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(54) **SOFTWARE-CONTROLLED BATTERY CHARGING AND MONITORING OF ACCESS CPE DEVICES**

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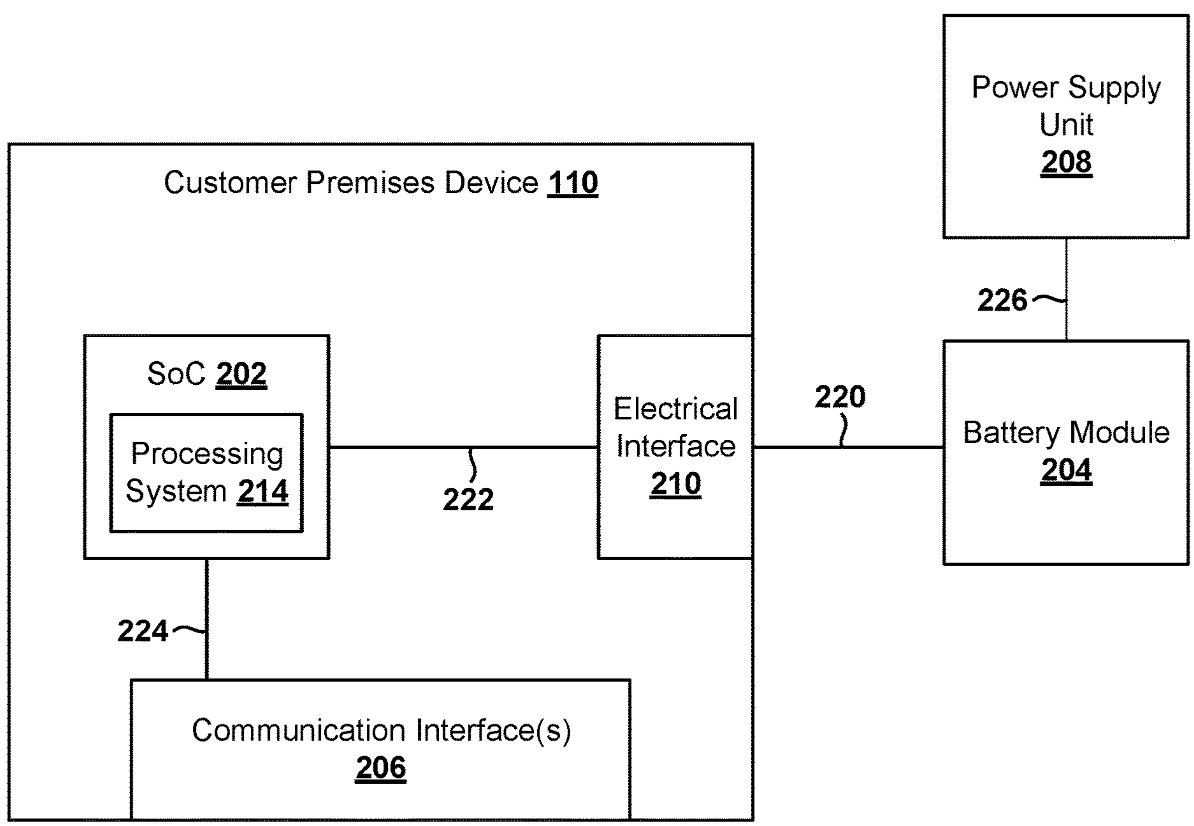
(57) **ABSTRACT**

Systems, methods, and devices for performing charging of at least one battery of a customer premises device (CPE). These may include calculating available electricity energy from a power supply unit (PSU), and charging the at least one battery of the CPE using the available electricity energy from the PSU. Some may include measuring electric energy usage of the CPE. Some may include determining whether the electric energy usage at the CPE exceeds an idle threshold and/or is less than a charge threshold, calculating the available electricity energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to the electric energy usage at the CPE exceeding the idle threshold and/or being less than the charge threshold, and using an idle electric energy usage of the CPE in response to the electric energy usage at the CPE not exceeding the idle threshold.



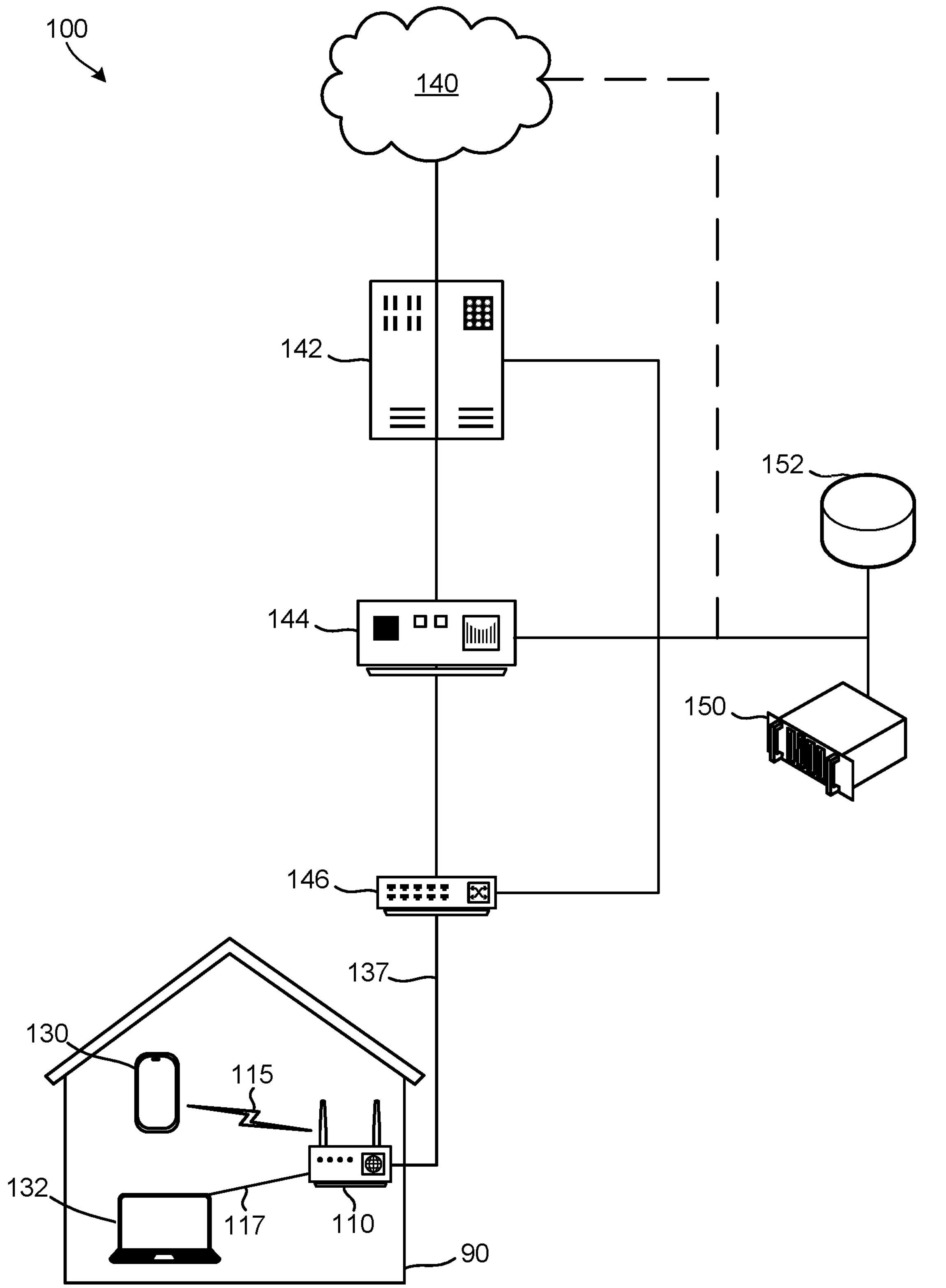


FIG. 1

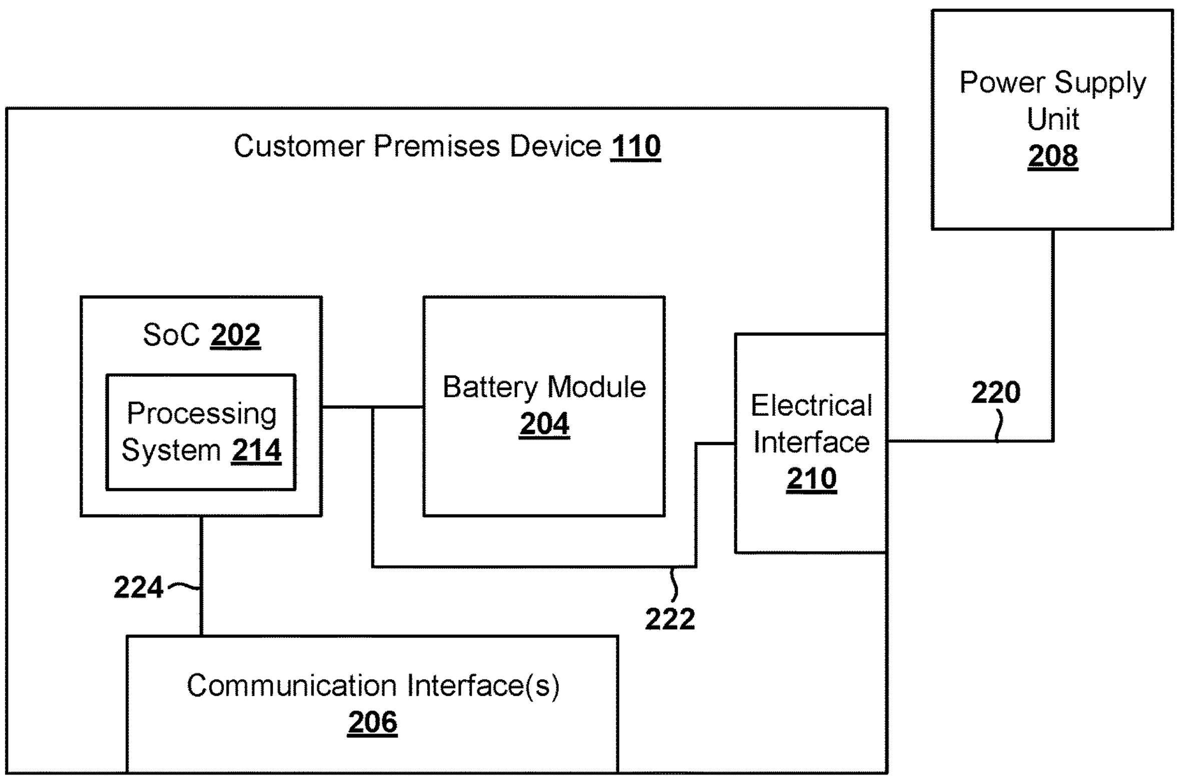

Customer Premises Device 110
SoC 202
Processing System 214
Battery Module 204
Electrical Interface 210
Power Supply Unit 208
220
222
224
Communication Interface(s) 206

FIG. 2A

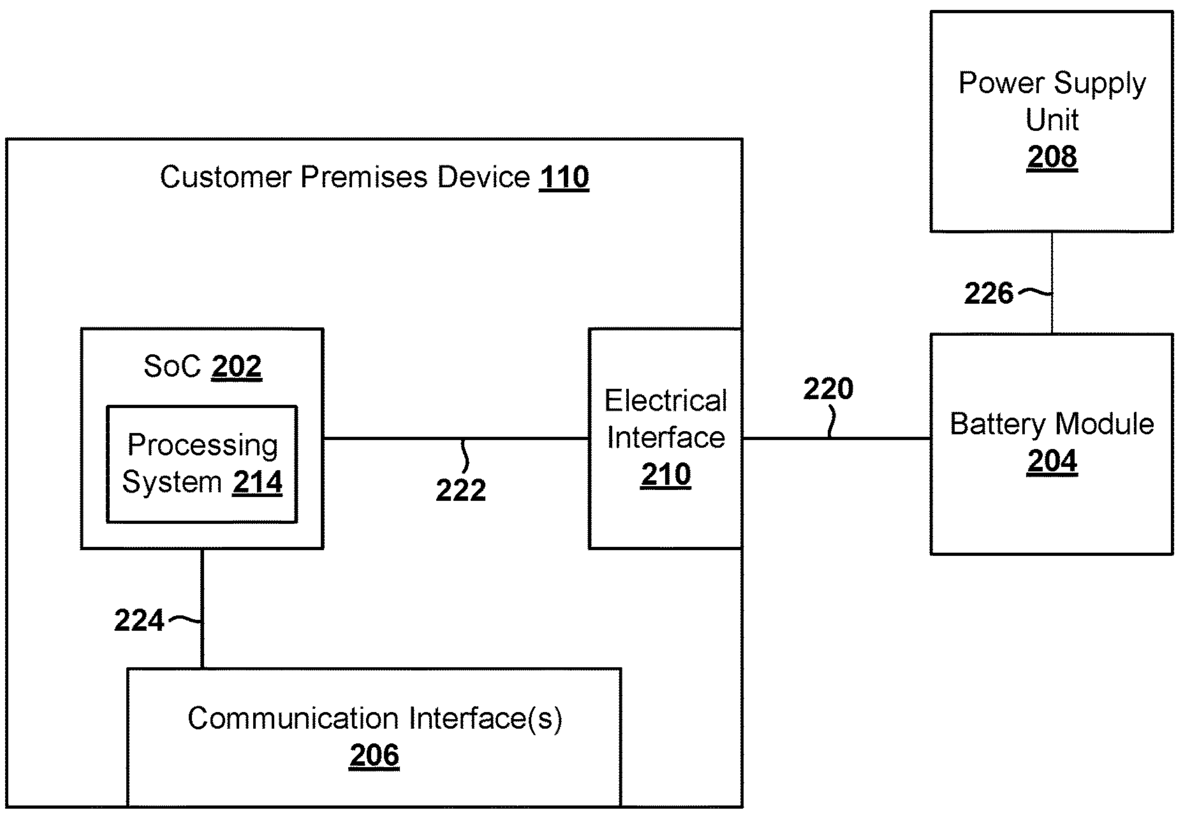

Power Supply Unit 208
226
Customer Premises Device 110
SoC 202
Processing System 214
222
Electrical Interface 210
220
Battery Module 204
224
Communication Interface(s) 206

FIG. 2B

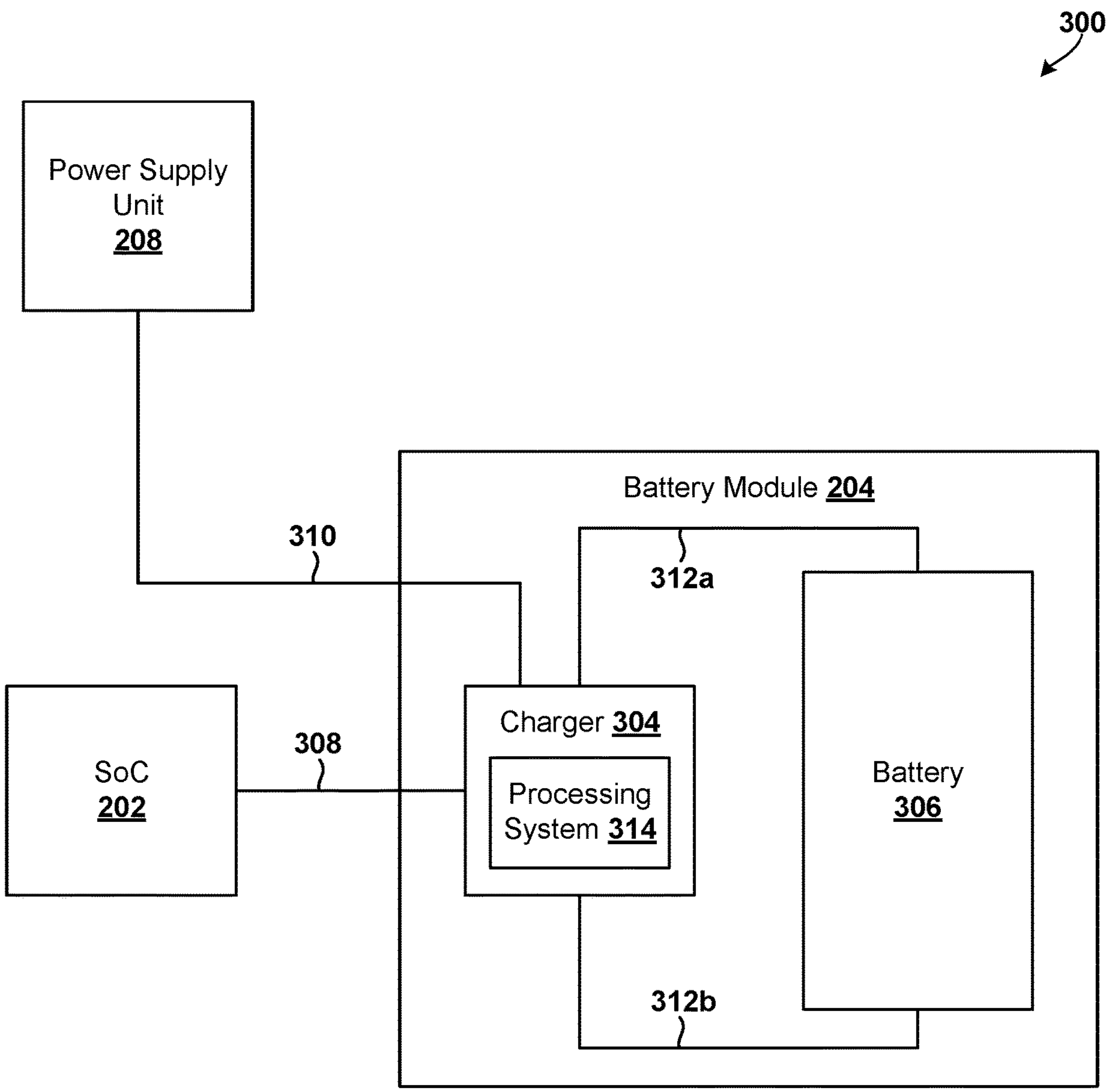

300
Power Supply Unit 208
Battery Module 204
310
312a
SoC 202
308
Charger 304
Processing System 314
Battery 306
312b

FIG. 3A

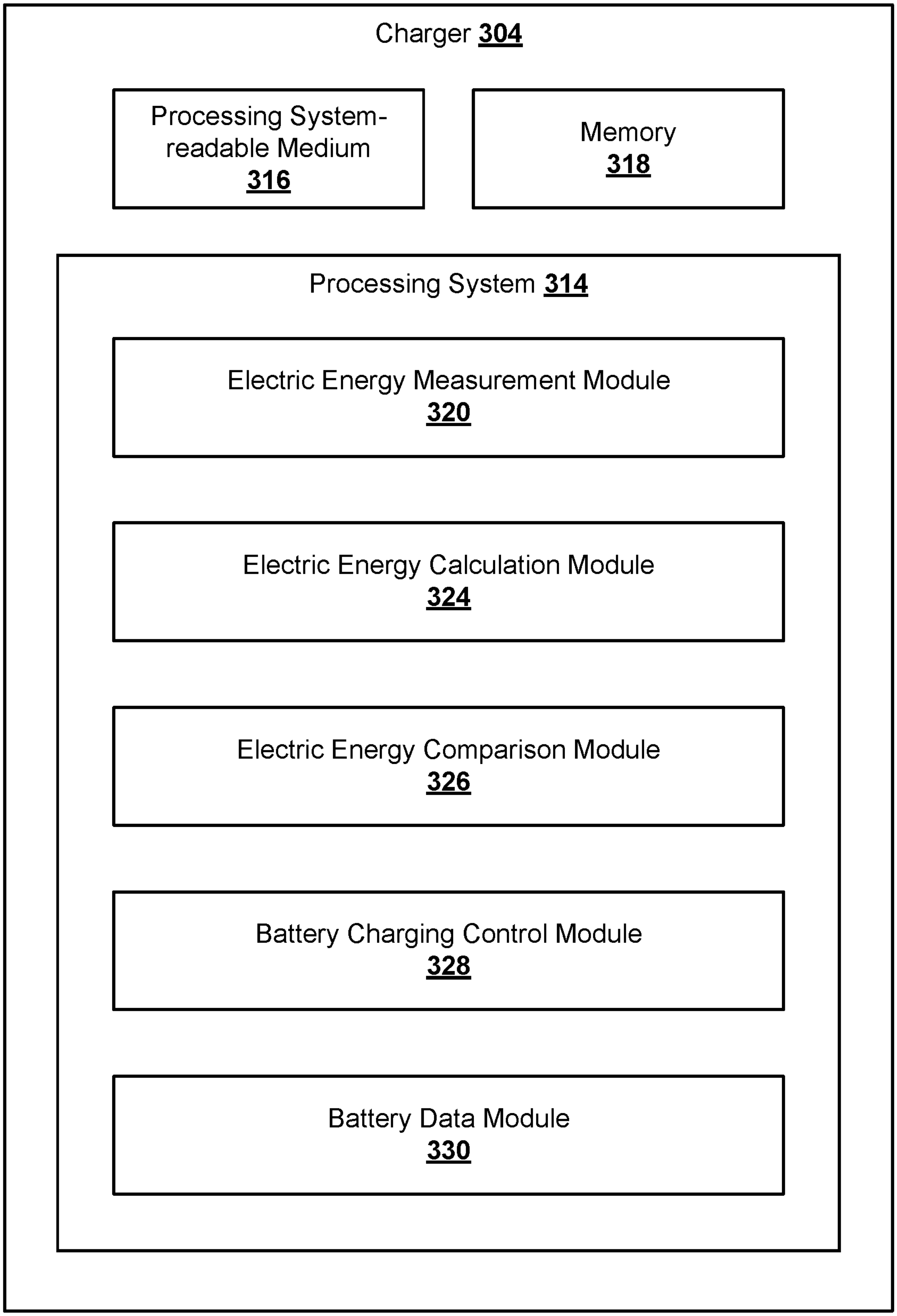

Charger 304
Processing System-readable Medium 316
Memory 318
Processing System 314
Electric Energy Measurement Module 320
Electric Energy Calculation Module 324
Electric Energy Comparison Module 326
Battery Charging Control Module 328
Battery Data Module 330

FIG. 3B

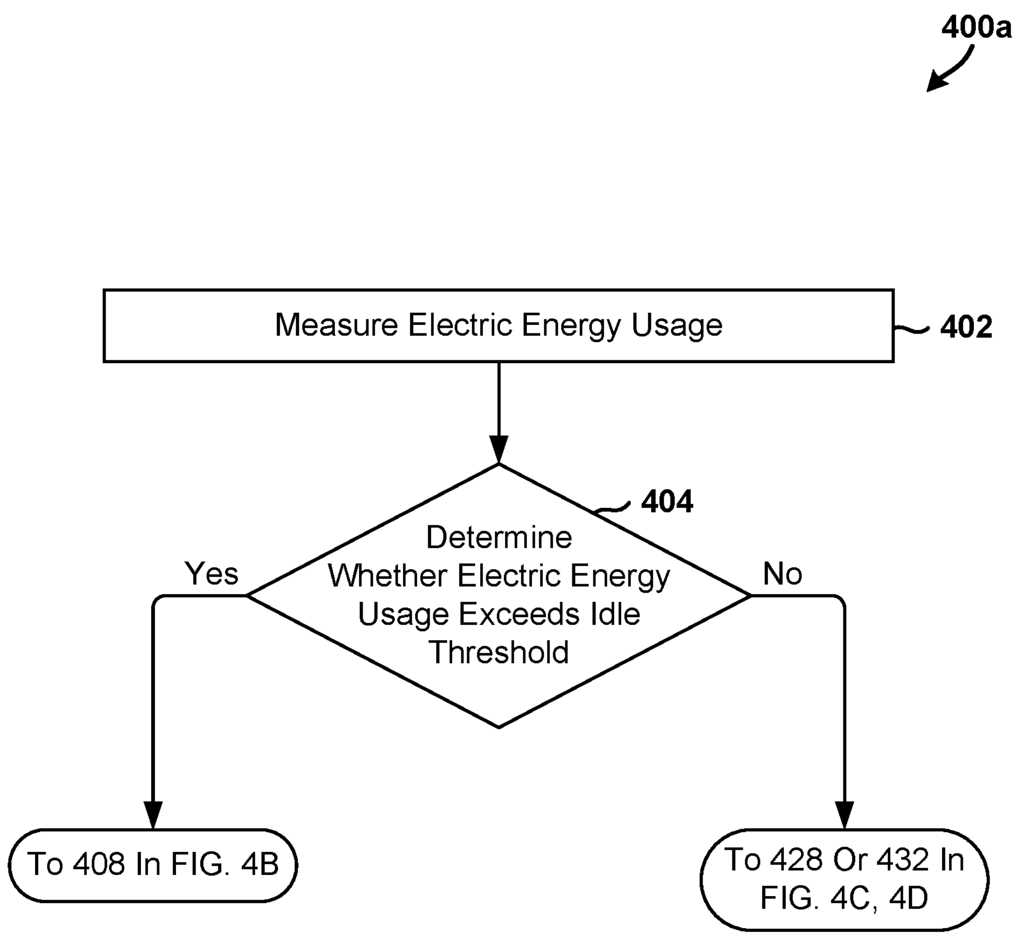

400a
Measure Electric Energy Usage
402
404
Determine Whether Electric Energy Usage Exceeds Idle Threshold
Yes
No
To 408 In FIG. 4B
To 428 Or 432 In FIG. 4C, 4D

FIG. 4A

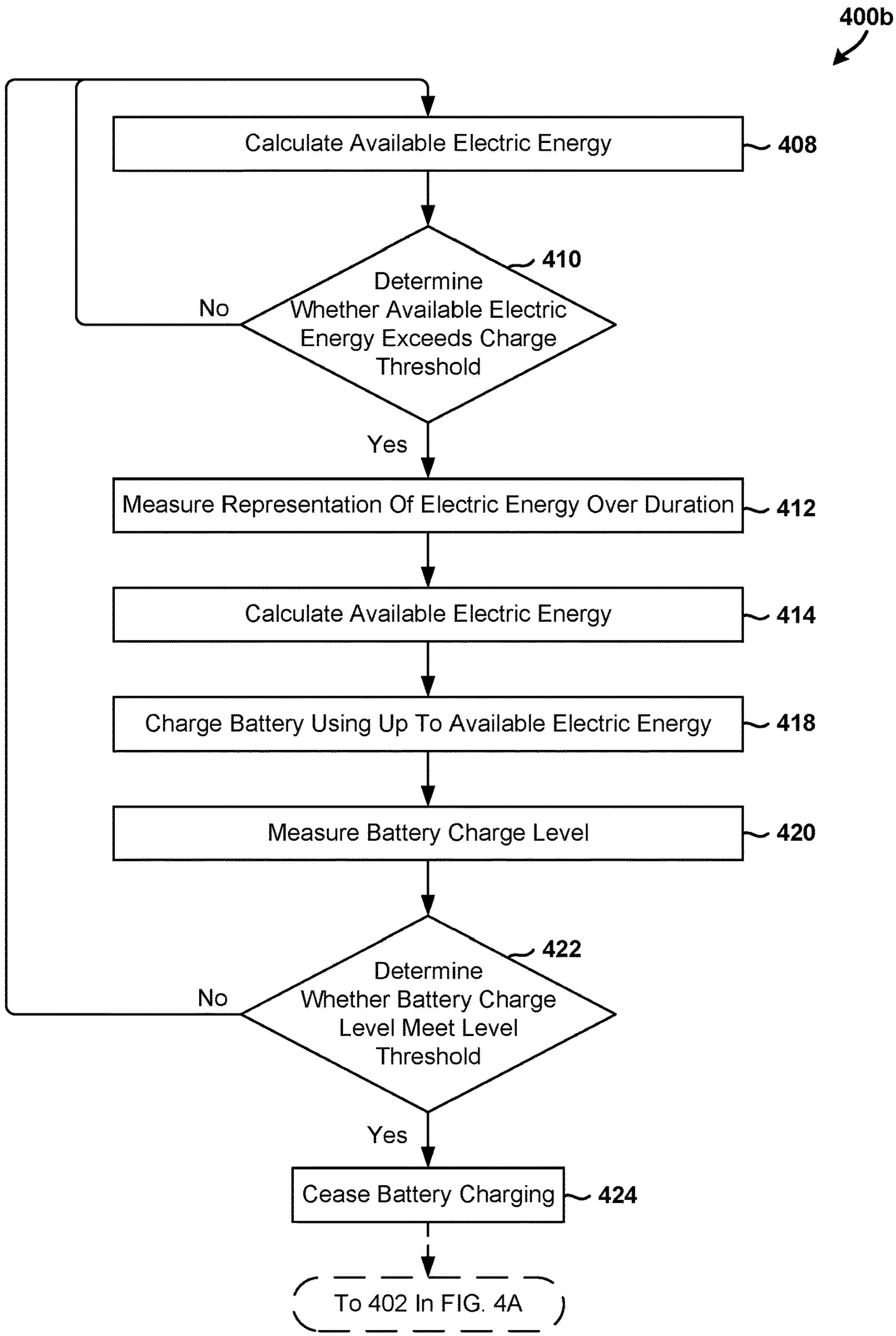

400b
Calculate Available Electric Energy
408
Determine Whether Available Electric Energy Exceeds Charge Threshold
410
No
Yes
Measure Representation Of Electric Energy Over Duration
412
Calculate Available Electric Energy
414
Charge Battery Using Up To Available Electric Energy
418
Measure Battery Charge Level
420
Determine Whether Battery Charge Level Meet Level Threshold
422
No
Yes
Cease Battery Charging
424
To 402 In FIG. 4A

FIG. 4B

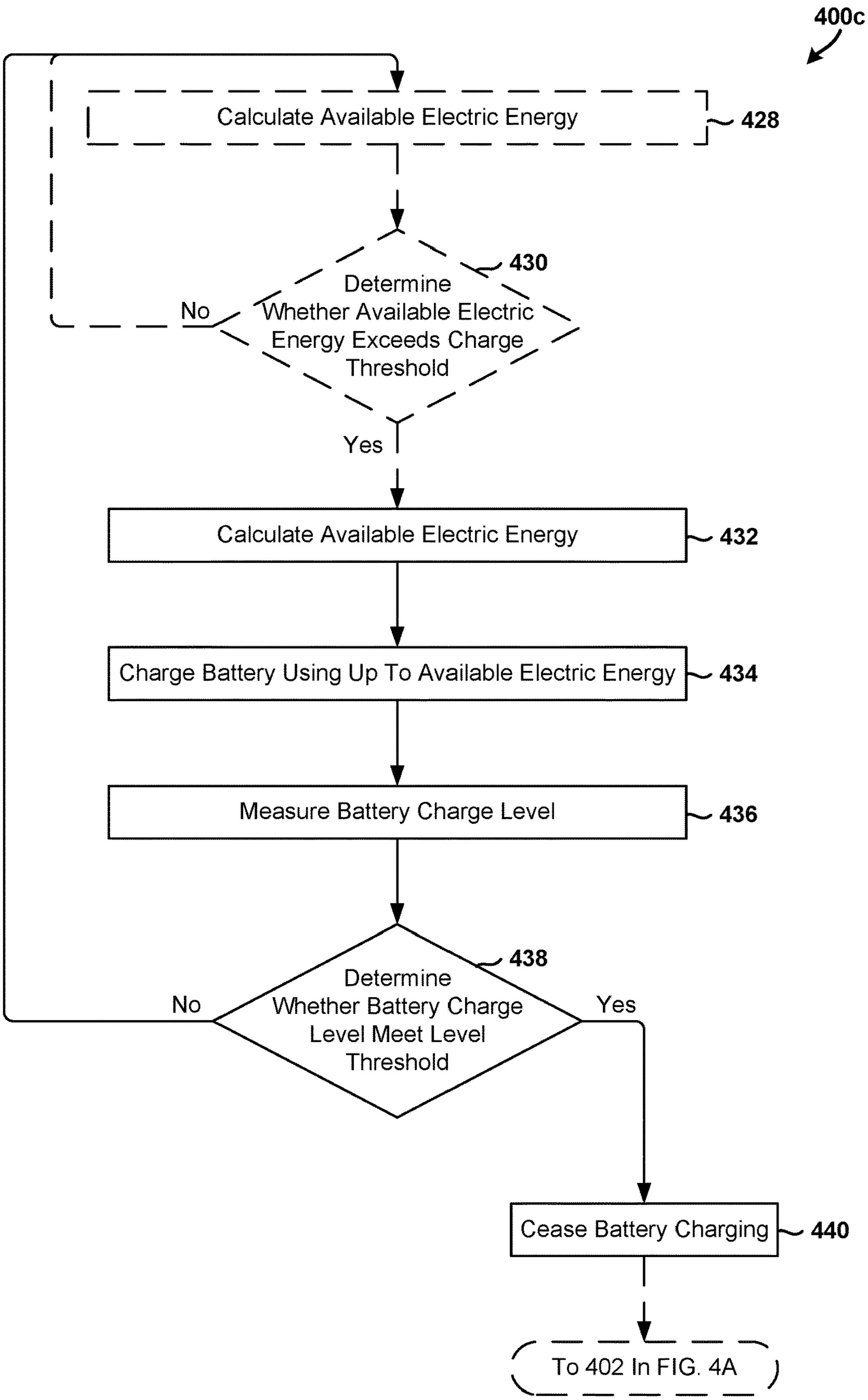

400c
Calculate Available Electric Energy
428
Determine Whether Available Electric Energy Exceeds Charge Threshold
430
No
Yes
Calculate Available Electric Energy
432
Charge Battery Using Up To Available Electric Energy
434
Measure Battery Charge Level
436
Determine Whether Battery Charge Level Meet Level Threshold
438
No
Yes
Cease Battery Charging
440
To 402 In FIG. 4A

FIG. 4C

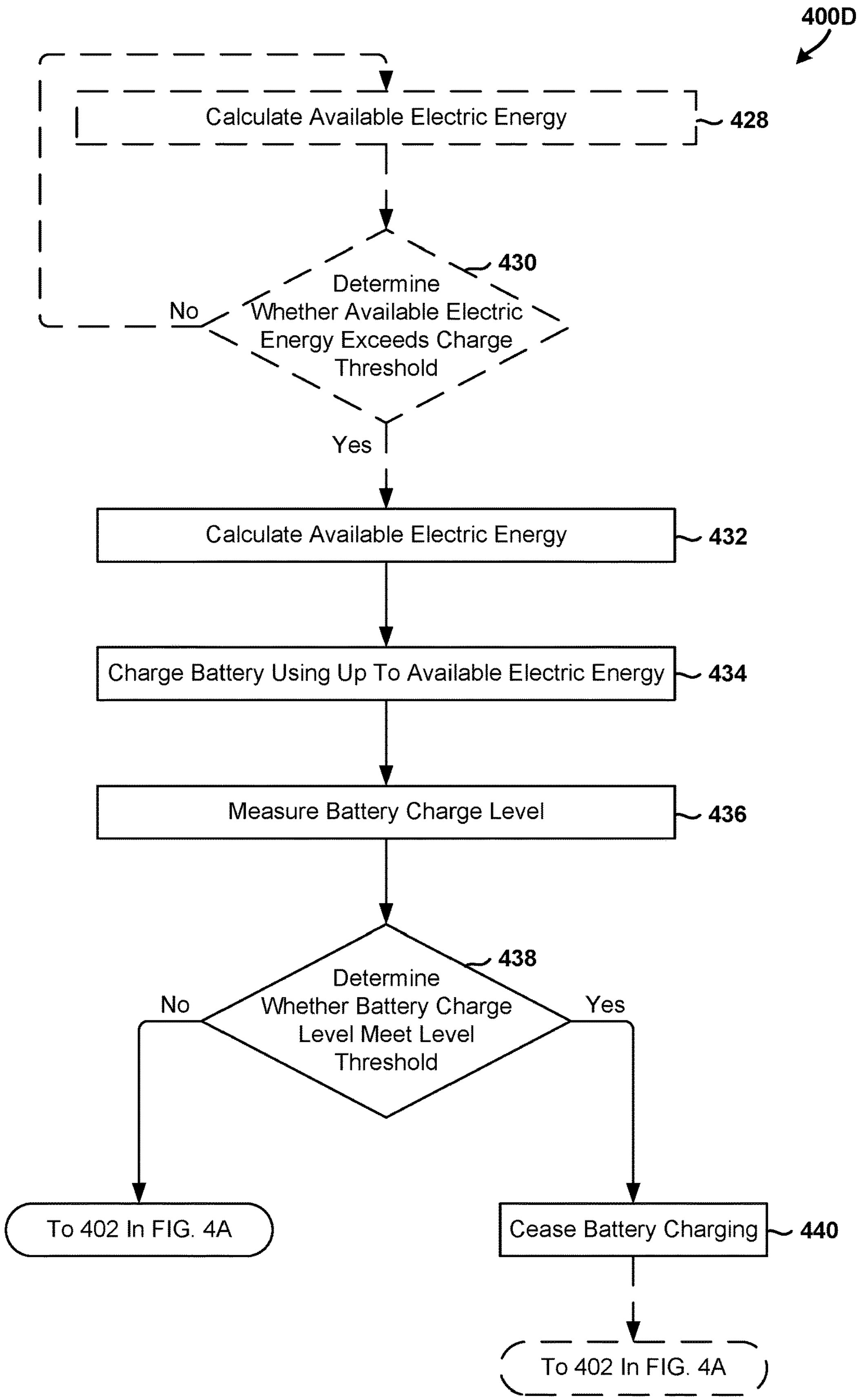

400D
Calculate Available Electric Energy
428
Determine Whether Available Electric Energy Exceeds Charge Threshold
430
No
Yes
Calculate Available Electric Energy
432
Charge Battery Using Up To Available Electric Energy
434
Measure Battery Charge Level
436
Determine Whether Battery Charge Level Meet Level Threshold
438
No
Yes
To 402 In FIG. 4A
Cease Battery Charging
440
To 402 In FIG. 4A

FIG. 4D

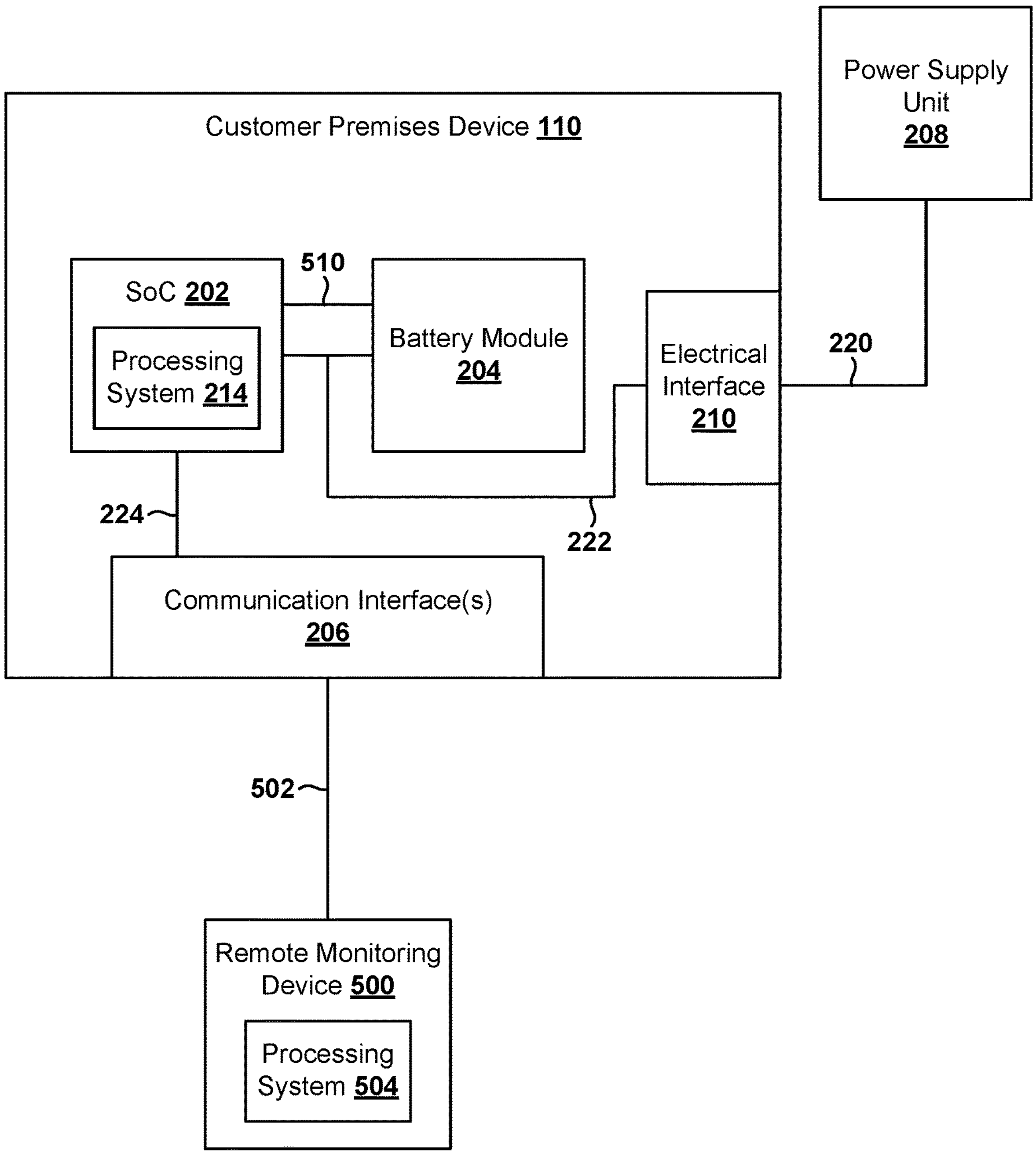
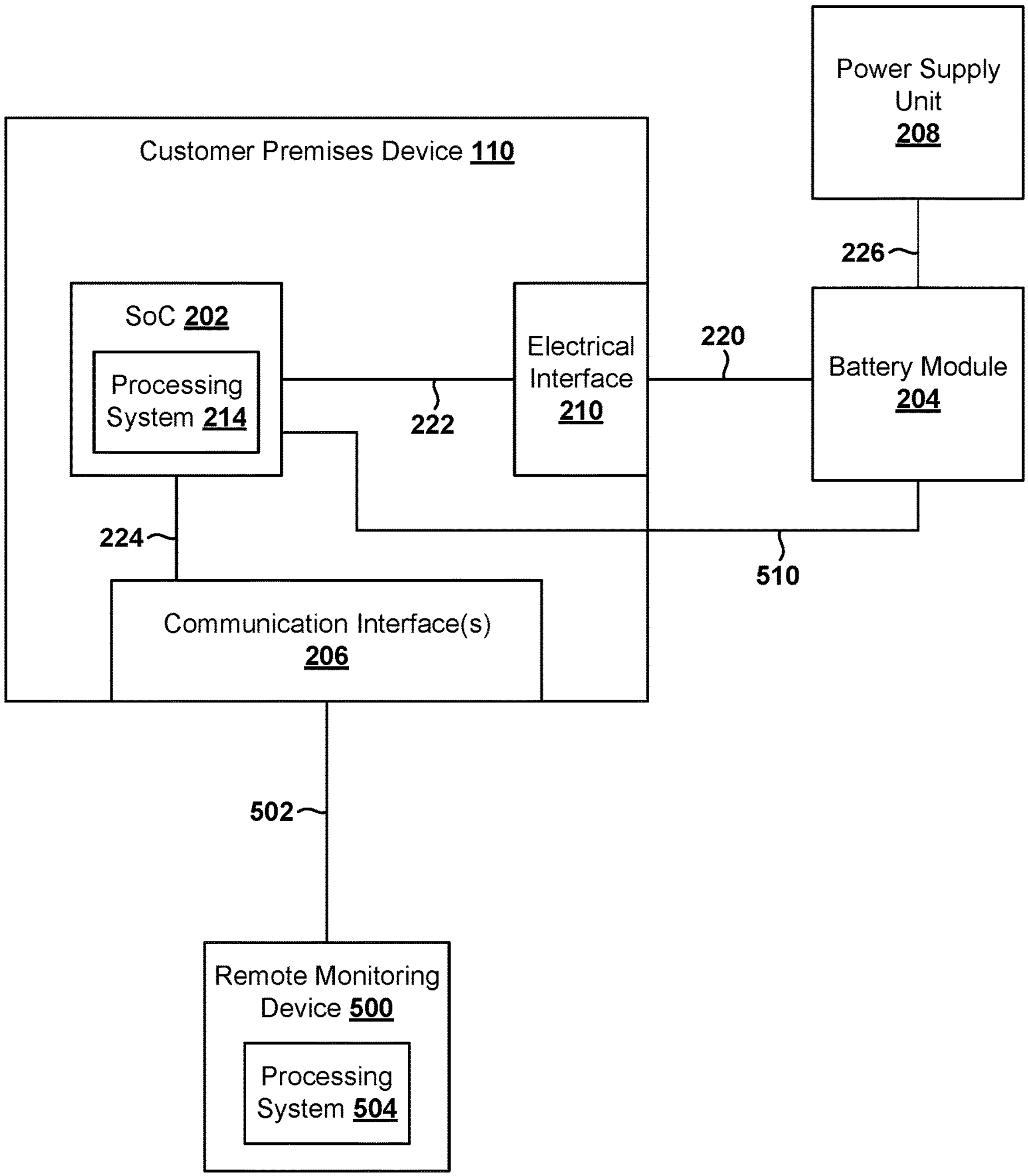

Power Supply Unit 208
Customer Premises Device 110
SoC 202
Processing System 214
510
Battery Module 204
Electrical Interface 210
220
224
222
Communication Interface(s) 206
502
Remote Monitoring Device 500
Processing System 504

FIG. 5A



Power Supply Unit 208
226
Customer Premises Device 110
SoC 202
Processing System 214
222
Electrical Interface 210
220
Battery Module 204
224
510
Communication Interface(s) 206
502
Remote Monitoring Device 500
Processing System 504

FIG. 5B

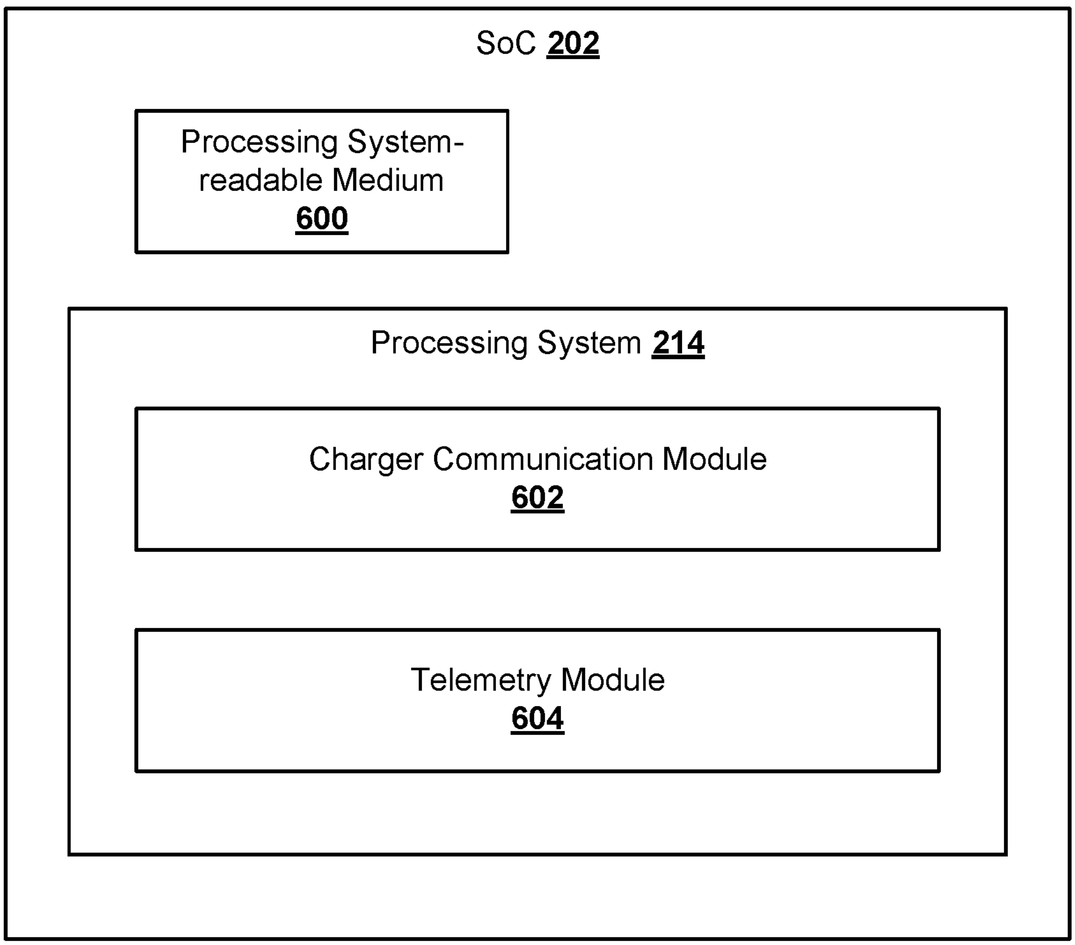

SoC 202
Processing System-readable Medium 600
Processing System 214
Charger Communication Module 602
Telemetry Module 604

FIG. 6

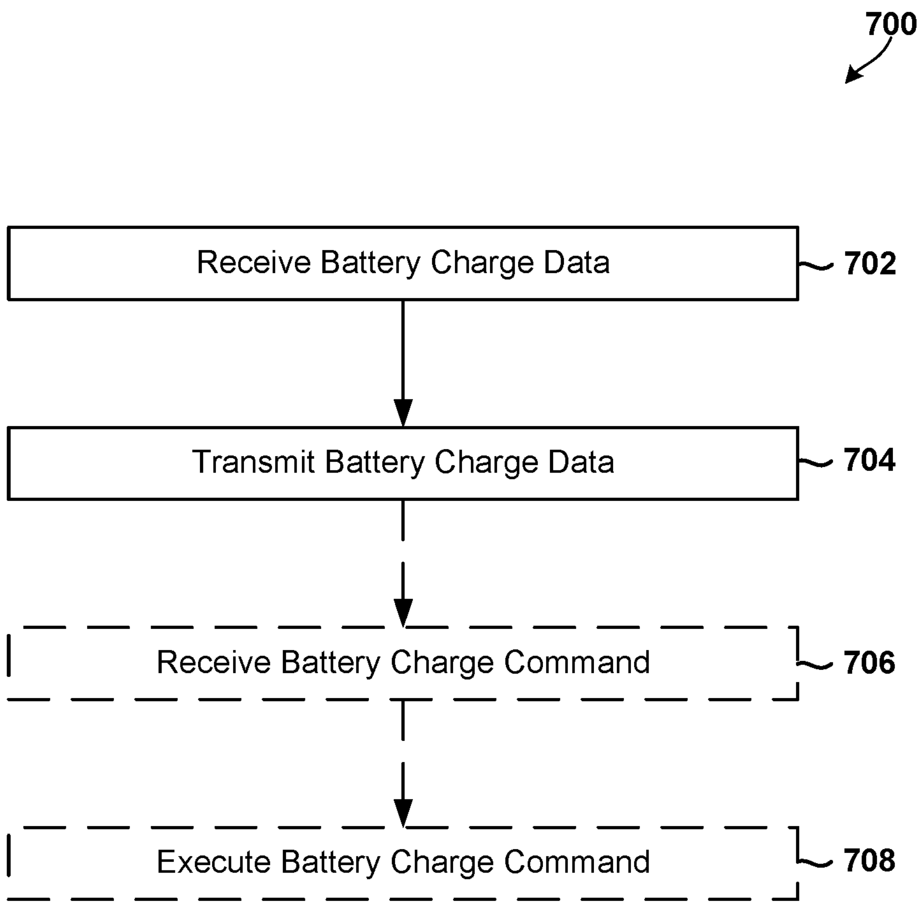

700
Receive Battery Charge Data
702
Transmit Battery Charge Data
704
Receive Battery Charge Command
706
Execute Battery Charge Command
708

FIG. 7

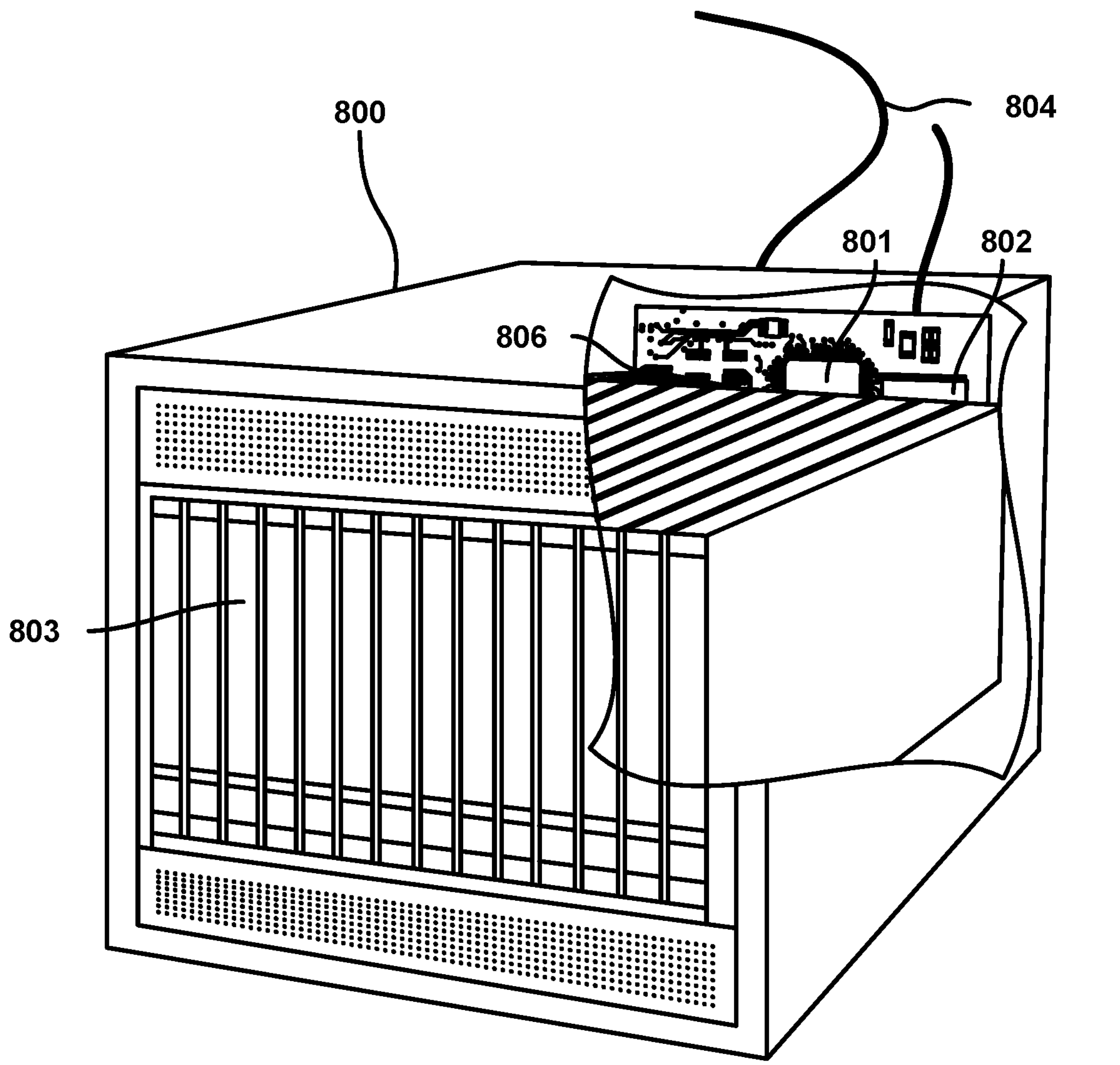


FIG. 8

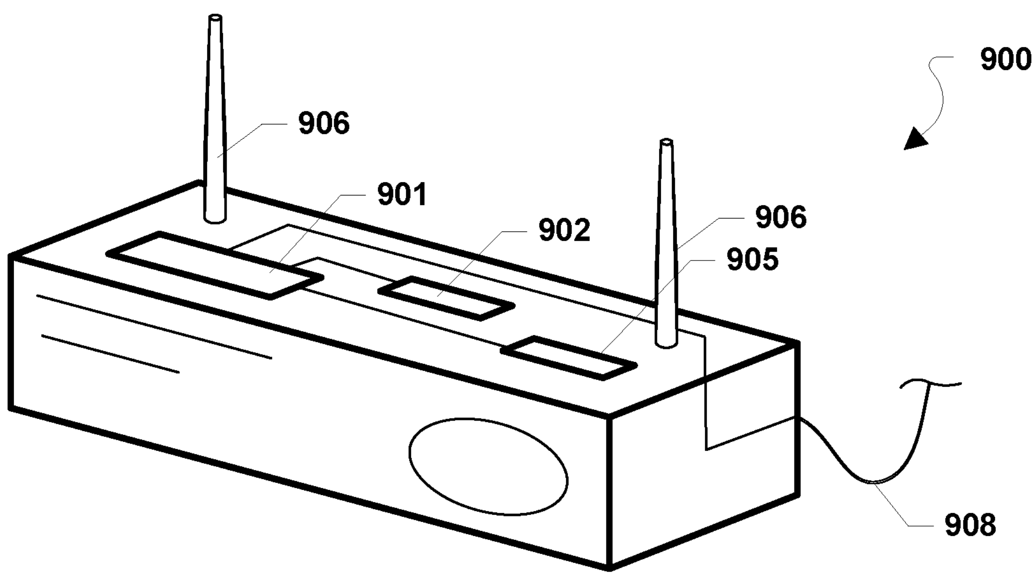


FIG. 9

SOFTWARE-CONTROLLED BATTERY CHARGING AND MONITORING OF ACCESS CPE DEVICES

BACKGROUND

[0001] Multiple system operators, which may include cable network operators, use as many as millions of field-deployed access customer premises devices (CPE) in their networks, serving residential and corporate subscribers. Many types of CPEs may be physically located at subscribers' local networks. A power supply unit (PSU) of a CPE is designed to provide a maximum output current under adverse operating conditions. However, PSU design may be limited to provide the maximum output current to support critical functions of the CPE only, but fail to provide sufficient output current to support other functions of the CPE such as charging a battery.

SUMMARY

[0002] The various aspects include methods of performing charging of at least one battery of a customer premises device (CPE. The various aspects may include calculating available electric energy from a power supply unit (PSU) of the CPE, and charging the at least one battery of the CPE using the available electric energy from the PSU, such that the maximum energy available to charge the at least one battery is the maximum available energy from the PSU.

[0003] Some aspects may further include measuring electric energy usage of the CPE, and determining whether the measured electric energy usage of the CPE exceeds an idle threshold, in which calculating the available electric energy from the PSU may include calculating the available electric energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to determining that the electric energy usage at the CPE exceeds the idle threshold, and in which calculating the available electric energy from the PSU may include calculating the available electric energy from the PSU using an idle electric energy usage of the CPE in response to determining that the electric energy usage at the CPE does not exceed the idle threshold.

[0004] In some aspects, calculating the available electric energy from the PSU may include calculating a first available electric energy from the PSU. Some aspects may further include calculating a representation of electric energy usage of the CPE over a duration, and calculating a second available electric energy from the PSU of the CPE using the representation of electric energy usage of the CPE over the duration, in which charging the at least one battery of the CPE using the available electric energy from the PSU may include charging the at least one battery of the CPE using the second available electric energy from the PSU.

[0005] Some aspects may further include measuring electric energy usage of the CPE, in which calculating the first available electric energy from the PSU may include calculating the first available electric energy from the PSU using the measuring electric energy usage of the CPE, and determining whether the first available electric energy from the PSU exceeds a charge threshold, in which calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration may include calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration in response to determining that the first available electric energy from the PSU exceeds the charge threshold.

[0006] In some aspects, calculating the available electric energy from the PSU may include calculating a first available electric energy from the PSU using an idle electric energy usage of the CPE.

[0007] Some aspects may further include measuring electric energy usage of the CPE, calculating a second available electric energy from the PSU of the CPE using the measured electric energy usage of the CPE, and determining whether the second available electric energy from the PSU exceeds a charge threshold, in which calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE may include calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE in response to determining that the second available electric energy from the PSU exceeds the charge threshold.

[0008] In some aspects, calculating the available electric energy from the PSU may include calculating the available electric energy from the PSU using a value representative of electric energy usage at the CPE operating with maximum upstream and downstream data throughputs with a foreign exchange subscriber port ringing even. Some aspects may further include determining whether the available electric energy from the PSU exceeds a charge threshold.

[0009] Some aspects may further include streaming battery status information from the CPE to a remote monitoring device.

[0010] Some aspects may further include receiving, at the CPE, a battery charge command from a remote monitoring device, in which charging the at least one battery of the CPE using the available electric energy from the PSU may include charging the at least one battery of the CPE in response to receiving the battery charge command.

[0011] Further aspects may include a computing device having a processing system configured to perform one or more operations of the methods summarized above. Further aspects may include a non-transitory processing system-readable storage medium having stored thereon processing system-executable instructions configured to cause a processing system of a computing device to perform operations of the methods summarized above. Further aspects include a computing device having means for performing functions of the methods summarized above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary embodiments, and together with the general description given above and the detailed description given below, serve to explain the features of various embodiments.

[0013] FIG. **1** is a block diagram of an example communication network that includes a customer premises device (CPE) and a remote monitoring server suitable for use with various embodiments.

[0014] FIGS. **2**A and **2**B are block diagrams of example CPEs suitable for use with various embodiments.

[0015] FIGS. **3**A and **3**B are block diagrams of an example battery charging system of a CPE suitable for use with various embodiments.

[0016] FIGS. **4**A-**4**D are process flow diagrams that illustrate a method for charging a battery of a CPE in accordance with the various embodiments.

[0017] FIGS. **5**A and **5**B are block diagrams of example CPEs connected to a remote monitoring device suitable for use with various embodiments.

[0018] FIG. **6** block diagrams of an example a system on chip of a CPE suitable for use with various embodiments.

[0019] FIG. **7** is a process flow diagram that illustrates a method for remote battery charging monitoring and control for a battery of a CPE in accordance with the various embodiments.

[0020] FIG. **8** is a component diagram of an example server suitable for implementing the various embodiments.

[0021] FIG. **9** is a component diagram of an example network device suitable for use with various embodiments.

DETAILED DESCRIPTION

[0022] The various embodiments will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. References made to particular examples and implementations are for illustrative purposes, and are not intended to limit the scope of the invention or the claims.

[0023] The term "service provider network" is used generically herein to refer to any network suitable for providing consumers with access to the Internet or IP services over broadband connections, and may encompass both wired and wireless networks/technologies. Examples of wired network technologies and networks that may be included within a service provider network include cable networks, fiber optic networks, hybrid-fiber-cable networks, Ethernet, local area networks (LAN), metropolitan area networks (MAN), wide area networks (WAN), networks that implement the data over cable service interface specification (DOCSIS), networks that utilize asymmetric digital subscriber line (ADSL) technologies, etc. Examples of wireless network technologies and networks that may be included within a service provider network include third generation partnership project (3GPP), long term evolution (LTE) systems, third generation wireless mobile communication technology (3G), fourth generation wireless mobile communication technology (4G), fifth generation wireless mobile communication technology (5G), global system for mobile communications (GSM), universal mobile telecommunications system (UMTS), high-speed downlink packet access (HSDPA), 3GSM, general packet radio service (GPRS), code division multiple access (CDMA) systems (e.g., cdmaOne, CDMA2000TM), enhanced data rates for GSM evolution (EDGE), advanced mobile phone system (AMPS), digital AMPS (IS-136/TDMA), evolution-data optimized (EV-DO), digital enhanced cordless telecommunications (DECT), Worldwide Interoperability for Microwave Access (WiMAX), wireless local area network (WLAN), Wi-Fi Protected Access I & II (WPA, WPA2), Bluetooth®, land mobile radio (LMR), and integrated digital enhanced network (iden). Each of these wired and wireless technologies involves, for example, the transmission and reception of data, signaling and/or content messages.

[0024] Any references to terminology and/or technical details related to an individual wired or wireless communications standard or technology are for illustrative purposes only, and not intended to limit the scope of the claims to a particular communication system or technology unless specifically recited in the claim language.

[0025] The term "user equipment (UE)" may be used herein to refer to any one or all of satellite or cable set top boxes, laptop computers, rack mounted computers, routers, cellular telephones, smart phones, personal or mobile multimedia players, personal data assistants (PDAs), customer premises equipment (CPE), personal computers, tablet computers, smart books, palm-top computers, desk-top computers, wireless electronic mail receivers, multimedia Internet enabled cellular telephones, wireless gaming controllers, streaming media players (such as, ROKU™), smart televisions, digital video recorders (DVRs), modems, routers, network switches, residential gateways (RG), access nodes (AN), bridged residential gateway (BRG), fixed mobile convergence products, home networking adapters and Internet access gateways that enable consumers to access communications service providers' services and distribute them around their house via a local area network (LAN), and similar electronic devices which include a programmable processor and memory and circuitry for providing the functionality described herein.

[0026] The terms "component," "system," and the like may be used herein to refer to a computer-related entity (e.g., hardware, firmware, a combination of hardware and software, software, software in execution, etc.) that is configured to perform particular operations or functions. For example, a component may be, but is not limited to, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computing device. By way of illustration, both an application running on a computing device and the computing device may be referred to as a component. One or more components may reside within a process and/or thread of execution and a component may be localized on one processor or core and/or distributed between two or more processors or cores. In addition, these components may execute from various non-transitory computer readable media having various instructions and/or data structures stored thereon. Components may communicate by way of local and/or remote processes, function or procedure calls, electronic signals, data packets, memory read/writes, and other known computer, processor, and/or process related communication methodologies.

[0027] The terms "customer premises device" or "customer premises equipment", which both may be abbreviated as "CPE", may include a cable modem, digital subscriber line modem, router, switch, firewall, packet filter, wireless access point, residential gateway, etc. that may provide network connectivity to residential and/or commercial (e.g., business, non-profit, worksite, retail, hospitality, service provider, etc. location) network. A CPE may allow user equipment (UE) devices on a local area network (LAN) to connect to a wide area network (WAN) and ultimately the Internet.

[0028] The term "electric energy" may refer to, individually and/or in any combination, electric current, voltage, or power. Similarly, any functions implemented by devices, components, circuits, hardware, processor systems, etc., such as use, measurement, calculation, identification, determination, charging, etc. regarding electric energy may be implemented based on, individually and/or in any combination, electric current, voltage, or power.

[0029] Multiple system operators, which may include cable network operators, use as many as millions of field-deployed access customer premises devices (CPE; or customer premises equipment) in their networks, serving residential and corporate subscribers. Many types of CPEs may be physically located at subscribers' local area networks. A power supply unit (PSU) of a CPE is designed to provide a maximum output current under adverse operating conditions. Current PSU designs are limited to providing the maximum output current to support critical functions of the CPE under the adverse operating conditions. Critical functions may include some, all, or only necessary functions of the CPE. The PSU designs may be limited by cost, form factor of a main PSU body, etc. However, such PSU designs have difficulty to provide sufficient output current to support other functions of the CPE, as the PSU is fully engaged to support the critical functions of the CPE. For example, current PSUs may have difficulty to charge CPE batteries as the PSU output supply may be devoted to supporting the CPE critical functions. The additional demands of also charging a CPE battery may be beyond the capabilities of the PSU, while CPE critical functions are on-going.

[0030] Some CPEs may include at least one battery that needs to be charged after a charge level of the battery is reduced due to use or periods of disuse of the at least one battery. The at least one battery may be a battery of a bank of batteries or a battery module. The at least one battery may include two or more batteries in which the at least one battery may be part of a pair of batteries. For example, the at least one battery may be relied upon in instances when power to the CPE from the PSU is lost, such as during power outage from an electrical grid. The at least one battery may output power to maintain operation of the CPE during the power loss from the PSU. However, output from the at least one battery reduces the electric energy availability at the at least one battery. At some point, the at least one battery will benefit from a recharge process to replenish the discharged electric energy. In particular, upon the restoration of power is restored following a power outage from the electrical grid, the CPE battery may seek a recharge to replenish its power storage capabilities. However, a typical PSU may not be able to provide sufficient electric energy to both support the critical functions of the CPE and recharge the battery concurrently. Since the support of the critical functions of the CPE is a priority, secondary functions such as recharging the CPE battery may not be supported at all times.

[0031] Various embodiments disclosed herein seek to overcome the foregoing problems. The embodiments may provide a charger of the CPE that may be configured to identify instances during CPE operation at which there is sufficient electric energy available from the PSU to provide a charge operation of the at least one battery. The charger may be configured to charge the at least one battery using the electric energy from the PSU based on availability of sufficient electric energy from the PSU to charge the at least one battery. The charger may identify availability of sufficient electric energy available from the PSU to charge the at least one battery based on electric energy usage by the CPE and PSU electric energy output capabilities. The charger may charge the at least one battery in response to identifying availability of the sufficient electric energy from the PSU to charge the at least one battery. For example, there may be sufficient electrical energy from the PSU in instances in which critical functions of the CPE require reduced amounts of electrical energy such as the CPE operating in idle mode.

[0032] In some embodiments, the CPE may be actively operating, such as in an active mode (i.e., not in an idle or standby mode). The CPE actively operating may include implementing varying levels (e.g., maximum, high, medium, low, etc.) of upstream and downstream throughputs. The CPE actively operating may also include or not include asynchronous foreign exchange subscriber (FXS) port ringing while implementing the varying levels of upstream and downstream throughputs. In some embodiments, the CPE may be inactively operating, such as not in an active mode or in an idle or standby mode. For example, the CPE inactively operating may include a power saving mode, which may be implemented during a power loss from the electrical grid. The charger may measure electric energy usage at the CPE. The electric energy usage at the CPE may be used by the charger to identify how the CPE is operating. The measurement of electric energy usage at the CPE may be used by the charger to identify whether the CPE is using too much of the electric energy from the PSU such that the PSU may not also support the charging of the at least one battery at present time. For example, the electric energy usage at the CPE by critical functions may be too great for there to be sufficient electric energy from the PSU to charge the at least one battery under the current electric energy consumption conditions.

[0033] A calculation, by the charger, of the electric energy available from the PSU to charge the at least one battery may vary based on how the CPE is operating. For example, electric energy usage at the CPE over a duration may be used to calculate the electric energy available from the PSU for the CPE operating in an active mode. For another example, electric energy usage at the CPE at a discreet moment may be used to calculate the electric energy available from the PSU for the CPE operating in an idle mode. The electric energy usage at the CPE may be compared with an electric energy output capability of the PSU by the charger to calculate the electric energy available from the PSU to charge the at least one battery.

[0034] One or more criterion for identifying whether there is sufficient electric energy available from the PSU to charge the at least one battery may vary depending on how the CPE is operating. For the CPE in an active mode, the criterion for identifying whether there is sufficient electric energy available from the PSU may be a comparison of the electric energy available from the PSU and an electric energy output capability of the PSU.

[0035] FIG. **1** illustrates an example of a communication network **100**, such as an internet network, in accordance with various embodiments. With reference to FIG. **1**, the communication network **100** may include various network operations sites such as one or more headends **142**, hubs **144**, or nodes **146**, any of which may be or be part of a cable-plant. The cable plant may include hybrid fiber coax (HFC) architecture or Distributed Access Architecture (DAA). Each of the network operations sites **142**, **144**, **146** may be configured to provide connectivity service between one or more customer premises equipment (CPE; or customer premises equipment) **110** and a communication network **140** (e.g., the Internet). Each of the network operations sites **142**, **144**, **146** may include network hardware to enable and control the connectivity service, such as a channel modulator, a frequency multiplexer, an amplifier, a tap, a splitter, a mode, a cable management termination system, a switch, a router, a quadrature amplitude modulator, etc. The CPE **110**, the network operations sites **142**, **144**, **146**, and the communication network **140** may be coupled by one or more communication links **137**.

[0036] One or more CPEs **110** may be located at one or more residential or commercial locations **90** and connect a user equipment (UE) devices **130**, **132** to the communication network **140**. The CPE **110** may be a network device that enables communication between networked devices, like the one or more UE devices **130**, **132** and the communication network **140**. The CPE **110** may include the functionality of a modem or router, which enables the UE devices **130**, **132** access to the communication network **140**. In some embodiments, the CPE **110** may be multiple devices that may include the functionality of a modem or router. In some embodiments, the CPE **110** may be a modem operating in a routing mode and connected wireless access point. In some embodiments, the CPE **110** may be a gateway device. A non-exhaustive and non-limiting list of examples of the CPE **110** may include a D4.0/D3.1 residential embedded multimedia terminal adapter (eMTA), D4.0/D3.1 small-medium business (SMB) eMTA, advanced wireless gateway (AWG), 1/10G Ethernet passive optical network (EPON) optical network unit (ONU), etc.

[0037] The UE device **130**, **132** may be any electronic device equipped with at least a processor, communication systems, and memory configured to receive and send data of the user computing device **130**, **132** via the communication network **140**. The UE device **130**, **132** may be coupled to the CPE **110** by a short-range wireless connection **115** (e.g., Wi-Fi, Bluetooth, etc.) or wired connection **117** (e.g., Ethernet, etc.). The CPE **110** may be coupled to the network operations sites **142**, **144**, **146** and the communication network **140** by one or more communication links **137**. The UE device **130**, **132** alternatively, or additionally, may be coupled to the network operations sites **142**, **144**, **146** and the communication network **140** by a long-range wireless connection (not shown).

[0038] Each of the network operations sites **142**, **144**, **146** may be connected to remotely, such as via the communication network **140**, or include locally a computing device **150** and a data storage device **152**. The computing device **150** may be any electronic device equipped with a processing system, communication systems, and memory, such as a server. The processing system may include one or more processors, processor cores, controllers, microcontrollers, etc. The processing system of the computing device **150** may be configured to execute computer software. The computing device **150** may be configured to process data from and transmit data or commands to the CPE **110** via the one or more communication links **137**, the network operations sites **142**, **144**, **146**, or the communication network **140**. The data storage device **152** may be any non-volatile, processor-system readable media, such as a solid-state storage device, optical storage device, magnetic storage device, etc. The data storage device **152** may be configured to persistently store data from and provide access to the data to the computing device **150**.

[0039] In some embodiments, the computing device **150** and the data storage device **152** may be located at the communication network **140**, such as part of a cloud computing network. The cloud computing network may include multiple computing devices **150** and data storage devices **152** configured to, individually or together, implement cloud-based services accessible by the UE device **130**, **132**, the CPE **110**, or the network operations sites **142**, **144**, **146**.

[0040] In some embodiments, any combination of the computing device **150** and the data storage device **152** may be located locally at the network operations sites **142**, **144**, **146** or remotely to the network hardware sites **142**, **144**, **146**. For example, both computing devices **150** and data storage devices **152** may be located locally at any of the network operations sites **142**, **144**, **146**. For another example, both the computing device **150** and the data storage device **152** may be located remotely from each of the network operations sites **142**, **144**, **146**. For another example, computing devices **150** may be located locally at any of the network operations sites **142**, **144**, **146** and the data storage device **152** may be located remotely from each of the network operations sites **142**, **144**, **146**.

[0041] The communication links **137** may use a variety of wireless (e.g., 5g-NR(u), LTE, Citizens Broadband Radio Service (CBRS), etc.) or wired networks (e.g., Ethernet, TV cable, telephony, fiber optic and other forms of physical network connections) that may use one or more communication protocols, such as Ethernet, Point-To-Point protocol, High-Level Data Link Control (HDLC), Advanced Data Communication Control Protocol (ADCCP), and Transmission Control Protocol/Internet Protocol (TCP/IP).

[0042] FIGS. **2**A and **2**B illustrate examples of the CPE **110** suitable for use with various embodiments. With reference to FIGS. **1**-**2**B, the CPE **110** may include a system on chip (SoC) **202**, one or more communication interfaces **206**, a battery module **204**, and a PSU **208**. The SoC **202** may include a processing system **214**, communication systems, and memory. The processing system **214** may include one or more processors, processor cores, controllers, microcontrollers, etc. The SoC **202** may be configured to control various functions of the CPE **110**. The functions of the CPE may include communications or access functions for communication between one or more connected UE devices (e.g., UE device **130**, **132** in FIG. **1**) and communication networks (e.g., communication network **140** in FIG. **1**). The one or more communication interfaces **206** may include processing systems, hardware, and physical ports configured for implementing communication functions of the CPE **110**. A non-exhaustive and non-limiting list of examples of physical ports of the one or more communication interfaces **206** may include voice ports (e.g., RJ11 ports), 10Gb Ethernet ports (e.g., RJ45 ports), 1Gb Ethernet ports (e.g., RJ45 ports), coaxial radio frequency ports (e.g., F81 connector), etc. The SoC **202** and the one or more communication interfaces **206** may be connected via one or more communication buses **224**.

[0043] The PSU **208** may be configured to provide electric energy from a power source (not shown) to the CPE **110**. For example, the PSU **208** may connect to an electrical outlet and provide electric energy from the electrical outlet to the CPE **110**. The PSU **208** may condition the electric energy from the power source to provide a stable and regulated electrical supply to the CPE **110**. The PSU **208** may adjust the output of electric energy to the CPE **110** to meet the precise electric energy requirements of the CPE **110**. The PSU **208** may be designed to optimize the electric energy quality, minimize electrical noise and interference, and enhance the reliability and efficiency of the CPE **110**. The PSU **208** may provide electric energy to the CPE **110** via an electrical connector **220** connected to an electrical interface **210** of the CPE **110**. In some embodiments, the electrical connector **220** may include an electrical conduit, wire, lead, bus, pin, printed circuit board, etc. In some embodiments, the electrical interface **210** may include an inline connection or a chassis connection having a physical port, such as an EIAJ jack, a USB port, etc. to which the electrical connector **220** may be connected. The electrical interface **210** may connect the electrical connector **220** and an electrical connector **222**. In some embodiments, the electrical connector **220** may include an electrical conduit, wire, lead, bus, pin, printed circuit board, etc. The electric energy may be distributed within the CPE **110**, such as at least to the SoC **202**, via the electrical connector **222**.

[0044] An optimized design of the PSU **208** may include the PSU **208** configured to provide a maximum electric energy sufficient to support the critical functions of the CPE **110**. In instances in which the critical functions of the CPE **110** demand large amounts of electrical energy, the maximum electric energy provided by the PSU **208** may be insufficient to support the critical functions of the CPE **110** concurrently with other functions of the CPE **110** (e.g., battery charge functions). Consumption of at least part of the maximum electric energy by the critical functions of the CPE **110** may result in insufficient electric energy from the PSU **208** to support the other functions of the CPE **110**. Critical functions of the CPE **110** may include, for example, the communications or access functions for communication between one or more connected UE devices (e.g., UE device **130**, **132** in FIG. **1**) and communication networks. Other functions of the CPE **110** may include charging the one or more batteries of the battery module **204**.

[0045] For a non-limiting example, the PSU **208** may be designed to provide electric energy sufficient to support the critical functions of the CPE **110** that may use an average maximum current of greater than 2A. For example, a D4.0 residential eMTA may use an average maximum current of approximately 2.22A for implementing high-throughput traffic and asynchronous foreign exchange subscriber (FXS) port ringing. For another example, a D4.0 SMB eMTA may use an average maximum current of approximately 2.67A for implementing high-throughput traffic and asynchronous FXS port ringing. The PSU **208** may be incapable of providing electric power to support the critical functions of the CPE **110** as well as providing additional electric energy sufficient to charge the one or more batteries of the battery module **204**. For example, the PSU **208** may be unable to provide an additional electric energy to the average maximum current. For example, the average maximum current may be consumed by the CPE **110** implementing the critical functions and the PSU **208** may not be able to provide an additional 500 mA needed to charge the one or more batteries of the battery module **204**.

[0046] In the example of FIG. **2**A, the CPE **110** may include the battery module **204** within a housing of the CPE **110**. The PSU **208** may provide electric energy to the battery module **204** via the electrical connector **220**, the electrical interface **210**, and the electrical connector **222**. In the example of FIG. **2**B, the CPE **110** may include the battery module **204** external to the housing of the CPE **110**. The PSU **208** may provide electric energy to the battery module **204** via an electrical connector **226** and to the CPE **110** via the electrical connector **220**, the electrical interface **210**, and the electrical connector **222**. The electrical connector **220** may be connected to or an extension of the electrical connector **226**. In some embodiments, the electrical connector **226** may include an electrical conduit, wire, lead, bus, pin, printed circuit board, etc.

[0047] FIGS. **3**A and **3**B illustrate an example of a battery charging system **300** of the CPE **110** suitable for use with various embodiments. With reference to FIGS. **1-3**B the battery charging system **300** may include the SoC **202** and the battery module **204**. The battery module **204** may include a charger **304** and a battery **306**, which may include one or more batteries. For example, the battery **306** may be a bank of batteries. For another example, the battery **306** may be two or more batteries in which batteries may be arranged in pairs. The charger **304** may be electrically connected to the PSU **208** and receive electric energy from the PSU **208** via an electrical connector **310** (e.g., electrical interface **210**, electrical connector **220**, **222**, **226** in FIGS. **2**A and **2**B). In some embodiments, the electrical connector **310** may include an electrical conduit, wire, lead, bus, pin, printed circuit board, etc. The charger **304** and the battery **306** may be electrically connected at a positive polarity terminal and a negative polarity terminal of the battery **306** by respective electrical connectors **312***a*, **312***b*. In some embodiments, the connector **312***a*, **312***b* may include an electrical conduit, wire, lead, bus, pin, printed circuit board, etc. The charger **304** may include electrical circuitry configured for providing electric energy to the battery **306** for charging. The SoC **202** and the charger **304** may be electrically connected via an electrical connector **308** (e.g., electrical connector **222**, **226** in FIGS. **2**A and **2**B) enabling the battery module **204** to provide electric energy from the battery **306** to the SoC **202**.

[0048] Referring to FIG. **3**B, the charger **304** may include hardware or a processing system **314** configured with software or firmware processor-executable instructions, for implementing functions of the charger **304**. The processing system **314** may include one or more processors, processor cores, controllers, microcontrollers, etc. Such functions of the charger **304** may include any combination of controlling charging of the battery **306**, measuring a level of charge of the battery **306**, measuring an electric energy usage of the CPE **110**, calculating a representation of electric energy usage of the CPE **110** over a duration, calculating an available electric energy from the PSU **208**, comparing various measured or calculated electric energy to levels or thresholds of electric energy, etc. In some embodiments, the software or firmware processor-executable instructions may be configured as modules, including: an electric energy measurement module **320**; an electric energy calculations module **324**; an electric energy comparison module **326**; a battery charging control module **328**; and a battery data module **330**.

[0049] The software or firmware, including the modules **320-330**, for implementing the functions of the charger **304** may be stored at a processing system-readable medium **316** (e.g., non-volatile memory, volatile memory, main memory, cache memory, etc.). The software or firmware, including the modules **320-330**, for implementing the functions of the charger **304** may be accessed by the processing system **314** from the processing system-readable medium **316**. The charger **304** may be configured with a memory **318** (e.g., an electrically programable read only memory (EPROM), electronic fuse (eFuse), register, etc.) that is accessible by the processing system **314**. The memory **318** may be configured to store an electric energy rating of the PSU **208**. The energy rating of the PSU **208** may indicate to the processing system **314** a maximum amount of electric energy provided by the PSU **208**.

[0050] In some embodiments, the charger **304** may include hardware (e.g., resistors, transistors, capacitors, inductors, etc.) configured as an electric energy measuring circuit. The hardware of the charger **304** may receive or sense electric energy at one or more of the electrical connectors **310**, **312***a*, **312***b* and output an electric energy measurement signal to the processing system **314**. The electric energy measurement signal may be configured to indicate to the processing system **314** an amount of electric energy being used by the CPE **110**.

[0051] Implementing the electric energy measurement module **320**, the processing system **314** may interpret the electric energy measurement signal. Electric energy usage information interpreted from the electric energy measurement signal may be used by the processing system **314** to implement functions of the charger **304**. For example, the processing system **314** may measure electric energy usage by the CPE **110** at a discreet moment or over a duration. Implementing the electric energy calculations module **324**, the processing system **314** may calculate a representation (e.g., an average, a mean, etc.) of the electric energy usage by the CPE **110** over the duration. Implementing the electric energy comparison module **326**, the processing system **314** may compare the measured or representation of electric energy usage by the CPE **110** to one or more of the electric energy rating of the PSU **208** or thresholds of electric energy. In various embodiments, the thresholds of electric energy may include values representative, individually and/or in any combination, of electric current, voltage, or power.

[0052] The thresholds of electric energy may include an idle threshold. The idle threshold may be a value representative of a certain amount of electric energy used by the CPE **110** operating in an idle mode. The thresholds of electric energy may include a charge threshold. The charge threshold may be a value representative of a minimum amount of electric energy from the PSU **208** sufficient to charge the battery **306**. For example, the charge threshold may be less than 1A, such as approximately 500 mA, approximately 1A, or more than 1A. The thresholds of electric energy may include a level threshold. The level threshold may be a value representative of a charge level for a fully charged battery **306**.

[0053] The electric energy measurement signal based on the electric energy at one or more of the electrical connectors **312***a*, **312***b* may be configured to indicate to the processing system **314** a level of charge of the battery **306**. Implementing the electric energy measurement module **320**, the processing system **314** may interpret the electric energy measurement signal. Information interpreted from the electric energy measurement signal may be used by the processing system **314** to implement functions of the charger **304**. For example, implementing the electric battery charging control module **328**, the processing system **314** may control whether and how to charge the battery **306**. The processing system **314** may base whether and how to charge the battery **306** on results of implementing other modules **320-326**. Implementing the battery data module **330**, the processing system **314** may provide the level of charge of the battery **306** to the SoC **202** for use in accessing cloud-based services. Accessing the cloud-based services may be achieved by transmitting the level of charge of the battery **306** (or telemetry) data for the battery **306** from the CPE to a remote monitoring device (not shown; computing device **150**, remote monitoring device **500** in FIGS. **5**A, **5**B), as described further herein.

[0054] FIGS. **4**A-**4**D illustrate methods **400***a*, **400***b*, **400***c*, **400***d* for implementing charging a battery **306** of a CPE **110** in accordance with the various embodiments. In some embodiments, the methods **400***a*, **400***b*, **400***c*, **400***d* may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. Additionally, the order in which the operations of methods **400***a*, **400***b*, **400***c*, **400***d* are illustrated in FIGS. **4**A-**4**D and described below is not intended to be limiting.

[0055] In some embodiment, methods **400***a*, **400***b*, **400***c*, **400***d* may be implemented in a processing system **314**, having one or more processors, in conjunction with memory (e.g., processing system-readable medium **316**, memory **318** in FIG. **3**B). The processing system **314** may include one or more device(s) executing some or all of the operations of the methods **400***a*, **400***b*, **400***c*, **400***d* in response to instructions (e.g., charger modules **320-328** in FIG. **3**B) stored electronically on an electronic storage medium (e.g., processing system-readable medium **316** in FIG. **3**B). The processing system **314** may include one or more devices configured through hardware, firmware, and/or software to be specifically designed for execution of one or more of the operations of the methods **400***a*-**400***d*. For example, with reference to FIGS. **1**-**4**D, the operations of the methods **400***a*-**400***d* may be performed by the processing system **314** of the charger **304** of the CPE **110**.

[0056] With reference to FIG. **4**A, in block **402**, the processing system **314** may measure an electric energy usage of the CPE **110**. The processing system **314** may be configured to receive an electric energy measurement signal configured to indicate to the processing system **314** an amount of electric energy usage by the CPE **110**. The electric energy signal may be based on electric energy sensed or received at hardware (e.g., resistors, transistors, capacitors, inductors, etc.) of the CPE **110** configured as an electric energy measuring circuit. The hardware of the CPE **110** may receive or sense electric energy at one or more electrical connectors (e.g., electrical connectors **310**, **312***a*, **312***b* in FIG. **3**A) and output an electric energy measurement signal to the processing system **314**. The processing system **314** may receive one or more electric energy measurement signals periodically, continuously, or episodically. The processing system **314** may interpret the electric energy measurement signal or use the electric energy measurement signal in operations to determine the electric energy usage of the CPE **110**. In some embodiments, the processing system **314** may periodically, continuously, or episodically implement measuring the electric energy usage of the CPE **110** in block **402**. For example, the processing system **314** may implement measuring the electric energy usage of the CPE **110** in block **402** prior to, following, or in parallel with any of blocks **404-440** of the methods **400***a*-**400** described herein with reference to FIGS. **4**A-**4**C.

[0057] In determination block **404**, the processing system **314** may determine whether the electric energy usage exceeds an idle threshold. The CPE **110** may use at most a certain amount of electric energy operating in an idle mode. The certain amount of electric energy used by the CPE **110** operating in an idle mode is less than an amount of electric energy used by the CPE **110** operating in an active mode.

The CPE **110** using more than the certain amount of electric energy may be indicative to the processing system **314** that the CPE **110** is operating in the active mode. In some embodiments, the idle threshold may be a value representative of the certain amount of electric energy used by the CPE **110** operating in the idle mode. The measured electric energy usage of the CPE **110** may be compared to the idle threshold by the processing system **314**. The measured electric energy usage of the CPE **110** exceeding the idle threshold may be indicative to the processing system **314** that the CPE **110** is not operating in the idle mode but rather is operating in the active mode.

[0058] Similarly, the CPE **110** may use at least a certain amount of electric energy operating in the active mode. The CPE **110** using less than the certain amount of electric energy may be indicative to the processing system **314** that the CPE **110** is operating in the idle mode. In some embodiments, the idle threshold (or alternatively referred to as an active threshold) may be a value representative of the certain amount of electric energy used by the CPE **110** operating in the active mode. The measured electric energy usage of the CPE **110** may be compared to the idle threshold by the processing system **314**. The measured electric energy usage of the CPE **110** equaling or exceeding the idle threshold may be indicative to the processing system **314** that the CPE **110** is not operating in the idle mode but rather is operating in the active mode. Put another way, embodiments may use either a threshold indicative of the idle mode or the active mode in the determination block **404**. In embodiments in which the threshold is indicative of the active mode, determination block **404** may determine whether electric energy usage exceeds the active threshold. For ease of discussion, the embodiment in which the idle threshold is used is described herein below. One of skill in the art would understand how to implement the active threshold.

[0059] In response to determining that the measured electric energy usage of the CPE **110** exceeds the idle threshold (i.e., determination block **404**="Yes"), the processing system **314** may implement block **408** of the method **400*b*** described herein with reference to FIG. **4**B. In response to determining that the measured electric energy usage of the CPE **110** does not exceed the idle threshold (i.e., determination block **404**="No"), the processing system **314** may implement block **432** (or optional block **428**, **430**) of the method **400*c*** or **400*d*** described herein with reference to FIGS. **4**C or **4**D.

[0060] The following table **1** includes a non-exhaustive and non-limiting list of examples of the CPE **110** conditions in an active mode and an idle mode. In some examples, the CPE **110** may be in the active mode for any of the low throughput, medium throughput, or high throughput traffic loads:

TABLE 1

Traffic Load	Test Condition	Current (Maximum)/A	Notes
High Throughput	DS 8.9G/US 3.4G + 10 Ringer Equivalent Number (REN) Ring	3.14	Each FXS ports with 5 REN ringing at the same time
	DS 8.9G/US 3.4G + 8 REN Ring	2.98	Each FXS ports with 4 REN ringing at the same time
	DS 8.9G/US 3.4G + 5 REN Ring	2.66	One FXS port is ringing with 5 REN, and the other FXS port is off-hook.
	DS 8.9G/US 3.4G + 4 REN Ring	2.571	One FXS port is ringing with 4 REN, and the other FXS port is off-hook.
	DS 8.9G/US 3.4G + On Hook	2.206	Two FXS ports are on-hook.
	DS 8.9G/US 3.4G + Off Hook	2.405	Two FXS ports are off-hook.
Middle Throughput	DS 1.0G/US 0.5G + 5 REN Ring	2.47	One FXS port is ringing with 5 REN, and the other FXS port is off-hook.
	DS 1.0G/US 0.5G + On Hook	2.013	Two FXS ports are on-hook.
	DS 1.0G/US 0.5G + Off Hook	2.241	Two FXS ports are off-hook.
Low Throughput	DS 100M/US 40M + 5 REN Ring	2.196	One FXS port is ringing with 5 REN, and the other FXS port is off-hook.
	DS 100M/US 40M + On Hook	1.719	Two FXS ports are on-hook.
	DS 100M/US 40M + Off Hook	1.948	Two FXS ports are off-hook.
	Standby (Online Only)	1.302	Idle state with two FXS ports on-hook

[0061] With reference to FIG. **4**B, in response to determining that the measured electric energy usage of the CPE **110** exceeds the idle threshold (i.e., determination block **404** in FIG. **4**A="Yes"), the processing system **314** may calculate an available electric energy from the PSU **208** in block **408**. In some instances, the PSU **208** may be able to provide the CPE **110** with more electrical energy than is currently being used by the CPE **110** (i.e., amount of electric energy usage by the CPE **110**). The available electric energy from the PSU **208** may be an amount of electric energy that may be provided by the PSU **208** greater than the amount of electric energy usage by the CPE **110**. In some embodiments, the amount of electric energy that may be provided by the PSU **208** may be known to the processing system **314** based on an energy rating of the PSU **208**. The processing system **314** may retrieve the energy rating of the PSU **208** from the memory **318**. In some embodiments, the amount of electric energy usage by the CPE **110** may be the measured electric energy usage of the CPE **110**. In some embodiments, the amount of electric energy usage by the CPE **110** may be the measured electric energy usage of the CPE **110** at a discreet time. For example, the discreet time may be an instantaneous time of an instantaneous time-sampling technique. In some embodiments, the amount of electric energy usage by the CPE **110** may be the representation of the electric energy usage by the CPE **110** over a duration.

[0062] The available electric energy from the PSU **208** may be a result of a comparison of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. For example, the available electric energy from the PSU **208** may be the result of a difference of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. The available electric energy from the PSU **208** may be available for charging the battery **306**. In some embodiments, the calculated available electric energy from the PSU **208** may be referred to as a first available electric energy or a second available electric energy.

[0063] In determination block **410**, processing system **314** may determine whether the available electric energy from the PSU **208** exceeds a charge threshold. The electric energy from the PSU **208** is used by the CPE **110** to support the critical functions and charge the battery **306** of the CPE **110**. Charging the battery **306** may require a minimum share of electric energy from the PSU **208**. In some instances, the electric energy usage by the CPE **110** to support the critical functions may exceed an amount that would enable the PSU **208** to provide sufficient electric energy to charge the battery **306**. In some instances, the electric energy usage by the CPE **110** to support the critical functions may be an amount low enough to enable the PSU **208** to provide sufficient electric energy to charge the battery **306**. The charge threshold may be a value representative of the minimum amount of electric energy from the PSU **208** sufficient to charge the battery **306**. For example, the available electric energy from the PSU **208** may be based on an amount of electric energy usage by the CPE **110** for maximum upstream and downstream throughputs and with an FXS port ringing event. The available electric energy from the PSU **208** may be compared to the charge threshold by the processing system **314**. The available electric energy from the PSU **208** exceeding the charge threshold may be indicative to the processing system **314** that there is sufficient electric energy available from the PSU **208** to charge the battery **306**. The available electric energy from the PSU **208** not exceeding the charge threshold may be indicative to the processing system **314** that there is insufficient electric energy available from the PSU **208** to charge the battery **306**.

[0064] In response to determining that the available electric energy from the PSU **208** does not exceed the charge threshold (i.e., determination block **410**="No"), the processing system **314** may repeat calculating an available electric energy from the PSU **208** in block **408**. As discussed herein, the processing system **314** may periodically, continuously, or episodically implement measuring the electric energy usage of the CPE **110** in block **402**. Changes in the measured electric energy usage of the CPE **110** may result in a different outcome of calculating an available electric energy from the PSU **208** in block **408**. For example, while the battery **306** is being charged, the CPE **110** may switch from low or medium upstream and downstream throughput to high or maximum upstream and downstream throughput with two FXS ports off-hook. The change in the CPE **110** operation may cause the charging process of battery **306** to be paused due to lack of sufficient electric energy from the PSU **208** to charge the battery **306**. Charging the battery **306** may resume in response to the CPE **110** switching to operating with low or medium upstream and downstream throughputs.

[0065] In response to determining that the available electric energy from the PSU **208** exceeds the charge threshold (i.e., determination block **410**="Yes"), the processing system **314** may measure a representation (e.g., an average, a mean, Root-Mean-Square, etc.) of the electric energy usage by the CPE **110** over a duration in block **412**. In some embodiments, the electric energy usage by the CPE **110** may be instantaneous electric energy usage by the CPE **110** measured at various points over the duration. The processing system **314** may periodically, continuously, or episodically measure the electric energy usage of the CPE **110**, similarly as described in block **402**, for a duration. In some embodiments, the duration may be any amount of time, such as less than a second, a second, or more than a second (e.g., approximately 2 seconds, 5 second, 10 seconds, 30 seconds, 60 seconds, 90 seconds, 300 seconds, etc.). The processing system **314** may calculate the representation of the electric energy usage by the CPE **110** measured over the duration.

[0066] In block **414**, the processing system **314** may calculate an available electric energy from the PSU **208**. The processing system **314** may calculate an available electric energy from the PSU **208** similarly as described herein for block **408**. The available electric energy from the PSU **208** may be a result of a comparison of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. In some embodiments, the processing system **314** may calculate an available electric energy from the PSU **208** using the representation of the electric energy usage by the CPE **110** over the duration. For example, the available electric energy from the PSU **208** may be the result of a difference of the amount of electric energy that may be provided by the PSU **208** and the representation of the electric energy usage by the CPE **110** over the duration. The available electric energy from the PSU **208** may be available for charging the battery **306**. In some embodiments, the calculated available electric energy from the PSU **208** may be referred to as a first available electric energy or a second available electric energy.

[0067] In block **418**, the processing system **314** may charge the battery **306** using up to the available electric energy from the PSU **208**. For various reasons, such as battery health, battery longevity, safety, regulation, etc., the amount of electric energy used to charge the battery **306** may be limited. Charging the battery **306** may be implemented using an amount of electric energy less than or equal to the available electric energy from the PSU **208**. The processing system **314** may control when and how much electric energy of the available electric energy from the PSU **208** is used to charge the battery **306**.

[0068] In block **420**, the processing system **314** may measure a battery charge level. The processing system **314** may receive an electric energy measurement signal configured to indicate to the processing system **314** an amount of electric energy stored at the battery **306**. The electric energy signal may be based on electric energy sensed or received at hardware (e.g., resistors, transistors, capacitors, inductors, etc.) of the CPE **110** configured as an electric energy measuring circuit. The hardware of the CPE **110** may receive or sense electric energy at one or more electrical connectors **312***a*, **312***b* and output an electric energy measurement signal to the processing system **314**. The processing system **314** may interpret or use the electric energy measurement signal in operations to determine the battery charge level. The processing system **314** may receive one or more electric energy measurement signals periodically, continuously, or episodically. In some embodiments, the processing system **314** may periodically, continuously, or episodically implement measuring the battery charge level in block **420**.

[0069] In determination block **422**, the processing system **314** may determine whether the battery charge level equals a level threshold. The level threshold may be a value representative of a charge level for a fully charged battery **306**. The processing system **314** may compare the measured battery charge level to the level threshold to determine whether battery charging has completed. The measured battery charge level being less than the level threshold may indicate to the processing system **314** that the battery **306** is not fully charged and that battery charging has not completed. The measured battery charge level equaling the level threshold may indicate to the processing system **314** that the battery **306** is fully charged and that battery charging has completed.

[0070] In response to determining that the battery charge level does not equal the level threshold (i.e., determination block **422**="No"), the processing system **314** may repeat calculating an available electric energy from the PSU **208** in block **408**. As discussed herein, the processing system **314** may periodically, continuously, or episodically implement measuring the electric energy usage of the CPE **110** in block **402**. Changes in the measured electric energy usage may result in a different outcome of calculating an available electric energy from the PSU **208** in block **408**. In response to determining that the battery charge level equals the level threshold (i.e., determination block **422**="Yes"), the processing system **314** may cease battery charging in block **424**. In some embodiments, the processing system **314** may optionally repeat measuring the electric energy usage of the CPE **110** in block **402**. In some embodiments, repeating measuring the electric energy usage of the CPE **110** in block **402** may be implemented periodically or episodically.

[0071] With reference to FIG. **4**C, optional block **428** and optional determination block **430** may be implemented by the CPE **110** operating in the idle mode that may be in a power save mode or may be powered down. In response to determining that the measured electric energy usage of the CPE **110** does not exceed the idle threshold (i.e., determination block **404** in FIG. **4**A="No"), the processing system **314** may calculate an available electric energy from the PSU **208** in optional block **428**. In some instances, the PSU **208** may be able to provide the CPE **110** with more electrical energy than is currently being used by the CPE **110** (i.e., amount of electric energy usage by the CPE **110**). The available electric energy from the PSU **208** may be an amount of electric energy that may be provided by the PSU **208** greater than the amount of electric energy usage by the CPE **110**. In some embodiments, the amount of electric energy that may be provided by the PSU **208** may be known to the processing system **314** based on an energy rating of the PSU **208**. The processing system **314** may retrieve the energy rating of the PSU **208** from the memory **318**. In some embodiments, the amount of electric energy usage by the CPE **110** may be the measured electric energy usage of the CPE **110**. In some embodiments, the amount of electric energy usage by the CPE **110** may be the measured electric energy usage of the CPE **110** at a discreet time. In some embodiments, the amount of electric energy usage by the CPE **110** may be the representation of the electric energy usage by the CPE **110** over a duration.

[0072] The available electric energy from the PSU **208** may be a result of a comparison of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. For example, the available electric energy from the PSU **208** may be the result of a difference of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. The available electric energy from the PSU **208** may be available for charging the battery **306**. In some embodiments, the calculated available electric energy from the PSU **208** may be referred to as a first available electric energy or a second available electric energy.

[0073] In optional determination block **430**, the processing system **314** may determine whether the available electric energy from the PSU **208** exceeds a charge threshold. The electric energy from the PSU **208** is used by the CPE **110** to support the critical functions and charge the battery **306** of the CPE **110**. Charging the battery **306** may require a minimum share of electric energy from the PSU **208**. In some instances, the electric energy usage by the CPE **110** to support the critical functions may exceed an amount that would enable the PSU **208** to provide sufficient electric energy to charge the battery **306**. In some instances, the electric energy usage by the CPE **110** to support the critical functions may be an amount low enough to enable the PSU **208** to provide sufficient electric energy to charge the battery **306**. The charge threshold may be a value representative of the minimum amount of available electric energy from the PSU **208** sufficient to charge the battery **306**. For example, the available electric energy from the PSU **208** may be based on an amount of electric energy usage by the CPE **110**. The CPE **110** operating in the idle mode may be in the power save mode or may be powered down. In the power save mode, the CPE **110** may be using electric energy from the battery **306** and may be able to make emergency calls to an emergency line, such as to "9-1-1." The available electric energy from the PSU **208** may be compared to the charge threshold by the processing system **314**. The available electric energy from the PSU **208** exceeding the charge threshold may be indicative to the processing system **314** that there is sufficient electric energy available from the PSU **208** to charge the battery **306**. The available electric energy from the PSU **208** not exceeding the charge threshold may be indicative to the processing system **314** that there is insufficient electric energy available from the PSU **208** to charge the battery **306**.

[0074] In response to determining that the available electric energy from the PSU **208** does not exceed the charge threshold (i.e., optional determination block **430**="No"), the processing system **314** calculating an available electric energy from the PSU **208** in optional block **428**. As discussed herein, the processing system **314** may periodically, continuously, or episodically implement measuring the electric energy usage of the CPE **110** in block **402**. Changes in the measured electric energy usage of the CPE **110** may result in a different outcome of calculating an available electric energy from the PSU **208** in optional block **428**.

[0075] In response to determining that the measured electric energy usage of the CPE **110** does not exceed the idle threshold (i.e., determination block **404** in FIG. **4**A="No"); or in response to determining that the available electric energy from the PSU **208** exceeds the charge threshold (i.e., optional determination block **430**="Yes"), the processing system **314** may calculate an available electric energy from the PSU **208** in block **432**. In some instances, the PSU **208** may be able to provide the CPE **110** with more electrical energy than is currently being used by the CPE **110** (i.e., amount of electric energy usage by the CPE **110**). The available electric energy from the PSU **208** may be an amount of electric energy that may be provided by the PSU **208** greater than the amount of electric energy usage by the CPE **110**. In some embodiments, the amount of electric energy that may be provided by the PSU **208** may be known to the processing system **314** based on an energy rating of the PSU **208**. The processing system **314** may retrieve the energy rating of the PSU **208** from the memory **318**. In some embodiments, the amount of electric energy usage by the CPE **110** may be known to the processing system **314** based on an idle mode electric energy usage by the CPE **110**. The processing system **314** may retrieve the idle mode electric energy usage by the CPE **110** from the memory **318**. In some embodiments, the amount of electric energy usage by the CPE **110** may be the measured electric energy usage of the CPE **110** at a discreet time. In some embodiments, the amount of electric energy usage by the CPE **110** may be the representation of the electric energy usage by the CPE **110** over the duration.

[0076] The available electric energy from the PSU **208** may be a result of a comparison of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. For example, the available electric energy from the PSU **208** may be the result of a difference of the amount of electric energy that may be provided by the PSU **208** and the amount of electric energy usage by the CPE **110**. The available electric energy from the PSU **208** may be available for charging the battery **306**. In some embodiments, the calculated available electric energy from the PSU **208** may be referred to as a first available electric energy or a second available electric energy.

[0077] In block **434** the processing system **314** may charge the battery **306** using up to the available electric energy from the PSU **208**. For various reasons, such as battery health, battery longevity, safety, regulation, etc., the amount of electric energy used to charge the battery **306** may be limited. Charging the battery **306** may be implemented using an amount of electric energy less than or equal to the available electric energy from the PSU **208**. The processing system **314** may control when and how much electric energy of the available electric energy from the PSU **208** is used to charge the battery **306**.

[0078] In block **436**, the processing system **314** may measure a battery charge level. The processing system **314** may receive an electric energy measurement signal configured to indicate to the processing system **314** an amount of electric energy stored at the battery **306**. The electric energy signal may be based on electric energy sensed or received at hardware (e.g., resistors, transistors, capacitors, inductors, etc.) of the CPE **110** configured as an electric energy measuring circuit. The hardware of the CPE **110** may receive or sense electric energy at one or more electrical connectors **312***a*, **312***b* and output an electric energy measurement signal to the processing system **314**. The processing system **314** may interpret or use the electric energy measurement signal in operations to determine the battery charge level. The processing system **314** may receive one or more electric energy measurement signals periodically, continuously, or episodically. In some embodiments, the processing system **314** may periodically, continuously, or episodically implement measuring the battery charge level in block **436**.

[0079] In determination block **438**, the processing system **314** may determine whether the battery charge level equals a level threshold. The level threshold may be a value representative of a charge level for a fully charged battery **306**. The processing system **314** may compare the measured battery charge level to the level threshold to determine whether battery charging has completed. The measured battery charge level being less than the level threshold may indicate to the processing system **314** that the battery **306** is not fully charged and that battery charging has not completed. The measured battery charge level equaling the level threshold may indicate to the processing system **314** that the battery **306** is fully charged and that battery charging has completed.

[0080] In some embodiments, in response to determining that the battery charge level does not equal the level threshold (i.e., determination block **438**="No"), the processing system **314** may optionally repeat calculating an available electric energy from the PSU **208** in optional block **428**. In response to determining that the battery charge level equals the level threshold (i.e., determination block **438**="Yes"), the processing system **314** may cease battery charging in block **440**. In some embodiments, the processing system **314** may optionally repeat measuring the electric energy usage of the CPE **110** in block **402**. In some embodiments, repeating measuring the electric energy usage of the CPE **110** in block **402** may be implemented periodically or episodically.

[0081] With reference to FIG. **4**D, optional blocks **428** and **430** and blocks **432-440** may be implemented in a manner similar to optional blocks **428** and **430** and blocks **432-440** of the method **400***c* described herein with reference to FIG. **4**C unless otherwise described herein. In response to determining that the battery charge level does not equal the level threshold (i.e., determination block **438**="No"), the processing system **314** may repeat measuring the electric energy usage of the CPE **110** in block **402** of FIG. **4**A. In some embodiments, repeating measuring the electric energy usage of the CPE **110** in block **402** may be alternative to or in addition to repeating calculating an available electric energy from the PSU **208** block **428**, **432** in the method **400***c* described herein with reference to FIG. **4**C. In some embodiments, repeating measuring the electric energy usage of the CPE **110** in block **402** may be implemented periodically or episodically. For example, repeating measuring the electric energy usage of the CPE **110** in block **402** may be triggered by a change in available electric energy from the PSU **208** indicating a change in operating mode of the CPE **110**, such as from an idle mode to an active mode.

[0082] FIGS. **5**A and **5**B illustrate examples of the CPE **110** connected to a remote monitoring device **500** suitable for use with various embodiments. With reference to FIGS.

1-5B, the CPE 110 and the components of the CPE 110 may be configured as described herein. The components of the CPE 110 may include the SoC 202, the battery module 204, the one or more communication interfaces 206, the PSU 208, the electrical interface 210, the electrical connectors 220, 222, 226, and the one or more communication buses 224.

[0083] The battery module 204 and the processing system 214 may be connected via a communication link 510, which may be wired or wireless. The communication link 510 may enable the processing system 214 to receive battery status information from the battery module 204. For example, the battery status information may relate to the battery 306 and may be transmitted to the processing system 214 of the CPE 110 by the processing system 314 of the charger 304. The communication link 510 may enable the processing system 214 to transmit battery charge commands to the battery module 204. For example, the battery charge commands may relate to the battery 306 and may be transmitted to the processing system 314 of the charger 304 by the processing system 214 of the CPE 110.

[0084] The processing system 214 of the CPE 110 may be configured with processor-executable instructions, such as software or firmware instructions, to implement an operating system. A non-exhaustive and non-limiting list of examples of the operating system may include a Linux based operating system, proprietary operating system, commercial operating system, open-source operating system, OpenWrt, prplOS, etc. The processing system 214 may implement, via the operating system, functions of a software that may enable the CPE 110 to access cloud-based services. A non-exhaustive and non-limiting list of examples of the software may include OpenSync, Cujo AI, EasyMesh, etc. For example, the processing system 214 may implement battery simple network management protocol (SNMP) management information base (MIB) functions. A non-exhaustive and non-limiting list of examples of the SNMP MIB functions for the battery 306 may include: upsIdentManufacturer; upsIdentModel; upsIdentAgentSoftware Version; upsBatteryStatus; upsSecondsOnBattery; upsEstimatedChargeRemaining; upsAlarmsPresent; upsAlarmDescr-upsAlarmOnBattery; upsAlarmDescr-upsAlarmLowBattery; upsAlarmDescr-upsAlarmDepletedBattery; upsReboot WithDuration; upsOutput Voltage; upsAlarmsPresent; upsAlarmDescr-upsAlarmShutdownPending; upsAlarmDescr-upsAlarmShutdownImminent; upsConfigLowBattTime; upsConfigAudibleStatus; mtaDevPwrSupplyBatteryTest; mtaDevPwrSupplyConfigReplaceBatteryTime; mtaDevPwrSupplyBatteryTestTime; upsIdentName; upsIdentAttachedDevices; upsEstimatedMinutesRemaining; upsAlarmDescr-upsAlarmBatteryBad; upsAlarmDescr-upsAlarmOutputOffAsRequested; upsAlarmDescr-upsAlarmUpsOutputOff; upsAlarmDescr-upsAlarmGeneralFault; upsAlarmDescr-upsAlarmAwaitingPower; upsShutdownType; upsShutdownAfterDelay; upsEstimatedMinutesRemaining; mtaDevPwrSupplyRatedMinutes; mtaDevPwrSupplyAvailableMinutes; mtaDevPwrSupplyFullChargeTime; mtaDevPwrSupplyConfigRunTime etc.

[0085] The processing system 214 may be connected to a remote monitoring device 500 (e.g., computing device 150 in FIG. 1) via the one or more communication interfaces 206 and a communication link 502 (e.g., communication link 137, communication network 140, network operations sites 142, 144, 146 in FIG. 1). In some embodiments, the remote monitoring device 500 may be located at a communication network (e.g., communication network 140 in FIG. 1), such as part of a cloud computing network. The cloud computing network may include multiple remote monitoring devices 500 configured to, individually or together, implement cloud-based services accessible by the CPE 110. The remote monitoring device 500 may include a processing system 504, communication systems, and memory configured to implement cloud-based services configured for remote battery charging monitoring and control. The processing system 504 may include one or more processors, processor cores, controllers, microcontrollers, etc.

[0086] The processing system 214 of the CPE 110 may implement functions for transmitting battery status (or telemetry) information for the battery module 204 from the CPE 110 to the remote monitoring device 500. The processing system 214 may transmit the battery status information to the remote monitoring device 500 continuously, periodically, or episodically. In some embodiments, transmitting the battery status information may include streaming the battery status information. The battery status information may include charge data for the battery 306, such as a level of charge of the battery 306. Other examples of charge data for the battery 306 may include time or date of battery charging, low-battery alarm, depleted battery alarm, duration of battery charging, etc. Other examples of battery status information may include battery type, battery size, battery manufacturer, battery model, battery hardware version, battery firmware version, battery manufacture date, battery expiration date, etc.

[0087] The processing system 504 of the remote monitoring device 500, executing software processor-executable instructions (e.g., Grafana, SigNoz, Kibana, etc.), may be configured to monitor the battery status information for the battery module 204. The processing system 504, executing the software processor-executable instructions, may provide the battery status information or representations of the information (e.g., raw data, analyzed data, pictorial/graphical data, etc.) to a monitoring entity (e.g., a dashboard). The processing system 504, executing the software processor-executable instructions, may be configured to present, analyze, or respond to the battery status information for the battery module 204.

[0088] In some examples, the processing system 504 may respond to the battery status information for the battery module 204 based on one or more criterion. The response to the battery status information may include commands to cause the processing system 214 of the CPE 110 to prompt the battery module 204 to implement battery charging functions. For example, the processing system 504 may determine that the battery charge capacity is depleted or the one or more batteries are not being charged. Based on the determination, the processing system 504 may raise an alarm, such as via the monitoring entity. The processing system 504 may transmit a command to the CPE 110 to reboot, such as via the upsRebootDuration MIB.

[0089] FIG. 6 illustrates an example of the SoC 202 of the CPE 110 suitable for use with various embodiments. With reference to FIGS. 1-6, the SoC 202 may include the processing system 214 configured with software or firmware processor-executable instructions, for implementing functions of battery status information telemetry. The processing system 214 may include one or more processors, processor cores, controllers, microcontrollers, etc. Such functions of battery status information telemetry may include any combination of controlling receiving and transmitting battery status information, receiving and transmitting battery charge commands, etc. In some embodiments, the software or firmware processor-executable instructions may be configured as modules, including a charger communication module **602** and a telemetry module **604**. The software or firmware, including the modules **602**, **604**, for implementing the functions of battery status information telemetry may be stored on and accessed by the processing system **214** from a processing system-readable medium **600**. The processing system-readable medium **600** may include one or more of a non-volatile memory, volatile memory, main memory, cache memory, etc.

[0090] The processing system **214**, implementing the charger communication module **602**, may receive battery status information from the charger **304**. For example, the processing system **214** may receive the battery status information from the processing system **314** of the charger **304**. For another example, the processing device **214** may retrieve the battery status information from the processing system-readable medium **316** or the memory **318**. The processing system **214**, implementing the telemetry module **602**, may transmit battery status information to the remote monitoring device **500**. In some embodiments, the processing system **214**, implementing the telemetry module **602**, may receive battery charging commands from the remote monitoring device **500**. In some embodiments, the processing system **214**, implementing the charger communication module **602**, may transmit the battery charging commands received from the remote monitoring device **500** to the processing system **314** of the charger **304**.

[0091] FIG. **7** illustrates a method **700** for implementing remote battery charging monitoring and control for the battery **306** of the CPE **110** in accordance with the various embodiments. In some embodiments, the method **700** may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. Additionally, the order in which the operations of the method **700** are illustrated in FIG. **7** and described below is not intended to be limiting.

[0092] In some embodiment, the method **700** may be implemented in a processing system **214** of the CPE **110**, having one or more processors, in conjunction with memory (e.g., processing system-readable medium **600** in FIG. **6**). The processing system **214** may include one or more device (s) executing some or all of the operations of the method **700** in response to instructions (e.g., SoC modules **602**, **604** in FIG. **6**) stored electronically on an electronic storage medium (e.g., processing system-readable medium **600** in FIG. **6**). The processing system **214** may include one or more devices configured through hardware, firmware, and/or software to be specifically designed for execution of one or more of the operations of the method **700**. For example, with reference to FIGS. **1-7**, the operations of the method **700** may be performed by the processing system **214** of the CPE **110**.

[0093] In block **702**, the processing system **214** may receive battery status information. For example, the battery status information may include charge data for the battery **306**, such as a level of charge of the battery **306**. The level of charge of the battery **306** may be the level of charge of the battery **306** measured in blocks **420**, **436** of the methods **400***b*, **400***c* described herein with reference to FIGS. **4**B and **4**C. Other examples of battery charge data for the battery **306** may include time or date of battery charging, low-battery alarm, depleted battery alarm, duration of battery charging, etc. Other examples of battery status information may include battery type, battery size, battery manufacturer, battery model, battery hardware version, battery firmware version, battery manufacture date, battery expiration date, etc. In some embodiments, the processing system **214** may retrieve the battery status information from a memory (e.g., processing system-readable medium **316**, **600**, memory **318** in FIGS. 3B and **6**). In some embodiments, the processing system **214** may receive the battery status information from a battery module **204**, such as from the processing system **314** of the charger **304**.

[0094] In block **704**, the processing system **214** may transmit the battery status information to a remote monitoring device **500**. The processing system **214** may transmit the battery status information via a communication interface **206**. The battery status information may transmit via one or more communication links **502** (e.g., communication links **137**, network operations sites **142**, **144**, **146**, communication network **140** in FIG. **1**). In some embodiments, the processing system **214** may implement an operating system (e.g., Linux based operating system, proprietary operating system, commercial operating system, open-source operating system, OpenWrt, prplOS, etc.). The processing system **214**, via the operating system, may implement functions of a software (e.g., OpenSync, Cujo AI, EasyMesh, etc.). The functions of the software may enable the processing system **214** to access cloud-based services based on the transmitted battery status information. For example, the processing system **214** may implement battery SNMP MIB functions.

[0095] In optional block **706**, the processing system **214** may receive a battery charge command from the remote monitoring device **600**. The battery charge command may be configured to prompt the processing system **214** to implement aspects of battery charging. The aspects of battery charging may include charging the battery, setting battery charging parameters, rebooting battery charging software or firmware, etc. The processing system **214** may receive the battery charge command at the communication interface **206**. The battery charge command may transmit via one or more of the communication links **502**.

[0096] In optional block **708**, the processing system **214** may execute the battery charge command. The processing system **214** may transmit the battery charge command to the processing system **314** of the charger **304**. The processing system **314** may implement the battery charge command for the battery **306**.

[0097] Various embodiments illustrated and described are provided merely as examples to illustrate various features of the claims. However, features shown and described with respect to any given embodiment are not necessarily limited to the associated embodiment and may be used or combined with other embodiments that are shown and described. Further, the claims are not intended to be limited by any one example embodiment. For example, one or more of the operations of the methods **400***a*-**400***c* and **700** may be substituted for or combined with one or more operations of the methods **400***a*-**400***c* and **700**, and vice versa.

[0098] Various embodiments (including, but not limited to, embodiments discussed above with reference to FIGS. **1-7**) may be implemented on any of a variety of commercially available computing devices, such as the server computing device **800** illustrated in FIG. **8**. Such a server device **800** may include a processor **801** coupled to volatile memory **802** and a large capacity nonvolatile memory, such as a disk drive **803**. The server device **800** may also include a floppy disc drive, USB, compact disc (CD) or DVD disc drive coupled to the processor **801**. The server device **800** may also include network access ports **806** coupled to the processor **801** for establishing data connections with a network connection circuit **804** and a communication network (e.g., IP network) coupled to other communication system network elements.

[0099] The various embodiments (including, but not limited to, embodiments discussed above with reference to FIGS. **1-7**) may be implemented for any of a variety of network devices **900** (e.g., CPE **110**, network hardware **142**, **144**, **146** in FIGS. **1-2**B, **5**A, and **5**B), as illustrated in FIG. **9**. With reference to FIGS. **1-9**, a network device **900** may include a processor **901** coupled to volatile memory **902**. The network device **900** may also include one or more connections or port(s) **908** coupled to the processor **901** and configured to input or output data from the port(s) **908**. The network device **900** may also include one or more network transceivers **905**, with one or more antenna **906** coupled thereto, providing a network access port, coupled to the processor **901** for establishing wired or wireless network interface connections with a communication network, such as a local area network coupled to other computing devices and routers/switches, the Internet, the public switched telephone network, or a cellular network (e.g., CDMA, TDMA, GSM, PCS, 3G, 4G, 5G, LTE, or any other type of cellular network). The network device **900** may transmit or receive data or other communications via the network transceiver **905** or the port(s) **908**.

[0100] Various embodiments illustrated and described are provided merely as examples to illustrate various features of the claims. However, features shown and described with respect to any given embodiment are not necessarily limited to the associated embodiment and may be used or combined with other embodiments that are shown and described. Further, the claims are not intended to be limited by any one example embodiment. For example, one or more of the methods and operations **400***a*, **400***b*, **400***c*, and **700** may be substituted for or combined with one or more operations of the methods and operations **400***a*, **400***b*, **400***c*, and **700**.

[0101] Implementation examples are described in the following paragraphs. While some of the following implementation examples are described in terms of example methods, further example implementations may include: the example methods discussed in the following paragraphs implemented by a CPE including a battery and a processor configured with processor-executable instructions to perform operations of the methods of the following implementation examples; the example methods discussed in the following paragraphs implemented by a CPE including means for performing functions of the methods of the following implementation examples; and the example methods discussed in the following paragraphs may be implemented as a non-transitory processor-readable storage medium having stored thereon processor-executable instructions configured to cause a processor of a base station to perform the operations of the methods of the following implementation examples.

[0102] Example 1. A method performed by a processor of a CPE for performing charging of at least one battery of the CPE, including calculating available electric energy from a power supply unit (PSU) of the CPE, and charging the at least one battery of the CPE using the available electric energy from the PSU.

[0103] Example 2. The method of example 1, including measuring electric energy usage of the CPE, and determining whether the measured electric energy usage of the CPE exceeds an idle threshold, wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to determining that the electric energy usage at the CPE exceeds the idle threshold, and wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using an idle electric energy usage of the CPE in response to determining that the electric energy usage at the CPE does not exceed the idle threshold.

[0104] Example 3. The method of example 1, wherein calculating the available electric energy from the PSU includes calculating a first available electric energy from the PSU, the method further including: calculating a representation of electric energy usage of the CPE over a duration, and calculating a second available electric energy from the PSU of the CPE using the representation of electric energy usage of the CPE over the duration, wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE using the second available electric energy from the PSU.

[0105] Example 4. The method of example 3, also including: measuring electric energy usage of the CPE, wherein calculating the first available electric energy from the PSU includes calculating the first available electric energy from the PSU using the measuring electric energy usage of the CPE; and determining whether the first available electric energy from the PSU exceeds a charge threshold, wherein calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration comprises calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration in response to determining that the first available electric energy from the PSU exceeds the charge threshold.

[0106] Example 5. The method of example 3, also including: determining whether the second available electric energy from the PSU exceeds an availability threshold, wherein charging the at least one battery of the CPE using the second available electric energy from the PSU comprises charging the at least one battery of the CPE using the second available electric energy from the PSU in response to determining that the available electric from the PSU exceeds the availability threshold.

[0107] Example 6. The method of example 1, wherein calculating the available electric energy from the PSU comprises calculating a first available electric energy from the PSU using an idle electric energy usage of the CPE.

[0108] Example 7. The method of example 6, also including: measuring electric energy usage of the CPE; calculating a second available electric energy from the PSU of the CPE using the measured electric energy usage of the CPE; and determining whether the second available electric energy from the PSU exceeds a charge threshold, wherein calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE comprises calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE in response to determining that the second available electric energy from the PSU exceeds the charge threshold.

[0109] Example 8. The method of example 1, wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a value representative of electric energy usage at the CPE operating with maximum upstream and downstream data throughputs with a foreign exchange subscriber port ringing even, the method further including determining whether the available electric energy from the PSU exceeds a charge threshold.

[0110] Example 9. The method of example 1, further including streaming battery status information from the CPE to a remote monitoring device.

[0111] Example 10. The method of example 1, further including receiving, at the CPE, a battery charge command from a remote monitoring device, wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE in response to receiving the battery charge command.

[0112] The processors discussed in this application may be any programmable microprocessor, microcomputer or multiple processor chip or chips that may be configured by software instructions (applications) to perform a variety of functions, including the functions of the various embodiments described above. In some devices, multiple processors may be provided, such as one processor dedicated to wireless communication functions and one processor dedicated to running other applications. Typically, software applications may be stored in the internal memory before they are accessed and loaded into the processors. The processors may include internal memory sufficient to store the application software instructions. In many devices, the internal memory may be a volatile or nonvolatile memory, such as flash memory, or a mixture of both. For the purposes of this description, a general reference to memory refers to memory accessible by the processors including internal memory or removable memory plugged into the device and memory within the processors themselves. Additionally, as used herein, any reference to a memory may be a reference to a memory storage and the terms may be used interchangeably.

[0113] The foregoing method descriptions and the process flow diagrams are provided merely as illustrative examples and are not intended to require or imply that the steps of the various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the order of steps in the foregoing embodiments may be performed in any order. Words such as "thereafter," "then," "next," etc. are not intended to limit the order of the steps; these words are simply used to guide the reader through the description of the methods. Further, any reference to claim elements in the singular, for example, using the articles "a," "an" or "the" is not to be construed as limiting the element to the singular.

[0114] The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[0115] The hardware used to implement the various illustrative logics, logical blocks, modules, components, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Alternatively, some steps or methods may be performed by circuitry that is specific to a given function.

[0116] In one or more exemplary embodiments, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a non-transitory computer-readable medium, non-transitory processor-readable medium, or non-transitory processor system-readable medium. The steps of a method or algorithm disclosed herein may be embodied in a processor-executable software module and/or processor-executable instructions, which may reside on a non-transitory computer-readable or non-transitory processor-readable storage medium. Non-transitory server-readable, computer-readable or processor-readable storage media may be any storage media that may be accessed by a computer or a processor. By way of example but not limitation, such non-transitory server-readable, computer-readable or processor-readable media may include RAM, ROM, EEPROM, FLASH memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, DVD, floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of non-transitory server-readable, computer-readable and processor-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory server-readable, processor-readable medium and/or computer-readable medium, which may be incorporated into a computer program product.

[0117] The preceding description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the following claims and the principles and novel features disclosed herein.

What is claimed is:

1. A method for performing charging of at least one battery of a customer premises device (CPE), the method comprising:
- calculating available electric energy from a power supply unit (PSU) of the CPE; and
- charging the at least one battery of the CPE using the available electric energy from the PSU.

2. The method of claim **1**, further comprising:
- measuring electric energy usage of the CPE; and
- determining whether the measured electric energy usage of the CPE exceeds an idle threshold,
- wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to determining that the electric energy usage at the CPE exceeds the idle threshold, and
- wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using an idle electric energy usage of the CPE in response to determining that the electric energy usage at the CPE does not exceed the idle threshold.

3. The method of claim **1**, wherein calculating the available electric energy from the PSU comprises calculating a first available electric energy from the PSU,
- the method further comprising:
  - calculating a representation of electric energy usage of the CPE over a duration; and
  - calculating a second available electric energy from the PSU of the CPE using the representation of electric energy usage of the CPE over the duration,
  - wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE using the second available electric energy from the PSU.

4. The method of claim **3**, further comprising:
- measuring electric energy usage of the CPE, wherein calculating the first available electric energy from the PSU comprises calculating the first available electric energy from the PSU using the measuring electric energy usage of the CPE; and
- determining whether the first available electric energy from the PSU exceeds a charge threshold,
- wherein calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration comprises calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration in response to determining that the first available electric energy from the PSU exceeds the charge threshold.

5. The method of claim **1**, wherein calculating the available electric energy from the PSU comprises calculating a first available electric energy from the PSU using an idle electric energy usage of the CPE.

6. The method of claim **5**, further comprising:
- measuring electric energy usage of the CPE;
- calculating a second available electric energy from the PSU of the CPE using the measured electric energy usage of the CPE; and
- determining whether the second available electric energy from the PSU exceeds a charge threshold,
- wherein calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE comprises calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE in response to determining that the second available electric energy from the PSU exceeds the charge threshold.

7. The method of claim **1**, wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a value representative of electric energy usage at the CPE operating with maximum upstream and downstream data throughputs with a foreign exchange subscriber port ringing even,
- the method further comprising determining whether the available electric energy from the PSU exceeds a charge threshold.

8. The method of claim **1**, further comprising streaming battery status information from the CPE to a remote monitoring device.

9. The method of claim **1**, further comprising receiving, at the CPE, a battery charge command from a remote monitoring device, wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE in response to receiving the battery charge command.

10. A customer premises device (CPE) comprising a processing system configured with processing system-executable instructions to cause the processing system to perform operations, comprising:
- calculating available electric energy from a power supply unit (PSU) of the CPE; and
- charging at least one battery of the CPE using the available electric energy from the PSU.

11. The CPE of claim **10**, wherein the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising:
- measuring electric energy usage of the CPE; and
- determining whether the measured electric energy usage of the CPE exceeds an idle threshold,
- wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to determining that the electric energy usage at the CPE exceeds the idle threshold, and
- wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using an idle electric energy usage of the CPE in response to determining that the electric energy usage at the CPE does not exceed the idle threshold.

12. The CPE of claim **10**, wherein:
- the processing system is configured with processing system-executable instructions to cause the processing system to perform operations such that calculating the

available electric energy from the PSU comprises calculating a first available electric energy from the PSU; and

the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising:

calculating a representation of electric energy usage of the CPE over a duration; and

calculating a second available electric energy from the PSU of the CPE using the representation of electric energy usage of the CPE over the duration,

wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE using the second available electric energy from the PSU.

13. The CPE of claim **12**, wherein the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising:

measuring electric energy usage of the CPE, wherein calculating the first available electric energy from the PSU comprises calculating the first available electric energy from the PSU using the measuring electric energy usage of the CPE; and

determining whether the first available electric energy from the PSU exceeds a charge threshold,

wherein calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration comprises calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration in response to determining that the first available electric energy from the PSU exceeds the charge threshold.

14. The CPE of claim **10**, wherein the processing system is configured with processing system-executable instructions to cause the processing system to perform operations such that calculating the available electric energy from the PSU comprises calculating a first available electric energy from the PSU using an idle electric energy usage of the CPE.

15. The CPE of claim **14**, wherein the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising:

measuring electric energy usage of the CPE;

calculating a second available electric energy from the PSU of the CPE using the measured electric energy usage of the CPE; and

determining whether the second available electric energy from the PSU exceeds a charge threshold,

wherein calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE comprises calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE in response to determining that the second available electric energy from the PSU exceeds the charge threshold.

16. The CPE of claim **10**, wherein:

the processing system is configured with processing system-executable instructions to cause the processing system to perform operations such that calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a value representative of electric energy usage at the CPE operating with maximum upstream and downstream data throughputs with a foreign exchange subscriber port ringing even; and

the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising determining whether the available electric energy from the PSU exceeds a charge threshold.

17. The CPE of claim **10**, wherein the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising streaming battery status information from the CPE to a remote monitoring device.

18. The CPE of claim **10**, wherein the processing system is configured with processing system-executable instructions to cause the processing system to perform operations further comprising receiving, at the CPE, a battery charge command from a remote monitoring device, wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE in response to receiving the battery charge command.

19. A customer premises device (CPE), comprising:

means for calculating available electric energy from a power supply unit (PSU) of the CPE; and

means for charging at least one battery of the CPE using the available electric energy from the PSU.

20. The CPE of claim **19**, further comprising:

means for measuring electric energy usage of the CPE; and

means for determining whether the measured electric energy usage of the CPE exceeds an idle threshold,

wherein means for calculating the available electric energy from the PSU comprises means for calculating the available electric energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to determining that the electric energy usage at the CPE exceeds the idle threshold, and

wherein means for calculating the available electric energy from the PSU comprises means for calculating the available electric energy from the PSU using an idle electric energy usage of the CPE in response to determining that the electric energy usage at the CPE does not exceed the idle threshold.

21. The CPE of claim **19**, wherein means for calculating the available electric energy from the PSU comprises means for calculating a first available electric energy from the PSU, the CPE further comprising:

means for calculating a representation of electric energy usage of the CPE over a duration; and

means for calculating a second available electric energy from the PSU of the CPE using the representation of electric energy usage of the CPE over the duration,

wherein means for charging the at least one battery of the CPE using the available electric energy from the PSU comprises means for charging the at least one battery of the CPE using the second available electric energy from the PSU.

22. The CPE of claim **21**, further comprising:

means for measuring electric energy usage of the CPE, wherein calculating the first available electric energy from the PSU comprises calculating the first available electric energy from the PSU using the measuring electric energy usage of the CPE; and

means for determining whether the first available electric energy from the PSU exceeds a charge threshold,

wherein means for calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration comprises means for calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration in response to determining that the first available electric energy from the PSU exceeds the charge threshold.

23. The CPE of claim **19**, wherein means for calculating the available electric energy from the PSU comprises means for calculating a first available electric energy from the PSU using an idle electric energy usage of the CPE.

24. The CPE of claim **23**, further comprising:

means for measuring electric energy usage of the CPE;

means for calculating a second available electric energy from the PSU of the CPE using the measured electric energy usage of the CPE; and

means for determining whether the second available electric energy from the PSU exceeds a charge threshold,

wherein means for calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE comprises means for calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE in response to determining that the second available electric energy from the PSU exceeds the charge threshold.

25. The CPE of claim **19**, wherein means for calculating the available electric energy from the PSU comprises means for calculating the available electric energy from the PSU using a value representative of electric energy usage at the CPE operating with maximum upstream and downstream data throughputs with a foreign exchange subscriber port ringing even,

the CPE further comprising means for determining whether the available electric energy from the PSU exceeds a charge threshold.

26. The CPE of claim **19**, further comprising means for streaming battery status information from the CPE to a remote monitoring device.

27. The CPE of claim **19**, further comprising means for receiving, at the CPE, a battery charge command from a remote monitoring device, wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE in response to receiving the battery charge command.

28. A non-transitory processing system-readable medium having stored thereon processing system-executable instructions configured to cause a processing system to perform operations comprising:

calculating available electric energy from a power supply unit (PSU) of the CPE; and

charging at least one battery of the CPE using the available electric energy from the PSU.

29. The non-transitory processor-readable medium of claim **28**, wherein the stored processing system-executable instructions are configured to cause the processing system to perform operations further comprising:

measuring electric energy usage of the CPE; and

determining whether the measured electric energy usage of the CPE exceeds an idle threshold,

wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a representation of electric energy usage of the CPE over a duration in response to determining that the electric energy usage at the CPE exceeds the idle threshold, and

wherein calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using an idle electric energy usage of the CPE in response to determining that the electric energy usage at the CPE does not exceed the idle threshold.

30. The non-transitory processor-readable medium of claim **28**, wherein:

the stored processing system-executable instructions are configured to cause the processing system to perform operations such that calculating the available electric energy from the PSU comprises calculating a first available electric energy from the PSU; and

the stored processing system-executable instructions are configured to cause the processing system to perform operations further comprising:

calculating a representation of electric energy usage of the CPE over a duration; and

calculating a second available electric energy from the PSU of the CPE using the representation of electric energy usage of the CPE over the duration,

wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE using the second available electric energy from the PSU.

31. The non-transitory processor-readable medium of claim **30**, wherein the stored processing system-executable instructions are configured to cause the processing system to perform operations further comprising:

measuring electric energy usage of the CPE, wherein calculating the first available electric energy from the PSU comprises calculating the first available electric energy from the PSU using the measuring electric energy usage of the CPE; and

determining whether the first available electric energy from the PSU exceeds a charge threshold,

wherein calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration comprises calculating the second available electric energy from the PSU using the representation of electric energy usage of the CPE over the duration in response to determining that the first available electric energy from the PSU exceeds the charge threshold.

32. The non-transitory processor-readable medium of claim **28**, wherein the stored processing system-executable instructions are configured to cause the processing system to perform operations such that calculating the available electric energy from the PSU comprises calculating a first available electric energy from the PSU using an idle electric energy usage of the CPE.

33. The non-transitory processor-readable medium of claim **32**, wherein the stored processing system-executable instructions are configured to cause the processing system to perform operations further comprising:

measuring electric energy usage of the CPE;

calculating a second available electric energy from the PSU of the CPE using the measured electric energy usage of the CPE; and

determining whether the second available electric energy from the PSU exceeds a charge threshold,

wherein calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE comprises calculating the first available electric energy from the PSU using the idle electric energy usage of the CPE in response to determining that the second available electric energy from the PSU exceeds the charge threshold.

34. The non-transitory processor-readable medium of claim **28**, wherein:

the stored processing system-executable instructions are configured to cause the processing system to perform operations such that calculating the available electric energy from the PSU comprises calculating the available electric energy from the PSU using a value representative of electric energy usage at the CPE operating with maximum upstream and downstream data throughputs with a foreign exchange subscriber port ringing even; and

the stored processing system-executable instructions are configured to cause the processing system to perform operations further comprising determining whether the available electric energy from the PSU exceeds a charge threshold.

35. The non-transitory processor-readable medium of claim **28**, wherein the stored processing system-executable instructions are configured to cause the processing system to perform operation further comprising streaming battery status information from the CPE to a remote monitoring device.

36. The non-transitory processor-readable medium of claim **28**, wherein the stored processing system-executable instructions are configured to cause the processing system to perform operation further comprising receiving, at the CPE, a battery charge command from a remote monitoring device, wherein charging the at least one battery of the CPE using the available electric energy from the PSU comprises charging the at least one battery of the CPE in response to receiving the battery charge command.

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