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(54) **SYSTEMS AND METHODS FOR LOCATION DETERMINATION OF DEVICES USING NETWORK FINGERPRINTS FOR POWER MANAGEMENT**

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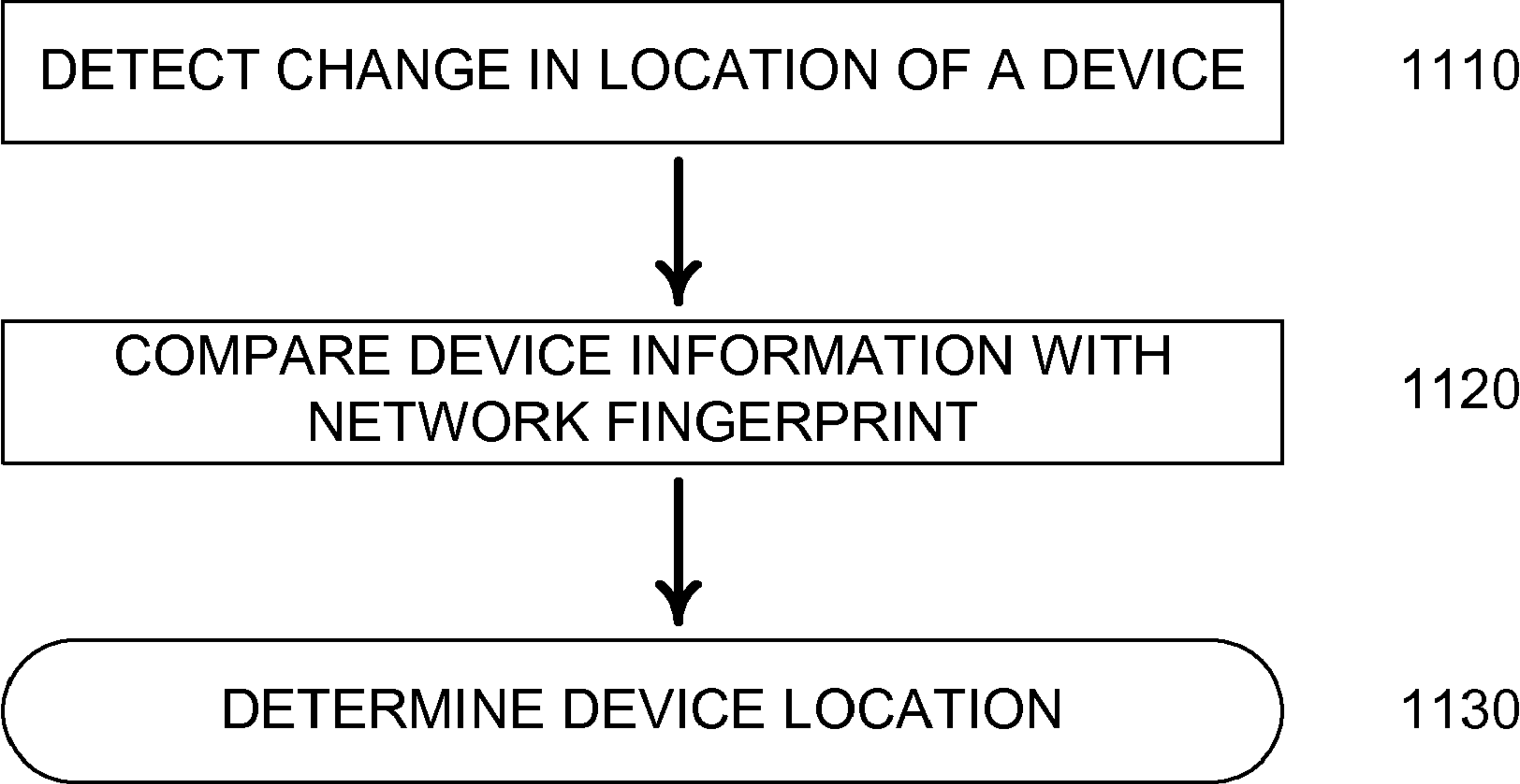
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G06F 19/00

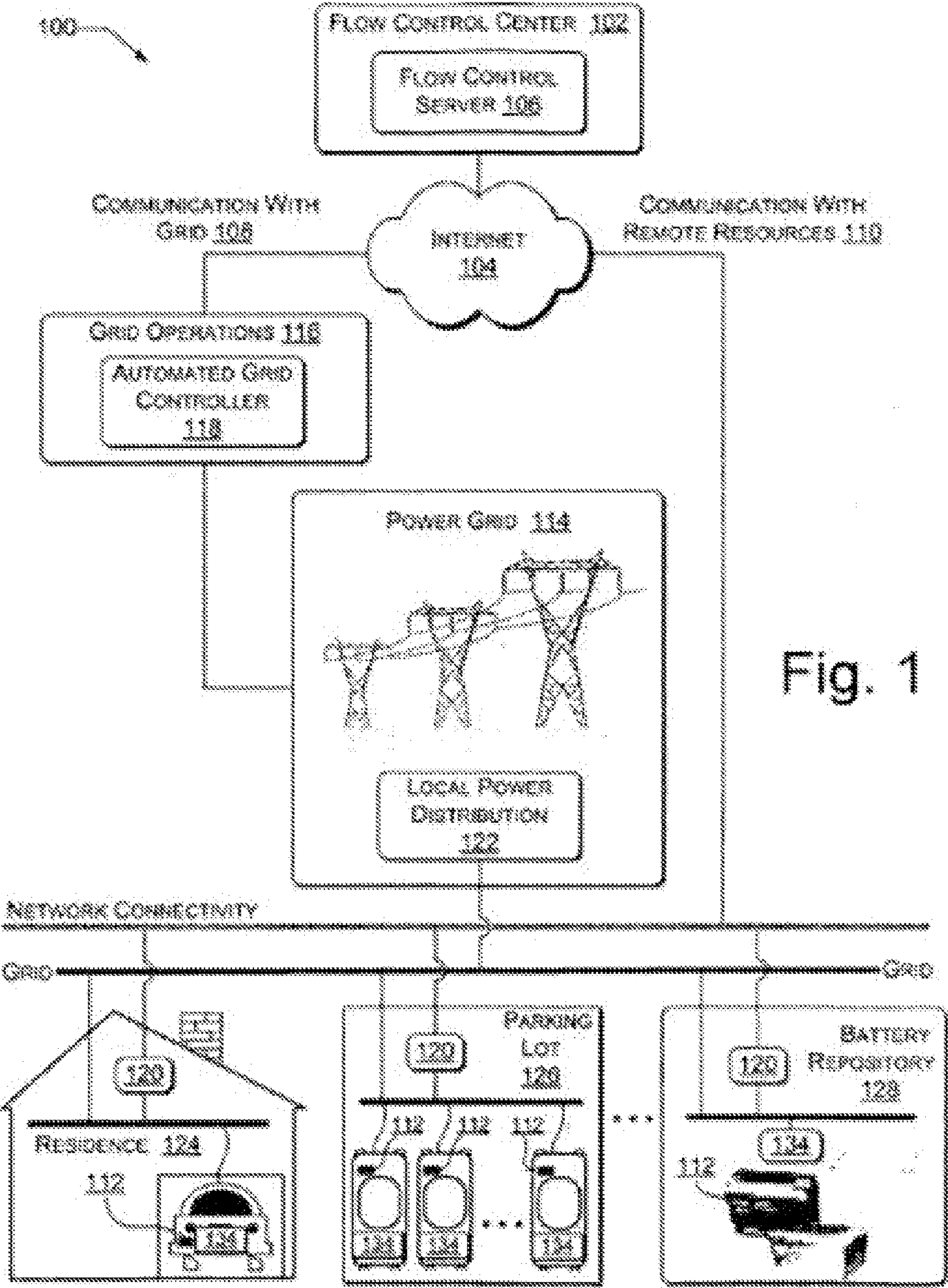
(2006.01)

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(57) **ABSTRACT**

A system and methods that enables the determination of the location of a device using a network fingerprint of a known location on the electrical grid. A collection of communication based information is utilized to construct a network fingerprint that is subsequently used to determine whether a device is at a previously known or unknown location. By detecting differences in some or all of this set of information, a system determines whether an electric car has moved from one known location to another or otherwise left a known location. Determining a change in the location of a device, the device or a server take further actions, such as: notifying a user, notifying another server, initiating a configuration process, or operating in different modes. Knowledge about network location assist with assessing the overall load characteristics of a given area of a power grid, and with determining billing related matters.





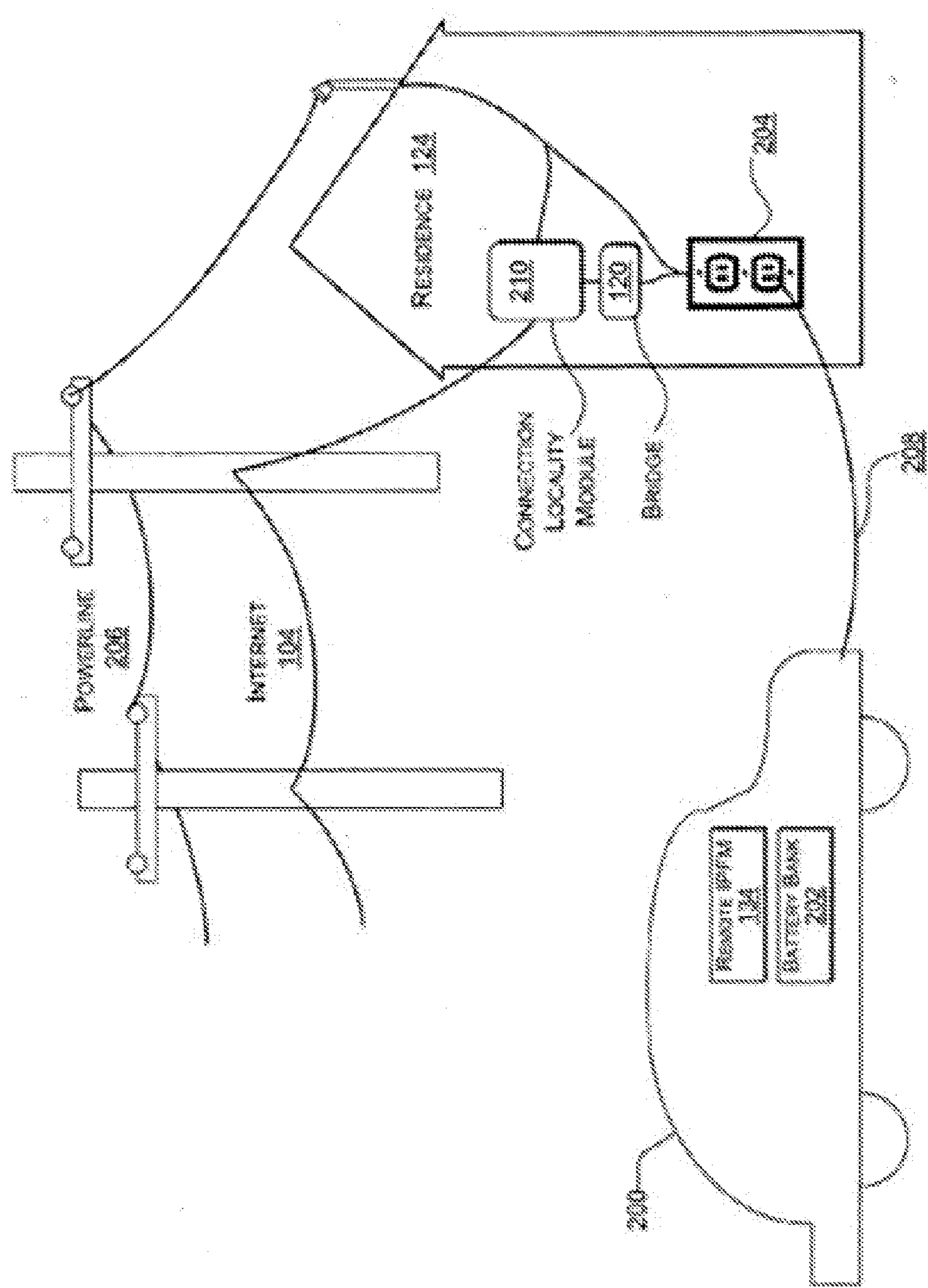


Fig. 2A

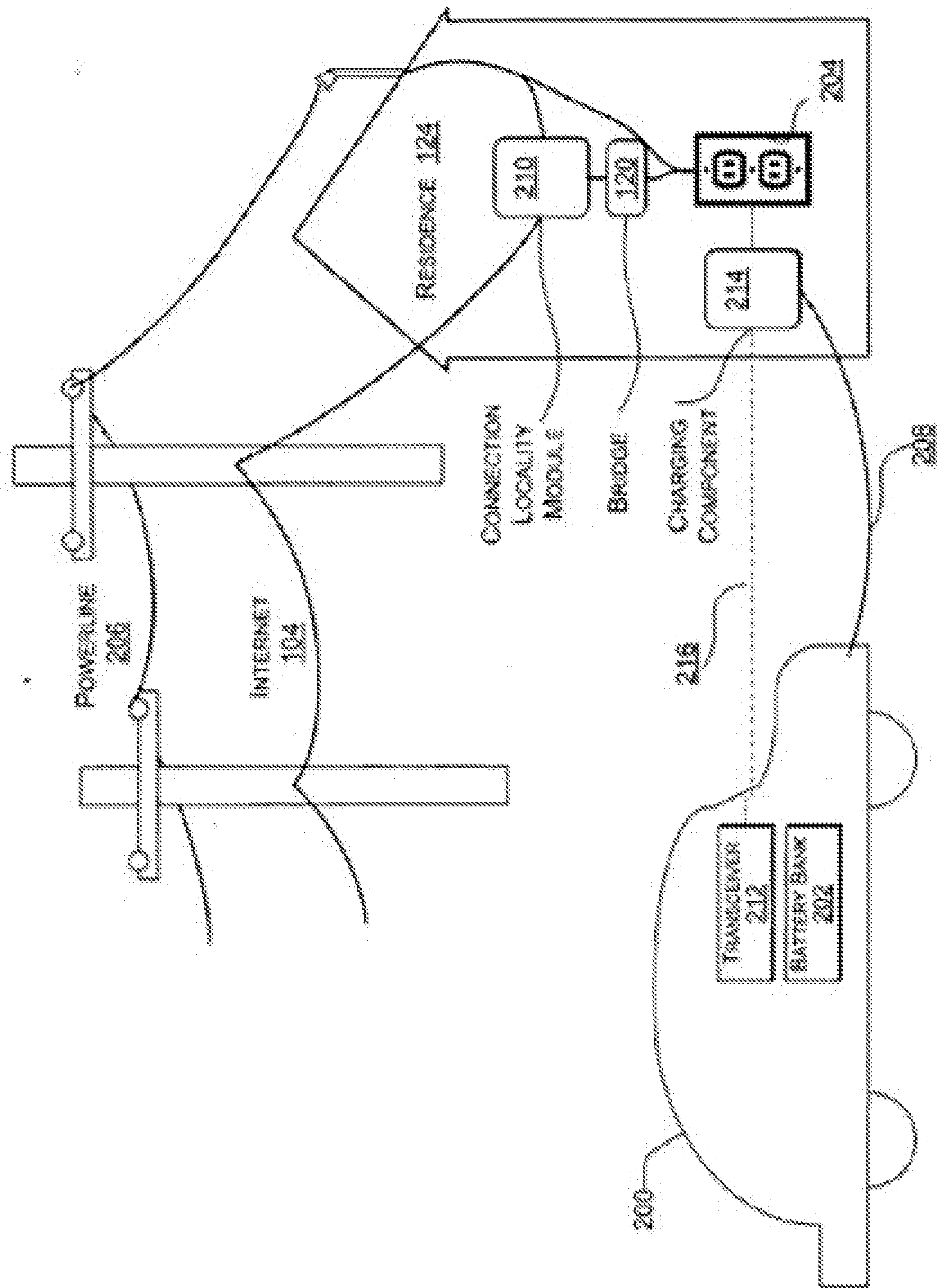


Fig. 2B

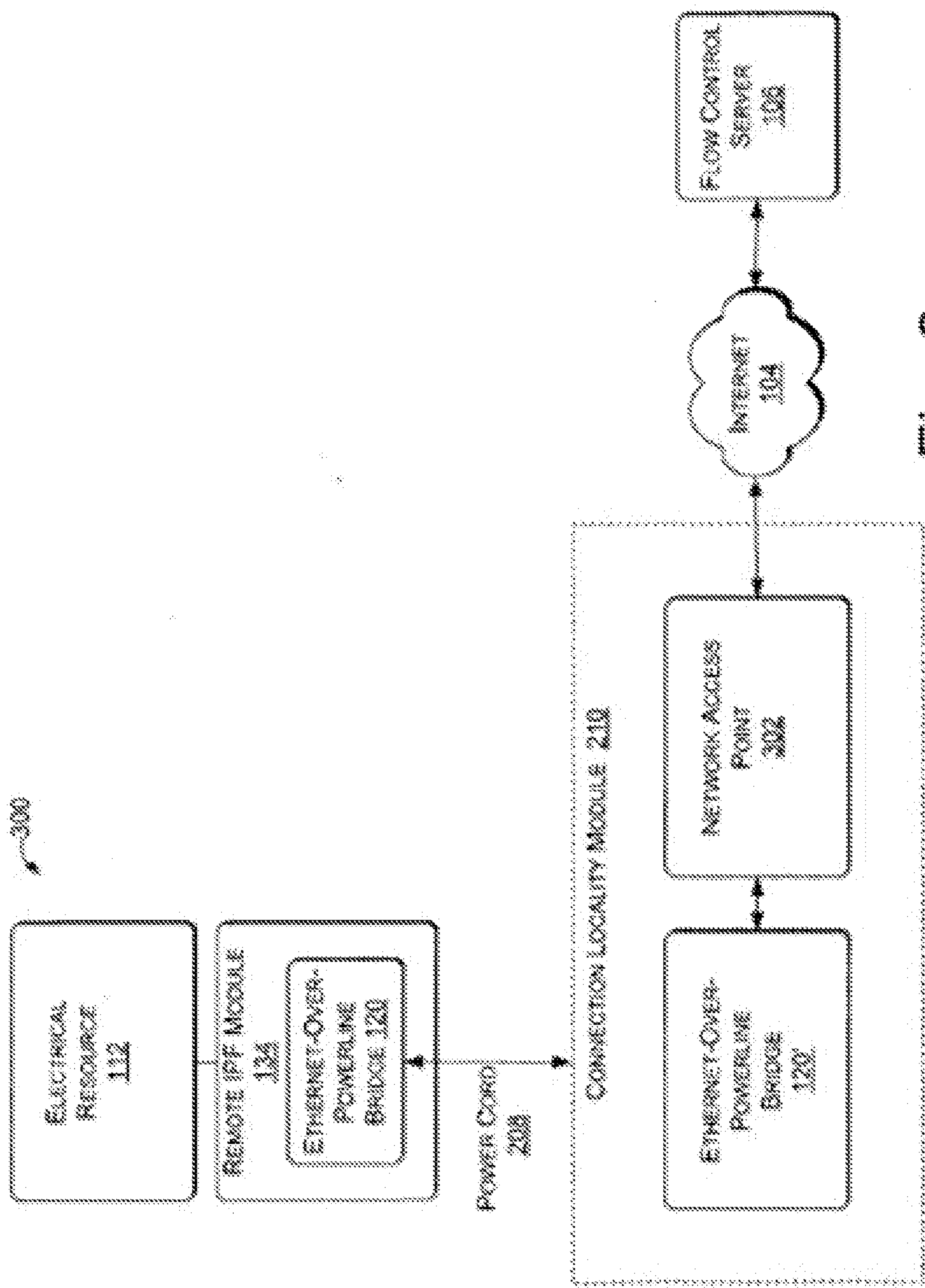


Fig. 3

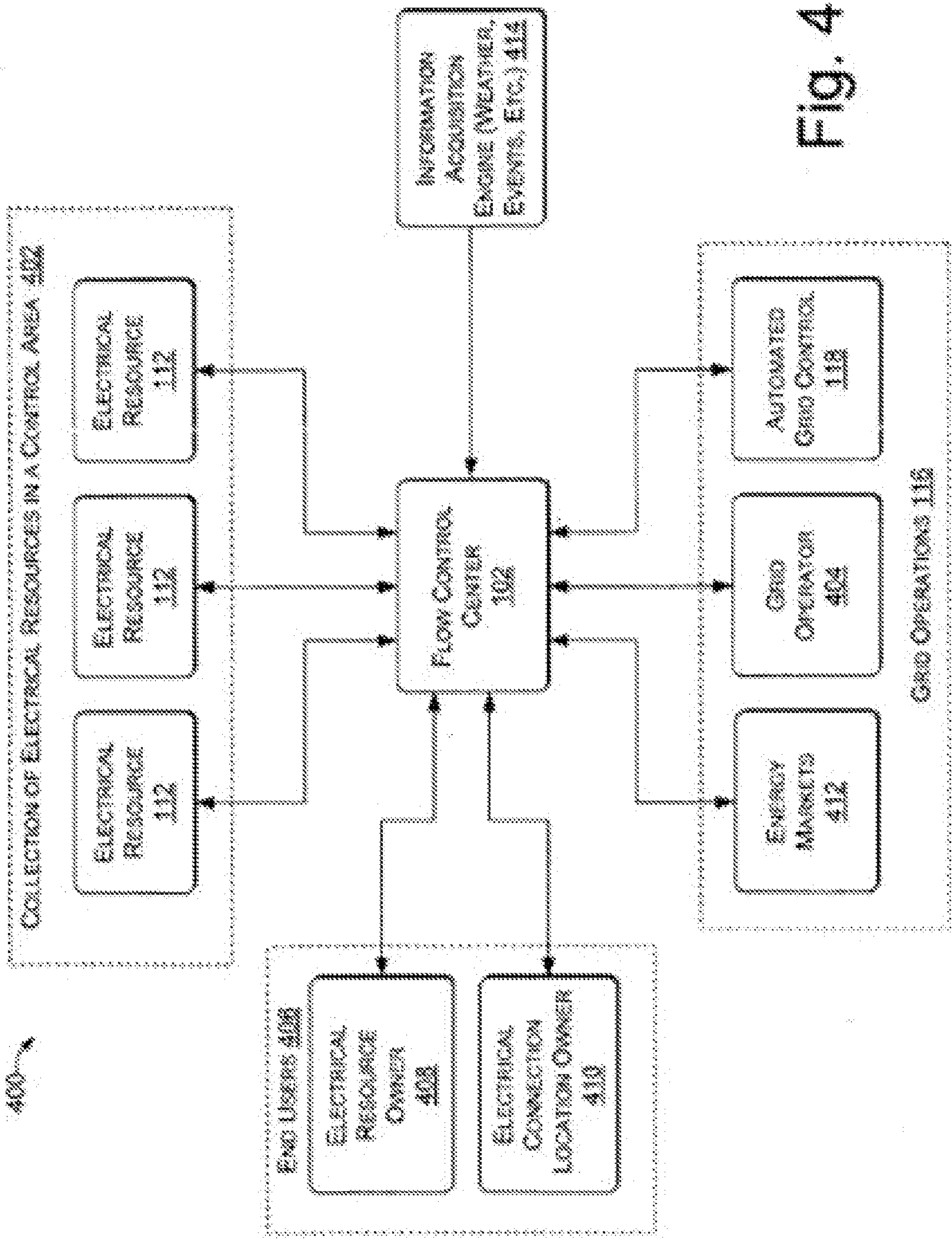


Fig. 4

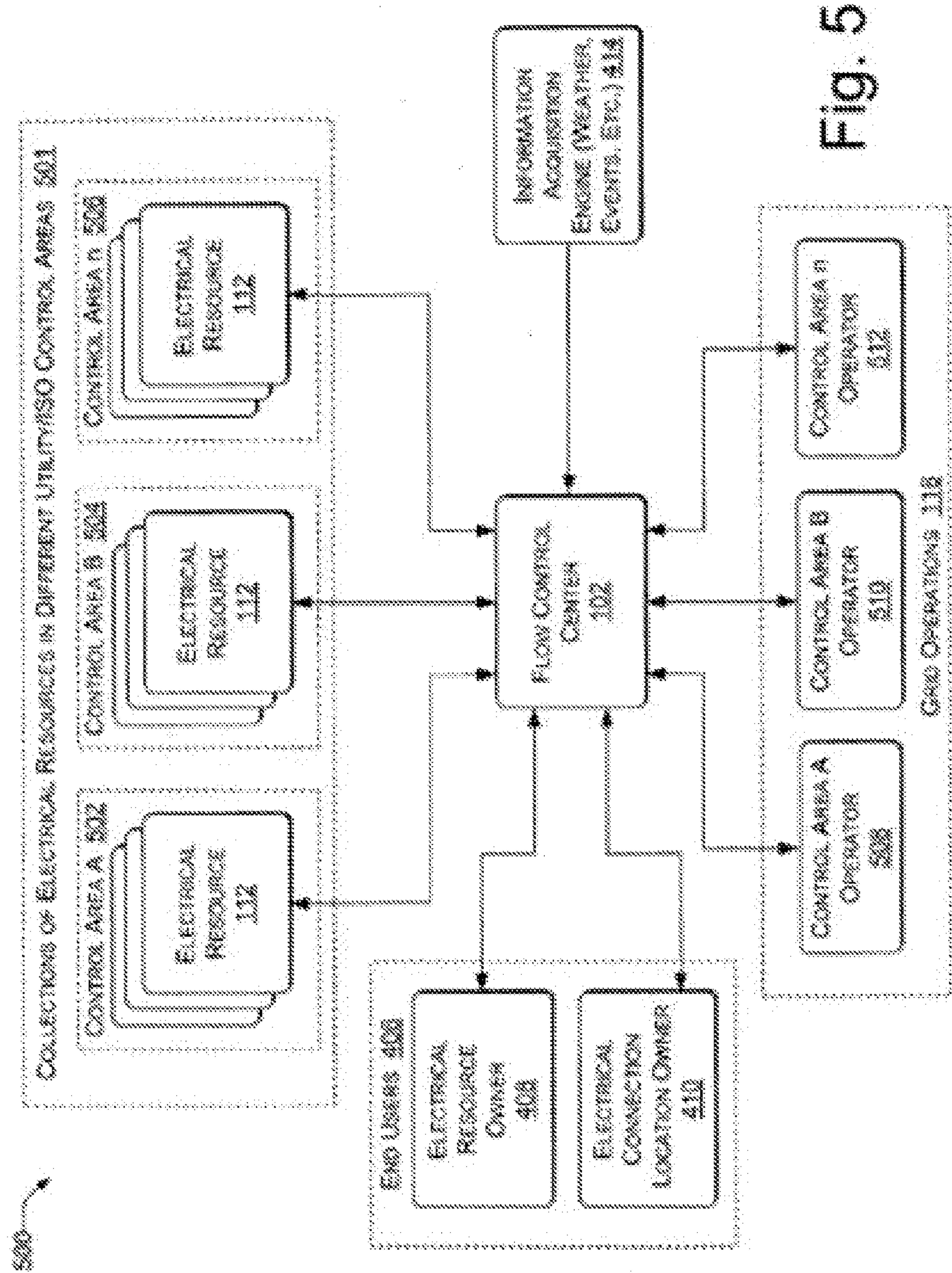


Fig. 5

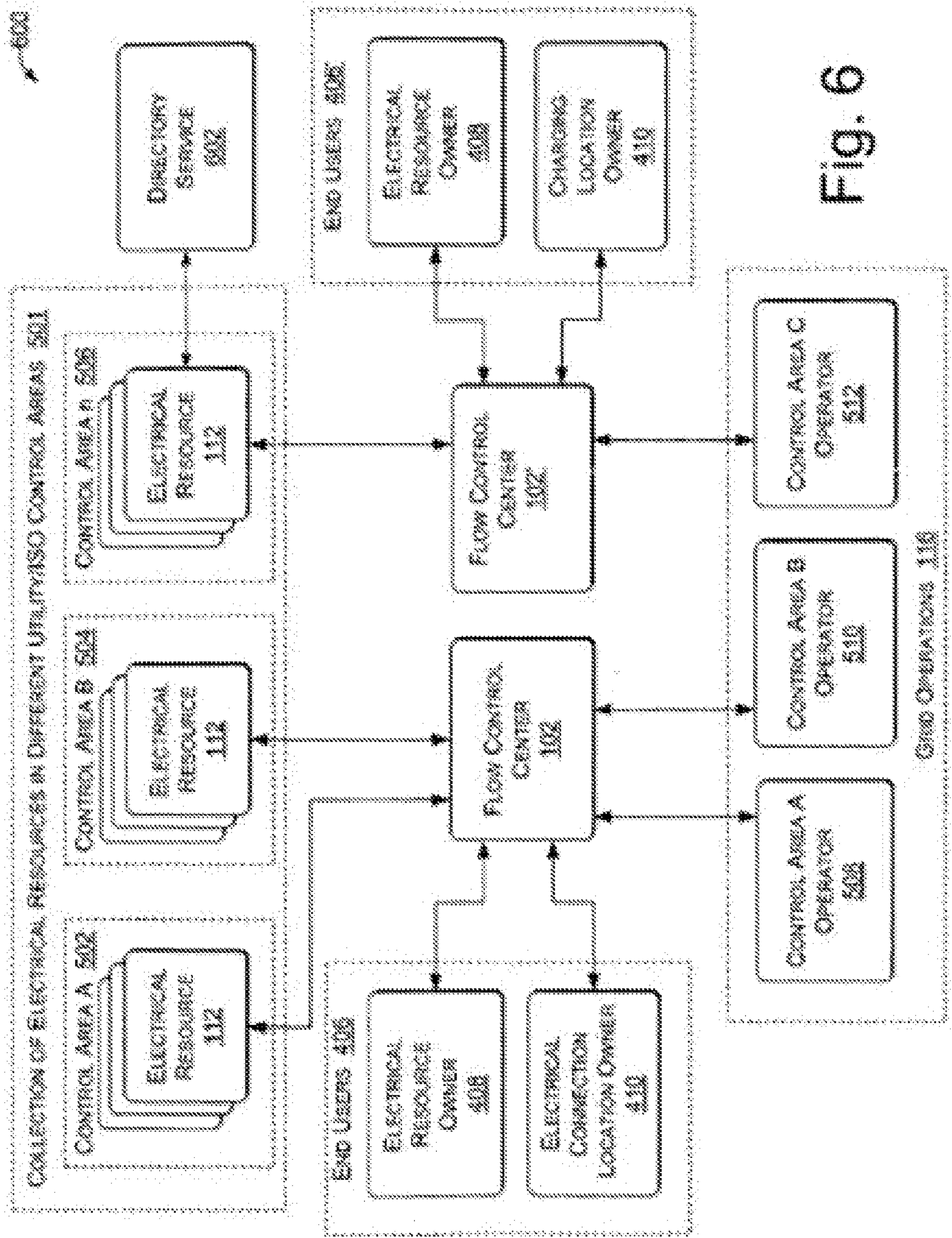


Fig. 6

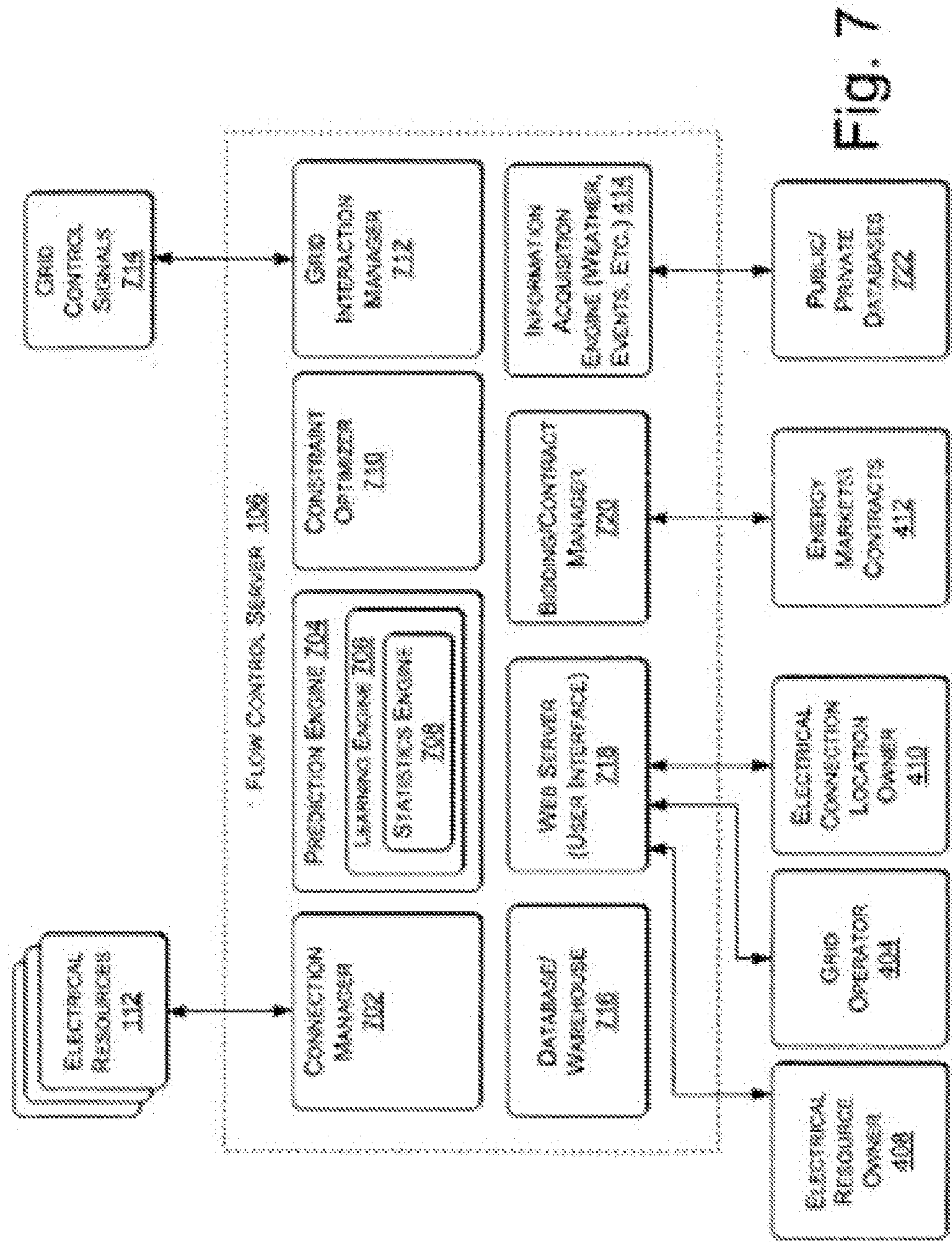
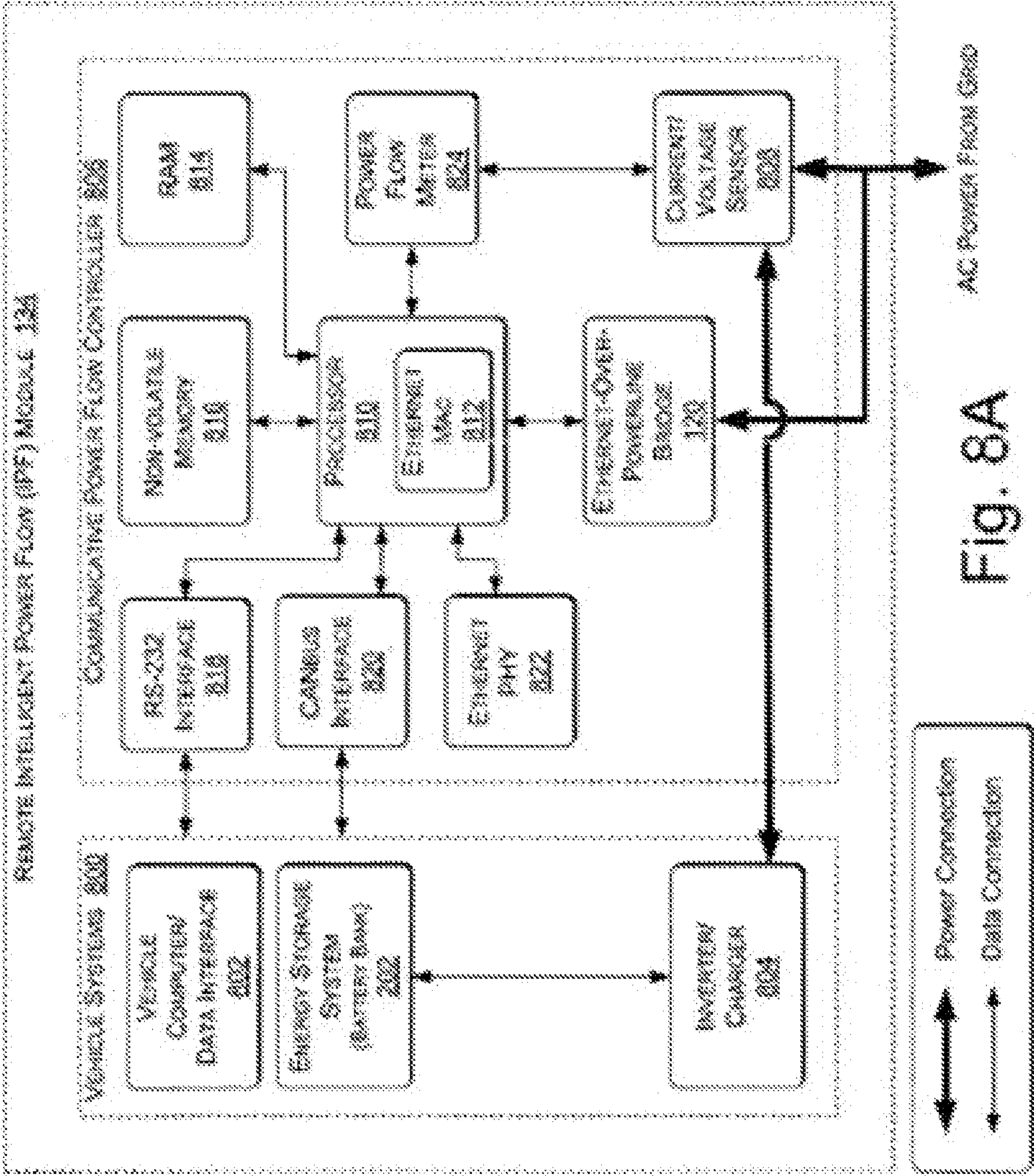


Fig. 7



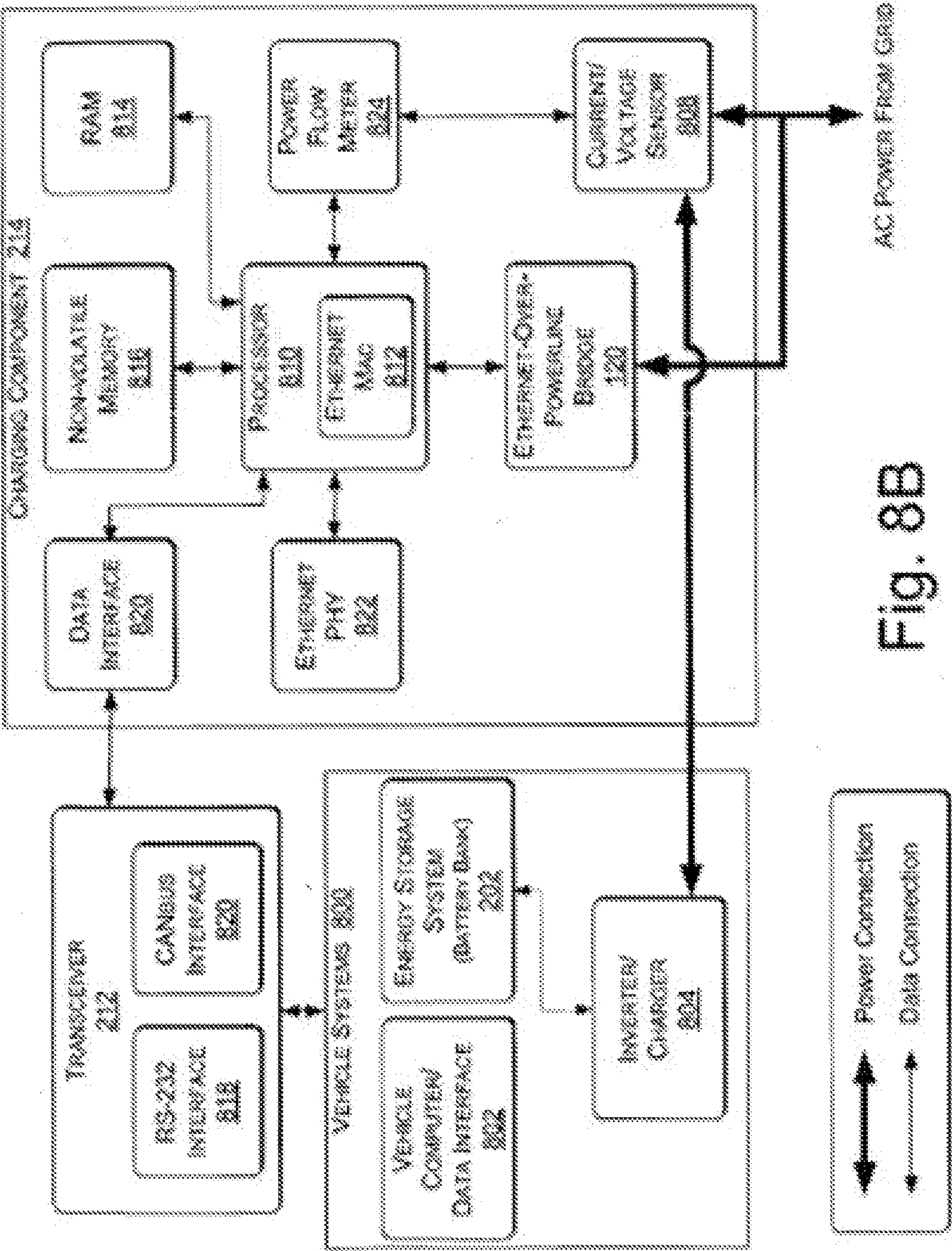


Fig. 8B

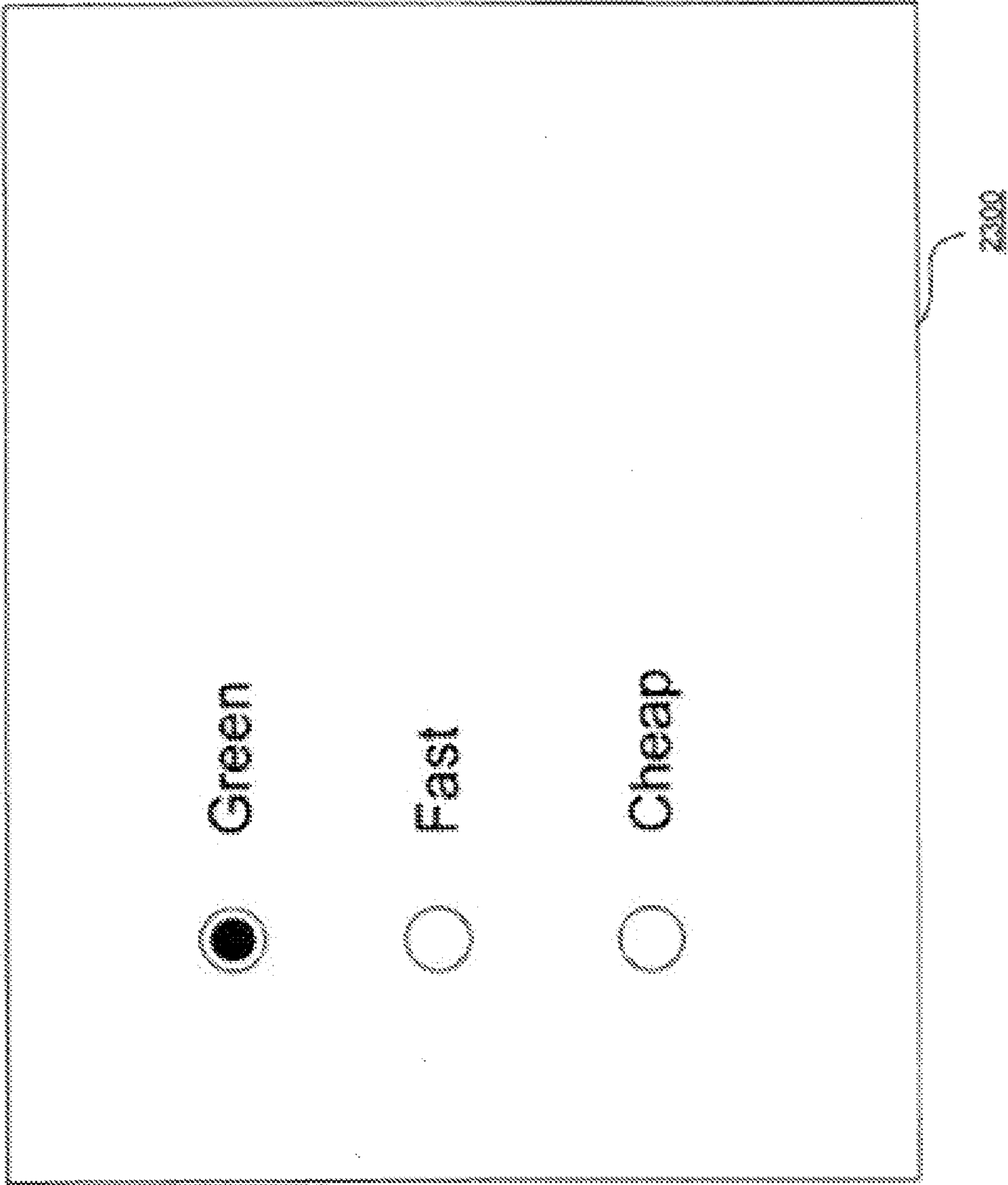


Fig. 8C

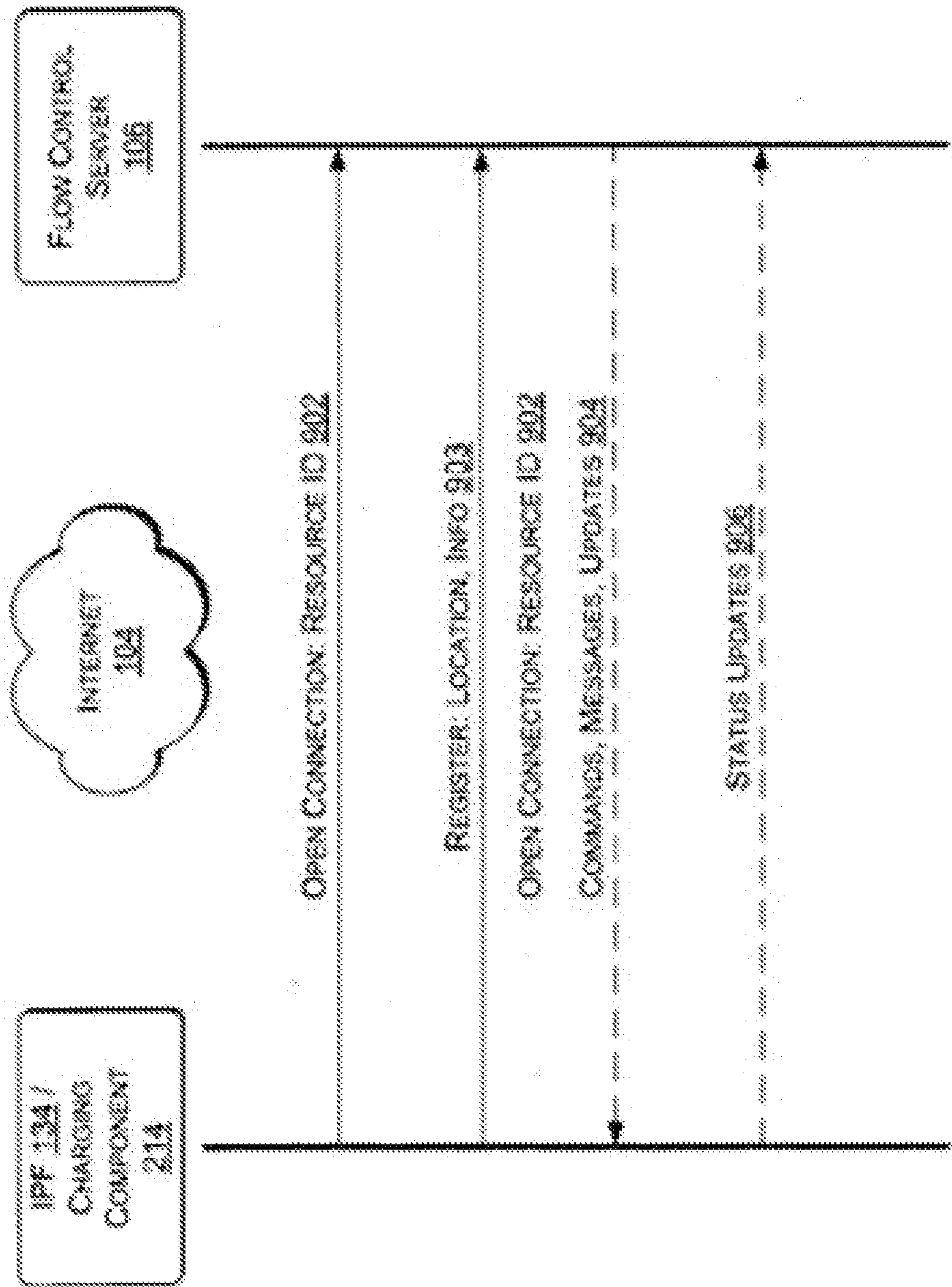


Fig. 9

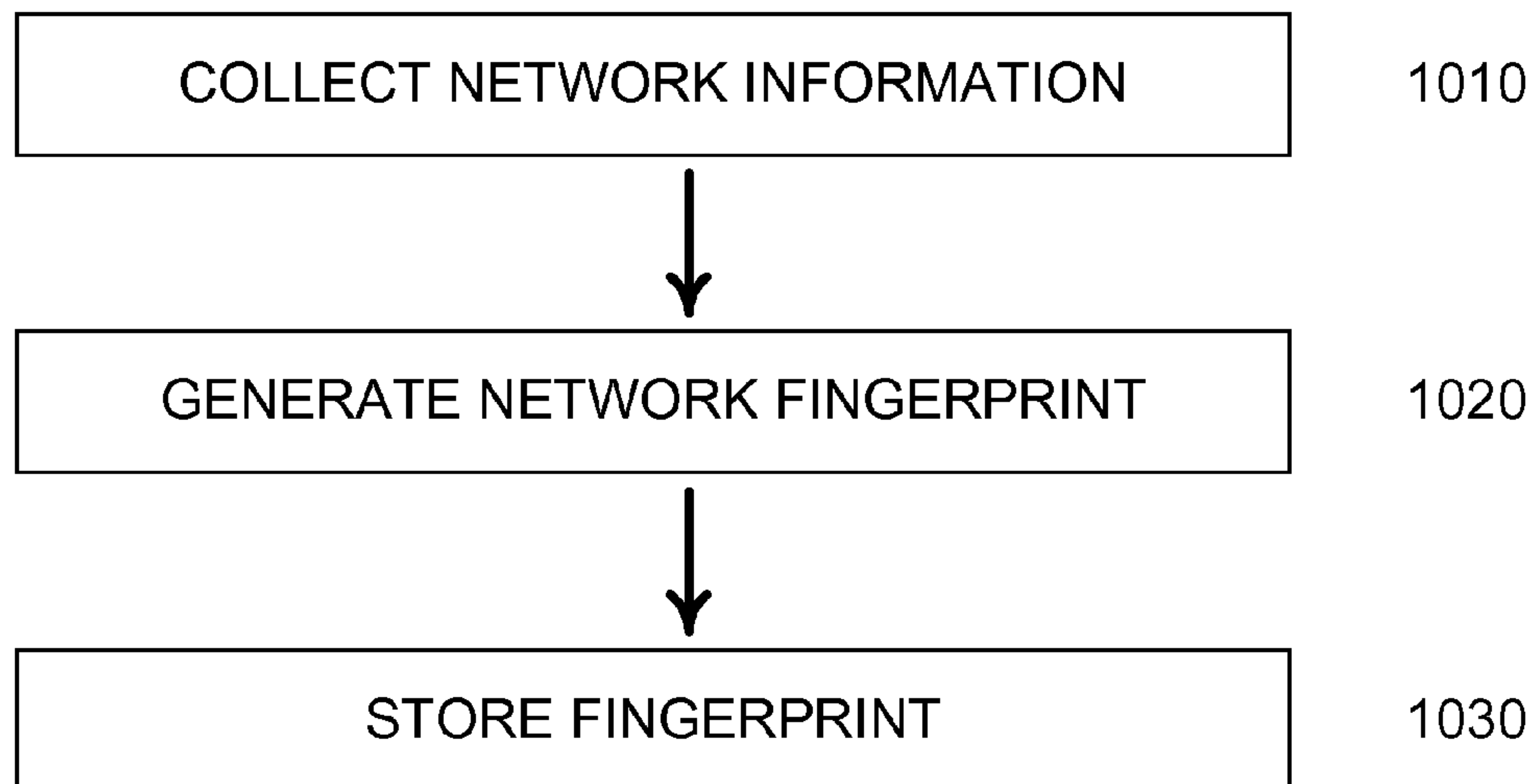


FIG. 10

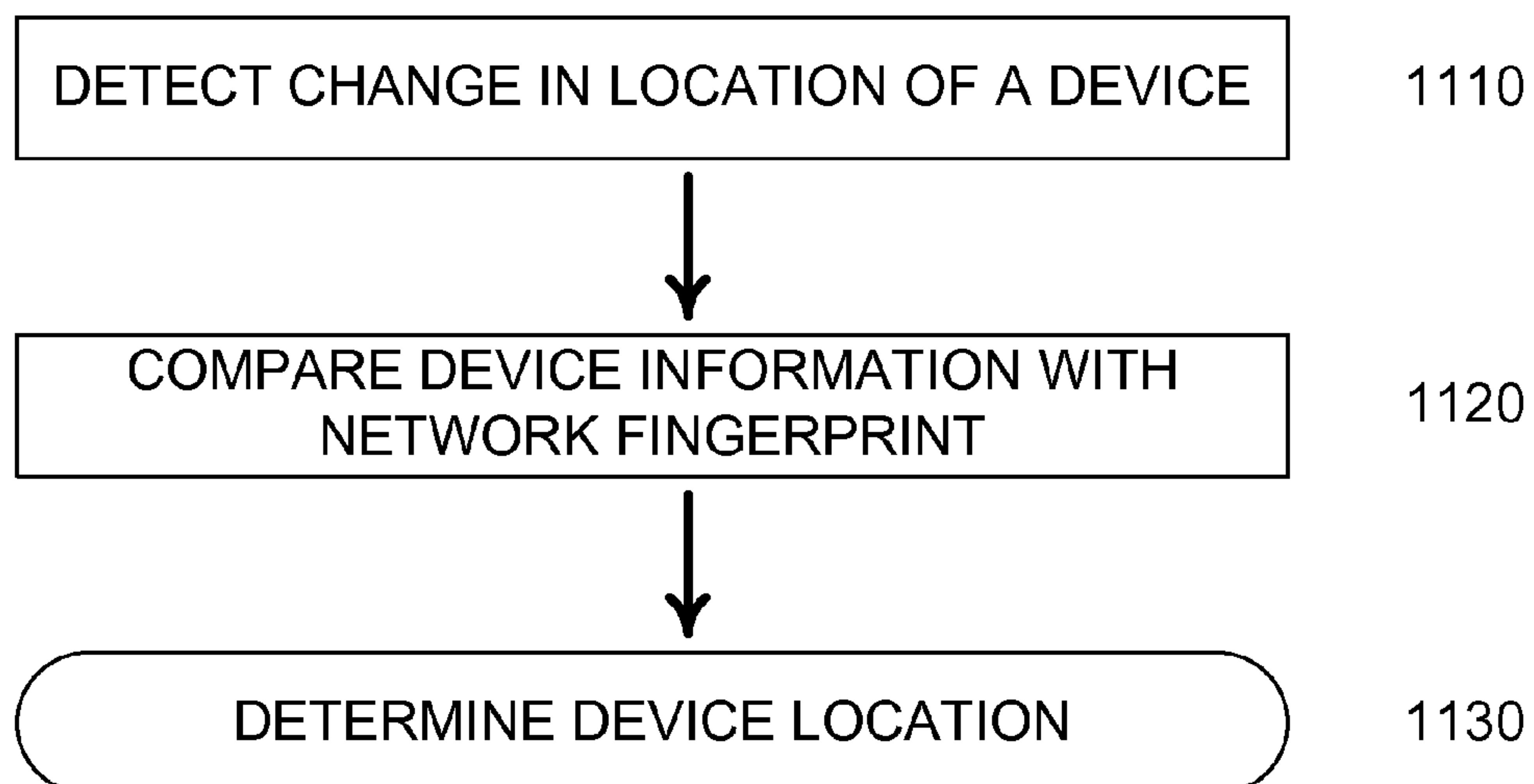


FIG. 11

SYSTEMS AND METHODS FOR LOCATION DETERMINATION OF DEVICES USING NETWORK FINGERPRINTS FOR 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.

[0002] This application includes material which is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by anyone of the patent disclosure, as it appears in the Patent and Trademark Office files or records, but otherwise reserves all copyright rights whatsoever.

FIELD OF THE INVENTION

[0003] The present invention relates in general to the field of power management systems, and in particular to novel systems and methods for determining locations of electric vehicles on an electrical grid using network fingerprints.

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] Communication parameters can be used to infer a remote machine's operating system fingerprint. For example, in an IP over Ethernet based system there are several layers of message framing all with unique or semi unique characteristics. The MAC address of the gateway, the number of network peers and their addresses can all be determined by watching existing network traffic, or by soliciting such information of the network peers themselves. Techniques like port scanning are in wide use for determining network topology. Several techniques exist for determining the host operating systems of network peers using IP stack fingerprinting.

[0006] While various other techniques for fingerprinting devices on a network are known in the art, novel methods are needed to determine the network location of mobile devices connected to a power grid in order to provide enhanced techniques for smart charging. Significant opportunities for improvement exist with respect to locating electric vehicles on a network that communications with power grids and various mobile devices. What is needed are systems and methods that determine the location of a device with respect to a known location on the electrical grid. With respect to the statistical nature of the fingerprint, there is also a need for novel statistical modeling that weighs the relevance of various pieces of communication based information collected to construct a network fingerprint. In particular, novel systems

and methods are needed that efficiently determine the network location of mobile devices on networks for power management systems.

SUMMARY OF THE INVENTION

[0007] In an embodiment, a method for determining the location of devices on power flow management system using network fingerprints includes receiving network information. Such network information is associated with electric devices, such as electric vehicles. The method includes generating a network fingerprint based on the network information, and storing the network fingerprint in a database. Further, the method includes detecting a change in device information for an electric devices. The changed device information of the electric devices is compared with the network fingerprint. The location of the electric device is determined based on the network fingerprint.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] 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.

[0009] FIG. 1 is a diagram of an example of a power aggregation system.

[0010] FIGS. 2A-2B are diagrams of an example of connections between an electric vehicle, the power grid, and the Internet.

[0011] 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.

[0012] FIG. 4 is a diagram of an example of a layout of the power aggregation system.

[0013] FIG. 5 is a diagram of an example of control areas in the power aggregation system.

[0014] 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.

[0015] FIG. 7 is a block diagram of an example of flow control server.

[0016] FIG. 8A is a block diagram of an example of remote intelligent power flow module.

[0017] FIG. 8B is a block diagram of an example of transceiver and charging component combination.

[0018] FIG. 8C is an illustration of an example of simple user interface for facilitating user controlled charging.

[0019] FIG. 9 is a diagram of an example of resource communication protocol.

[0020] FIG. 10 is a flow chart of an example of fingerprinting a local network for a power management system, in accordance with the currently disclosed invention.

[0021] FIG. 11 is a flow chart of an example of determining the location of an electric vehicle using a network fingerprint.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0022] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

[0023] Overview

[0024] 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).

[0025] “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.

[0026] “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.

[0027] “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.

[0028] “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.

[0029] “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.

[0030] “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.

[0031] “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.

[0032] “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.

[0033] “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.

[0034] “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.

[0035] 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.

[0036] An Example of the Presently Disclosed System

[0037] 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**.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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**.

[0042] 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 conducting 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 local-

ity 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**.

[0043] 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.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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**.

[0048] 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.

[0049] Further details about the transceiver **212** and charging component **214** are illustrated by FIG. 8B and described in greater detail herein.

[0050] 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**.

[0051] 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**.

[0052] 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.

[0053] System Layouts

[0054] 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.

[0055] 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**.

[0056] Electrical connection location owners **410** can include:

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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.

[0061] 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**.

[0062] 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**.

[0063] 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**.

[0064] Thus, a power aggregation system **100** may consist of components that:

[0065] communicate with the electric resources **112** to gather data and actuate charging/discharging of the electric resources **112**;

[0066] gather real-time energy prices;

[0067] gather real-time resource statistics;

[0068] predict behavior of electric resources **112** (connect- edness, location, state (such as battery State-Of-Charge) at a given time of interest, such as a time of connect/disconnect);

[0069] predict behavior of the power grid **114**/load;

[0070] encrypt communications for privacy and data secu- rity;

[0071] actuate charging of electric vehicles **200** to optimize some figure(s) of merit;

[0072] offer guidelines or guarantees about load availabil- ity for various points in the future, etc.

[0073] These components can be running on a single com- puting resource (computer, etc.), or on a distributed set of resources (either physically co-located or not).

[0074] 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.

[0075] 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.

[0076] 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.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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'.

[0081] Flow Control Server

[0082] 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.

[0083] 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.

[0084] Remote IPF Module

[0085] 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.

[0086] 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.

[0087] 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 Eth-

ernet-over-powerline bridge **120**, and a current or current/voltage (power) sensor **808**, such as a current sensing transformer.

[0088] 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**.

[0089] 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**.

[0090] 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:

- [0091] an intra-vehicle communications mechanism that enables communication with other vehicle components;
- [0092] a mechanism to communicate with the flow control center **102**;
- [0093] a processing element;
- [0094] a data storage element;
- [0095] a power meter; and
- [0096] optionally, a user interface.

[0097] Implementations of the communicative power flow controller **806** can enable functionality including:

- [0098] executing pre-programmed or learned behaviors when the electric resource **112** is offline (not connected to Internet **104**, or service is unavailable);
- [0099] 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);
- [0100] allowing the user to override current system behavior; and
- [0101] metering power-flow information and caching meter data during offline operation for later transaction.

[0102] 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**.

[0103] Power Flow Meter

[0104] 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.

[0105] Transceiver and Charging Component

[0106] 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.

[0107] 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.

[0108] 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.

[0109] 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.

[0110] 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.

[0111] 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.

[0112] 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.

[0113] 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.

[0114] 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.

[0115] 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.

[0116] 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.

[0117] 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.

[0118] Implementations of the charging component 214 can enable functionality including:

[0119] executing pre-programmed or learned behaviors when the electric resource 112 is offline (not connected to Internet 104, or service is unavailable);

[0120] 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);

[0121] allowing the user to override current system behavior; and

[0122] metering power-flow information and caching meter data during offline operation for later transaction.

[0123] User Interfaces (UI)

[0124] 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.

[0125] 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.

[0126] 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.

[0127] 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 disconnecting and reconnecting, the user may again need to interact with the UI mechanism to override the charge control management.

[0128] 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.

[0129] 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.

[0130] 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**.

[0131] Electric Resource Communication Protocol

[0132] 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**.

[0133] 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).

[0134] 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.

[0135] 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.

[0136] 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.

[0137] 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**.

[0138] Mobile Resource Locator

[0139] Referring back to FIG. **1**, the exemplary power aggregation system **100** also includes various techniques for determining the electrical network location of a mobile electric resource **112**, such as a plug-in electric vehicle **200** as illustrated in FIG. **2A**. Electric vehicles **200** can connect to the grid **114** in numerous locations and accurate control and transaction of energy exchange can be enabled by specific knowledge of the charging location. Some of the exemplary techniques for determining electric vehicle charging locations include:

[0140] querying a unique identifier for the location (via wired, wireless, etc.), which can be:

[0141] the unique ID of the network hardware at the charging site;

[0142] the unique ID of the locally installed smart meter, by communicating with the meter;

[0143] a unique ID installed specifically for this purpose at a site; and

[0144] using GPS or other signal sources (cell, WiMAX, etc.) to establish a “soft” (estimated geographic) location, which is then refined based on user preferences and historical data (e.g., vehicles tend to be plugged-in at the owner’s residence 124, not a neighbor’s residence).

[0145] Location Determination Using A Network Fingerprint

[0146] The presently disclosed systems and methods can solve the problem of determining the location of a device with respect to a known location on the electrical grid or a known physical location (e.g. my home, my office) associated with a location on the electrical grid. Traditional approaches of using the Global Positioning System (GPS) or cellular tower based Location Based Services (LBS) are not sufficient. Limitations in GPS and cellular resolution make the precise determination of a location difficult, especially in cases where two locations are overlapping or in close proximity. When two locations are too close to distinguish and resolve their locations using GPS and/or cellular information, or in cases where GPS and cellular information is not available because of the lack of a transceiver or the lack of signal, the device described herein uses a collection of other communication based information to construct a network fingerprint of a known location that is subsequently used to determine whether a device is at a previously known or unknown location.

[0147] In one embodiment, the disclosed methods determine whether an electric car, or other electrical equipment such as a charging station that may be semi or completely mobile, has moved from one known location to another or otherwise left a known location. This is crucial when determining billing related matters; for example, when deciding whether to bill my home or my office for the electric power used or produced. It is also important to have knowledge about which devices are located on a network when establishing the overall load characteristics of a given area of the grid. In one example, such knowledge is useful in determining whether charging a device affects, or will affect, the overall load of my home neighborhood or my office neighborhood.

[0148] To address the issue of location resolution, a device may contain one or more communications adapters, such as Ethernet, Wi-Fi, ZigBee, Cellular, LBS, or GPS. The device may use some or all of these communications mediums in a combination of active or passive modes to extract information that is unique to a given location. Various techniques fingerprinting devices on a network may be combined to construct an overall fingerprint of the surrounding network as a whole.

[0149] Once a network location fingerprint is collected and stored it may be associated with a known location (e.g. home, or office, or parking lot space #12), or it may be assigned an otherwise random location identifier. The fingerprint may be stored in a database for later use when trying to determine a device’s location.

[0150] The disclosed system can also take into account the dynamic nature of such information. A portion of the finger-

print may be expected to change over time. For example, the list of network peers may change as new peers are added or removed from the network. The MAC address of devices may change as they are replaced with new hardware. Host operating system information collected in IP stack fingerprinting may change as operating systems are upgraded. As such, the fingerprint of a location may change over time and the database can record the last fingerprint. The database may also record the entire history of fingerprints of a location in cases where the variation over time is itself useful in identifying the location. For example, a given home location may have three network peers in the evenings while various people are home from work with their networked laptops and phones, but may have only one peer during the workweek while they are at work. Depending on the time that the network location fingerprint is compared, this sort of dynamic information can be used to resolve the location name.

[0151] Pattern matching can be used to match one location fingerprint against another. Based on the statistical nature of the fingerprint, the disclosed system is capable of making a location determination in the presence of partial or changing fingerprints by applying any number of statistical methods, such as regression analysis, logistic regression, Bayesian, pattern matching, or ad hoc weighting of various parts of the fingerprint. For example, the likelihood that a given location will replace the communications gateway that a car would connect to (and thus a change in the MAC address present in IP traffic from the gateway) is probably low in comparison to the probability of adding or removing of peers to the same network.

[0152] In an embodiment, the disclosed method uses a process by which a device connected to a network can query network peers and collect and store a set of identification information, such as MAC address, IP address, and trace routes. The method may utilize other various pieces of information to construct a fingerprint of the device’s current location such as ping latencies to gateways, other network peers, cell tower information, or GPS information. As such, the method constructs a location fingerprint that is the aggregation of various sources of information, and may further use a statistical model weighting the relevance of the various pieces of information. The information can be stored on a server or the device.

[0153] When a device subsequently performs the fingerprint process, the device can subsequently detect whether the device has changed locations by detecting differences in some or all of this set of information. Upon detecting that the device has returned to a known location, or that the device is at a new location, the device or a server can take certain actions. Such actions may include: notifying a user, notifying another server, initiating a configuration process, or operating in different modes.

[0154] According to an embodiment, a user plugs in a device to their home network, and the device scans for and records the MAC addresses of the user’s router, home PC and printer. The device transmits this information to a server, such that a fingerprint is associated with the location. The user may move the device to a new location, e.g. the user’s office. The device detects a different fingerprint from the MAC of a new router, and several dozen work computers. Another information relating to the new location is stored in the server so that the fingerprint is associated with the location. When the user returns the device to the home network, the device recognizes it is at home. The device can recognize a location even if

some, but not all, of the fingerprint has changed. For example, a printer may no longer be present.

[0155] FIG. 10 shows an embodiment of fingerprinting a local network for a power management system. Network information from devices, such as electric vehicles, is collected **1010** in order to generate a network fingerprint **1020**, which is stored **1030** in a database. As shown in FIG. 11, according to an embodiment, a change in the location of a device is detected **1110** and compared with a network fingerprint **1120** in order to determine **1130** the location of an electric vehicle.

CONCLUSION

[0156] 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.

1. A method for determining the location of devices on power flow management system using network fingerprints, comprising:

- receiving network information, wherein the network information is associated with a plurality of electric devices;
- generating a network fingerprint based on the network information; storing the network fingerprint in a database;
- detecting a change in device information of at least one of the plurality of electric devices;

comparing the changed device information of the at least one of the plurality of electric devices with the network fingerprint; and

determining a location of the at least one of the plurality of electric devices based on the network fingerprint.

2. The method of claim **1**, wherein the network information is received by a power flow management system.

3. The method of claim **1**, wherein the network information is received by at least one of the plurality of electric devices.

4. The method of claim **1**, wherein the database is stored by a power flow management system.

5. The method of claim **1**, wherein the database is stored by at least one of the plurality of electric devices.

6. The method of claim **1**, wherein the network fingerprint is generated using an approach selected from a group consisting of Global Positioning System (GPS) or cellular tower based Location Based Services (LBS).

7. The method of claim **1**, wherein the device information of the at least one of the plurality of electric devices is information selected from a group consisting of a MAC addresses, IP addresses, or trace routes.

8. The method of claim **1**, wherein the changed device information and the network fingerprint is compared using pattern matching.

9. (canceled)

10. The method of claim **1**, wherein the location of the at least one of the plurality of electric devices is a network reference.

11. The method of claim **1**, further comprising: assigning a random location identifier.

* * * * *