communications protocol that is different from a second communications protocol utilized by at least a second network of the plurality of networks;

a communications protocol translation device operable to communicate with the plurality of networks, wherein the communications protocol translation device formulates a message from the first communications protocol to the second communications protocol, whereby the reformulated message passes from the first network to the second network.

16. The system of claim 15, wherein the first network connects an electric device to the power flow management system, and wherein the second network connects an electric power supply to the power flow management system.

17. The system of claim 15, wherein the first network connects an electric power supply to the power flow management system, and wherein the second network connects an electric device to the power flow management system.

18. The system of claim 15, wherein the first network connects an electric power supply to an electric device, and wherein the second network connects a second electric device to the electric power supply.

19. The system of claim 15, wherein the communications protocol translation device is an electric device.

20. The system of claim 19, wherein the electric device is an electric vehicle service equipment.

21. The system of claim 15, wherein the communications protocol translation device is located within a power outlet.

22. The system of claim 15, wherein at least one of the plurality of networks utilizes a communications protocol selected from a group consisting of the following: SAE2836 or ZigBee.

23. The system of claim 15, wherein the communications protocol translation device comprises:

a microprocessor;

a power supply;

physical transceivers for each of a plurality of supported communications protocol stacks; and,

a software stack capable of decoding messages coded in the first protocol to the application level and re-encoding the decoded messages into the second communications protocol.

24. The system of claim 15, wherein the communications protocol translation device is located remotely from the electric devices connected to the plurality of networks.

25. A device comprising

a first transceiver adapted to be connected to a first network supporting a first network protocol;

a second transceiver adapted to be connected to a second network supporting a second network protocol;

a translation module comprising one or more processors programmed to execute software code retrieved from a computer readable storage medium storing software configured to receive, using the first transceiver, at least one application level message in the first protocol from the first network;

decode the at least one application level message;

encode the at least one application level message in the second protocol;

transmit, using the second transceiver, the at least one application level message encoded in the second protocol over the second network.

26. The system of claim 25 wherein the first network is a network in a vehicle and the second network is a network providing access to a central charge management server.

27. The system of claim 26 wherein the first protocol is a SAE2836 protocol over PLC.

28. The system of claim 27 wherein the second protocol is a wireless ZigBee protocol.

29. The system of claim 25 wherein the translation module is integrated into the electric vehicle service equipment.

30. The system of claim 25 the device is a self-contained box plugged in to a power outlet.

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