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(54) **METHOD AND SYSTEM FOR DECREMENTING ACCOUNT BALANCE BASED ON AIR-INTERFACE RESOURCE INFORMATION**

2007/0179974	A1*	8/2007	Cai et al.	707/104.1
2011/0225281	A1*	9/2011	Riley et al.	709/223
2011/0291882	A1	12/2011	Walsh	
2013/0029710	A1	1/2013	Nakamura	
2013/0107702	A1*	5/2013	Gupta et al.	370/230
2014/0115654	A1	4/2014	Rogers et al.	
2014/0169375	A1	6/2014	Khan et al.	
2014/0233479	A1	8/2014	Dahod et al.	
2015/0036687	A1	2/2015	Belling	

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H04W 48/02 (2009.01)

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CPC **H04M 15/888** (2013.01); **H04W 4/26** (2013.01); **H04W 48/02** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,215,942	B1*	5/2007	McQuaide et al.	455/408
2003/0125968	A1	7/2003	Uppal	
2007/0109956	A1	5/2007	Kwon et al.	

OTHER PUBLICATIONS

First Action interview Pilot Program Pre-Interview Communication for U.S. Appl. No. 14/200,734, dated Aug. 5, 2015.

Office action for pending U.S. Appl. No. 14/200,734, dated Oct. 16, 2015.

* cited by examiner

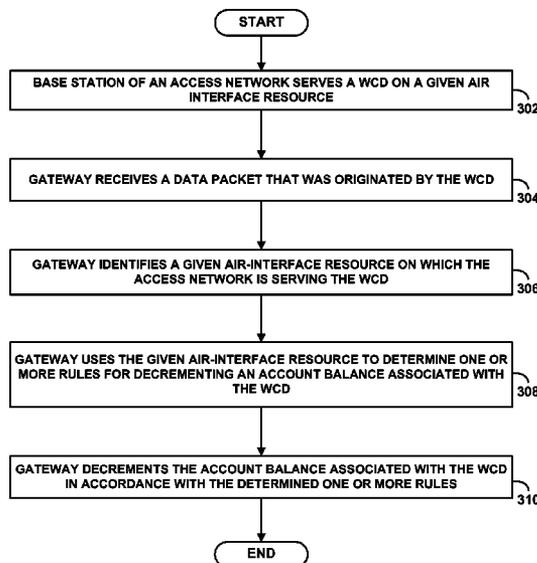
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(57) **ABSTRACT**

One embodiment takes the form of a method carried out by a gateway. The method includes the gateway receiving a message that was originated by a wireless communication device (WCD) being served by an access network. Next, the gateway may identify a given air-interface resource on which the access network is serving the WCD. After receiving the message, the gateway may use the given air-interface resource to determine one or more rules for decrementing an account balance associated with the WCD. The gateway may then decrement the account balance associated with the WCD in accordance with the determined one or more rules.

15 Claims, 5 Drawing Sheets



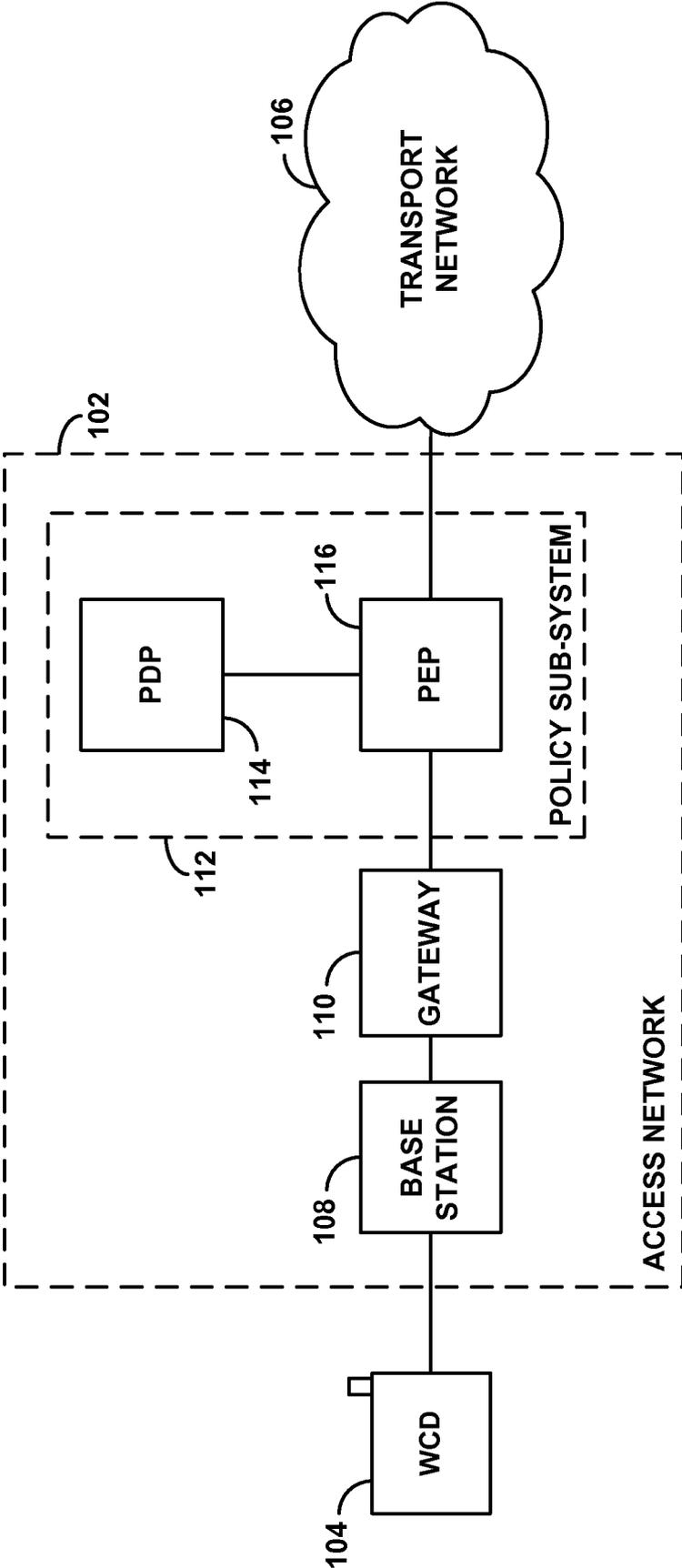


Fig. 1

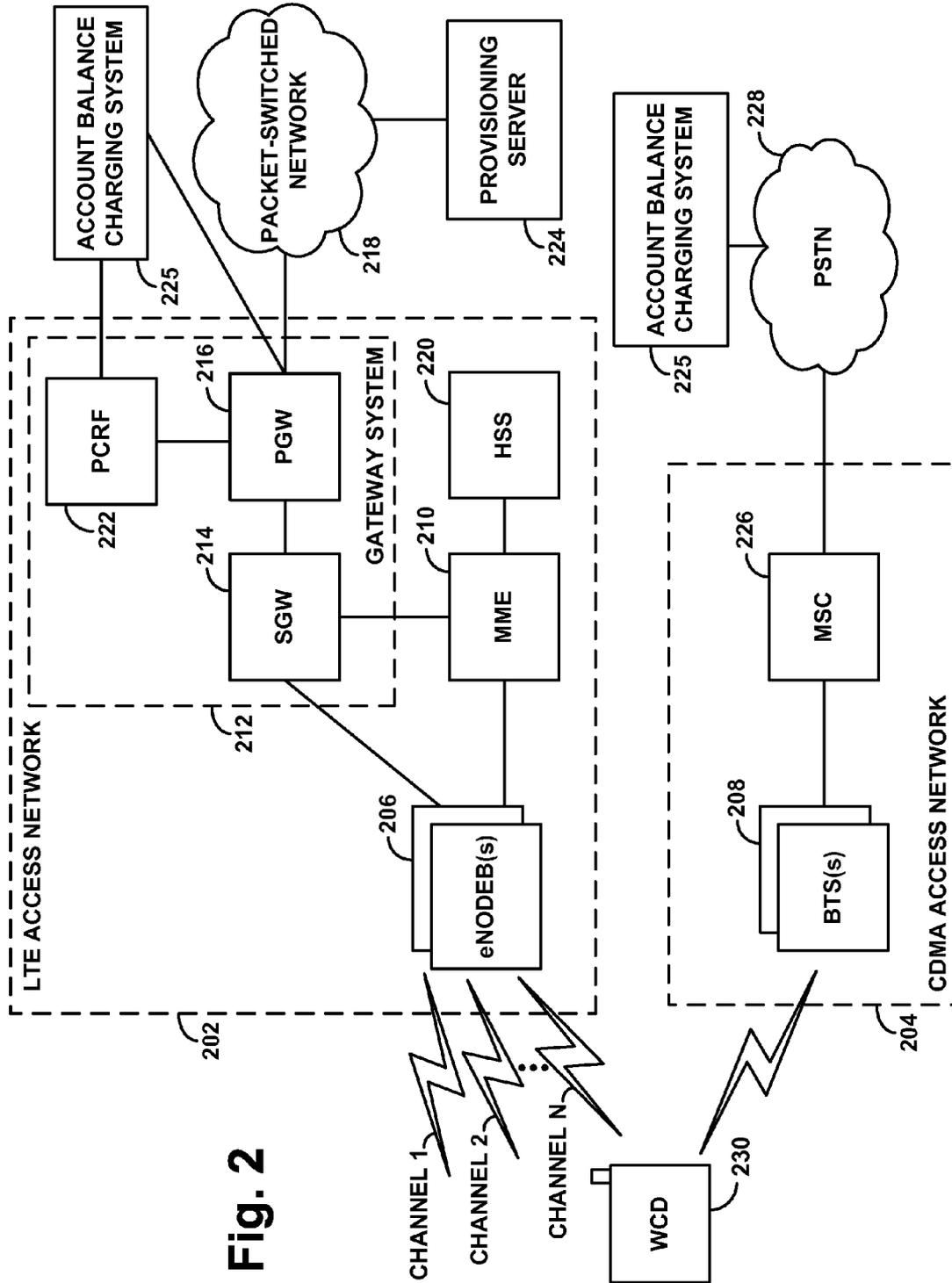


Fig. 2

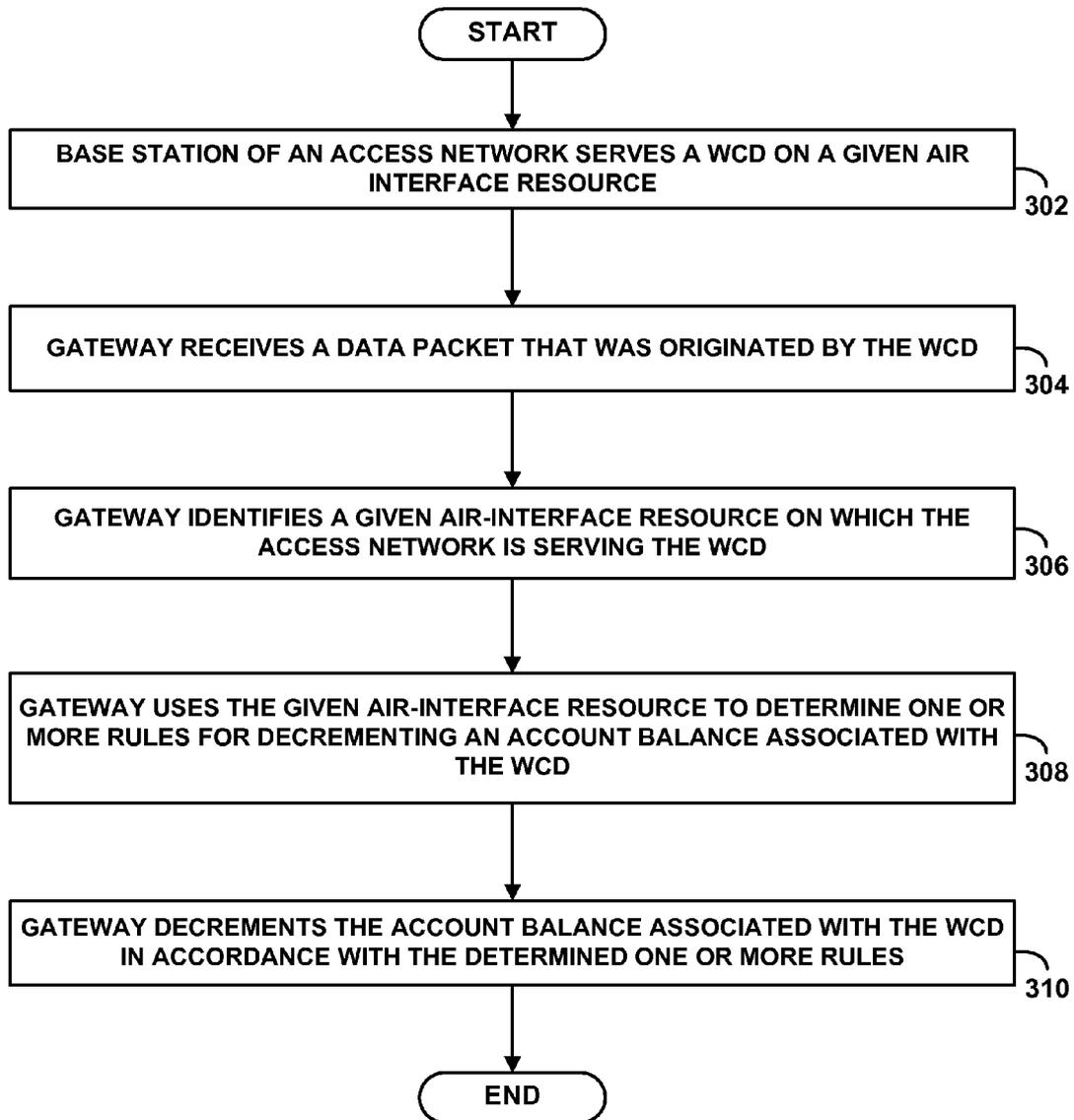


FIG. 3

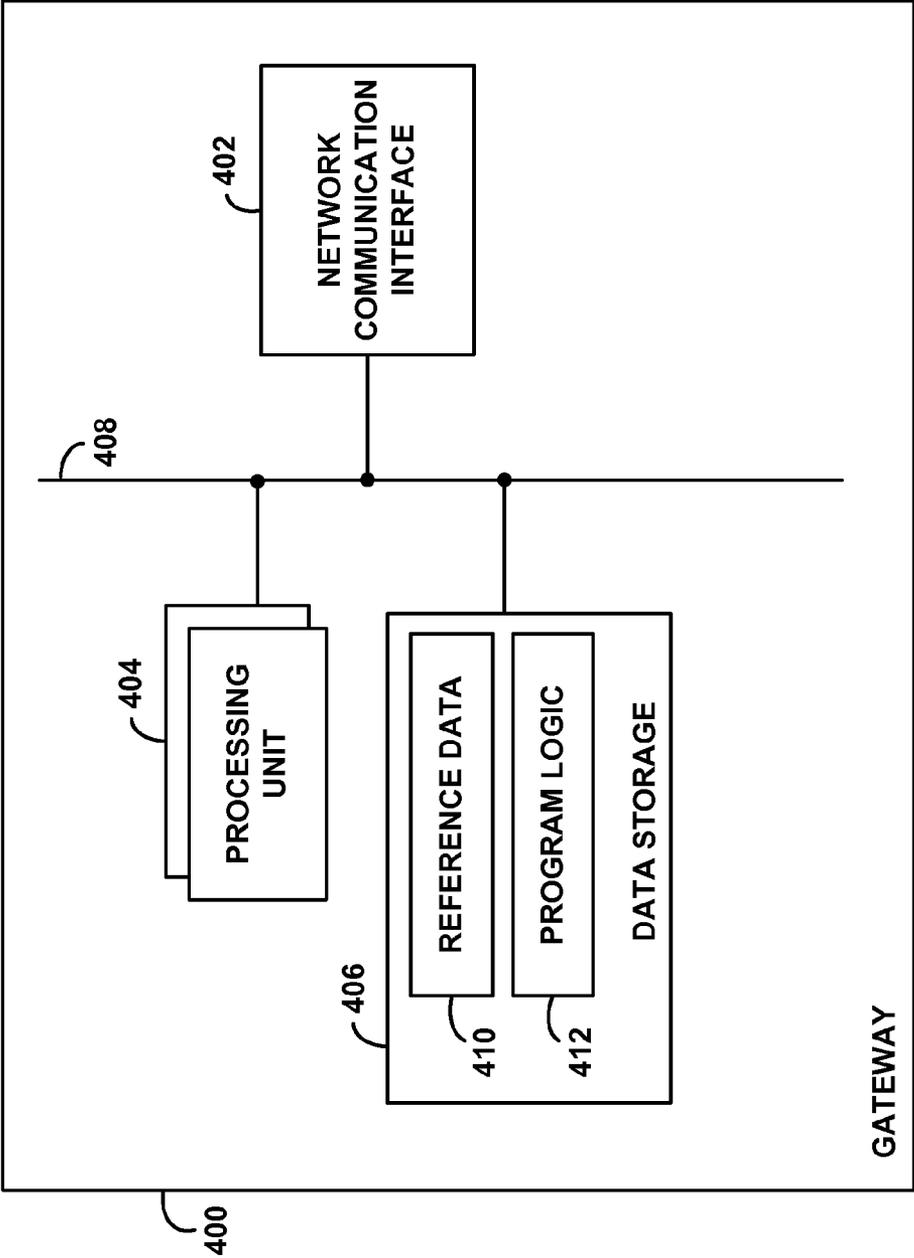


Fig. 4

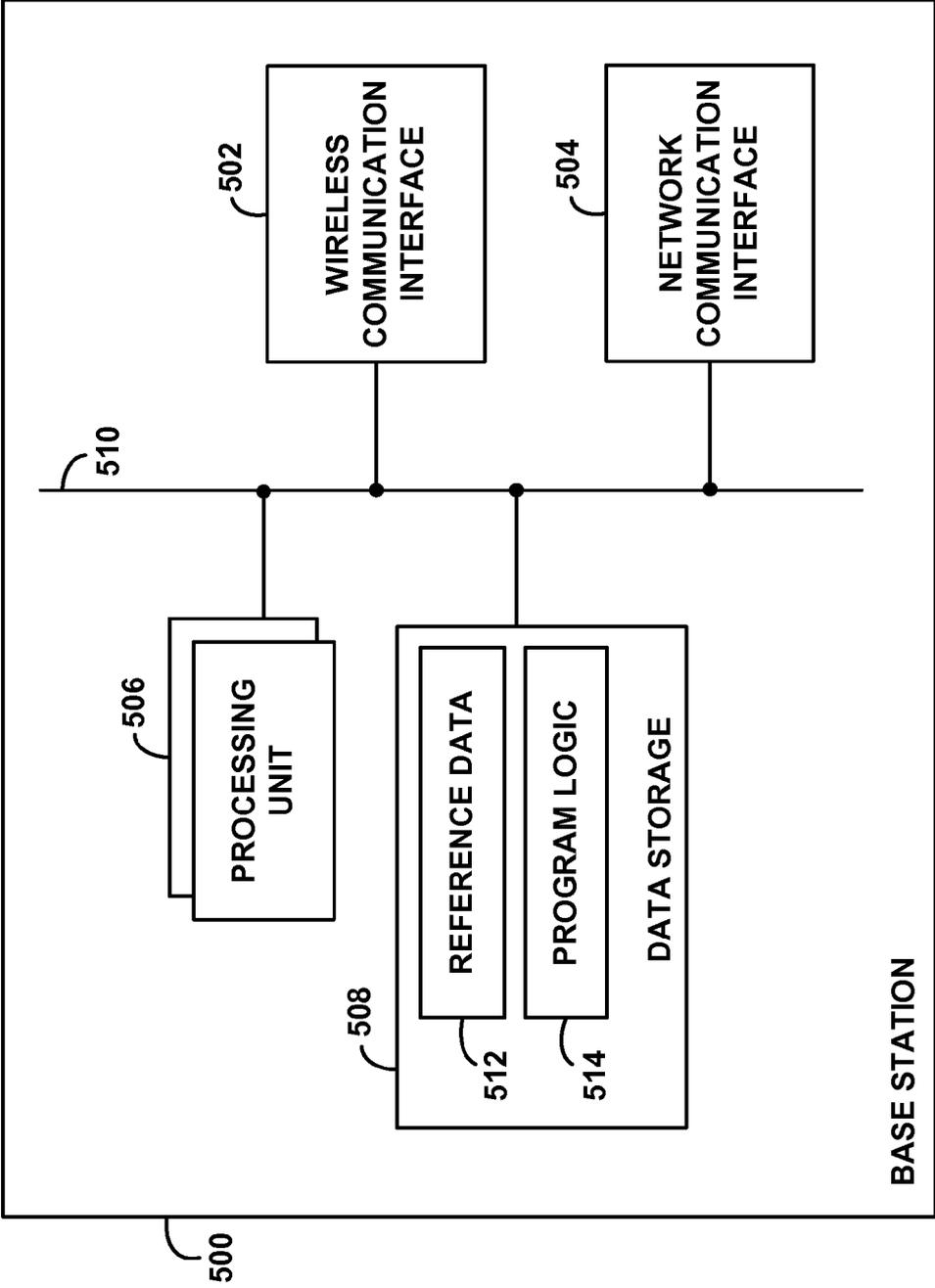


Fig. 5

**METHOD AND SYSTEM FOR
DECREMENTING ACCOUNT BALANCE
BASED ON AIR-INTERFACE RESOURCE
INFORMATION**

BACKGROUND

Unless otherwise indicated herein, the materials described in this section are not prior art to the claims and are not admitted to be prior art by inclusion in this section.

Wireless service providers may operate access networks each arranged to provide wireless communication devices (WCDs), such as cell phones, tablet computers, tracking devices, embedded wireless modules, and other wirelessly-equipped communication devices, with wireless communication service. Each such access network may include a number of base stations that radiate to define an air interface over which to provide wireless service to WCDs according to an agreed air-interface protocol, such as Orthogonal Frequency Division Multiple Access (OFDMA (e.g., Long Term Evolution (LTE) or Wireless Operability for Microwave Access (WiMAX)), Code Division Multiple Access (CDMA) (e.g., 1xRTT and 1xEV-DO), WIFI, and BLUETOOTH, or others now known or later developed. In turn, each base station may be coupled with network infrastructure that provides connectivity with one or more transport networks, such as the public switched telephone network (PSTN) and/or the Internet for instance. With this arrangement, a WCD within coverage of the access network may engage in air-interface communication with a base station and may thereby communicate via the base station with various remote network entities and/or with other WCDs served by the base station or by other base stations.

In accordance with an agreed air-interface protocol, the air interface provided by the access network may be comprised of various air-interface resources that are utilized by the base stations to serve WCDs. For instance, each base station may radiate to define one or more air-interface coverage areas, such as cells and cell sectors, in which WCDs can operate and engage in air-interface communication with the base station. Within each air-interface coverage area, the base station may operate on one or more carrier frequencies (or "carriers"), each defining a frequency channel for communicating with WCDs. In a typical example, the base station's one or more carriers may each take the form of a particular frequency block (e.g., a 1.25 MHz, 5 MHz, or 10 MHz block) in a profile frequency band used by the wireless service provider, such as a 800 MHz band, a 1.9 GHz band, or a 2.5 GHz band.

In practice, each of the base station's one or more frequency channels may be divided into a downlink (or forward link) for carrying communications from the base station to WCDs and an uplink (or reverse link) for carrying communications from WCDs to the base stations. For example, according to some air-interface protocols, each frequency channel may be divided over frequency into a first block of frequency for downlink communications and a second block of frequency for uplink communications. Alternatively, according to other air-interface protocols, each frequency channel may be divided over time into a first set of timeslots for carrying downlink communications and a second set of timeslots for carrying uplink communications. Other techniques for dividing a frequency channel into a downlink and uplink may exist as well.

Further, the agreed air-interface protocol may employ techniques such as time-division multiplexing, frequency-division multiplexing, and/or code-division multiplexing to further divide a frequency channel's downlink and/or uplink into

discrete sub-resources (e.g., LTE resource blocks, 1xEV-DO forward-link timeslots and/or reverse-link channels, etc.), which may then be used to carry control and/or bearer data between the base station and WCDs on the frequency channel.

In operation, each base station may be configured to broadcast, on each of its one or more frequency channels, (1) a list of the frequency channel(s) provided by the base station and (2) a pilot (or reference) signal that WCDs are configured to monitor in order to evaluate coverage strength (e.g., signal strength and/or signal to noise ratio). For example, in a representative LTE system, each base station may broadcast, on each of its one or more frequency channels, a system information block (SIB) message that lists the frequency channels on which the base station provides service and a reference signal that LTE-compliant WCDs are arranged to monitor in order to evaluate LTE coverage provided by the base station. As another example, in a representative CDMA system, each base station may broadcast, on each of its one or more frequency channels, a Channel List Message (CLM) that lists the frequency channels on which the base station provides service and a pilot signal that CDMA-compliant WCDs are arranged to monitor in order to evaluate CDMA coverage provided by the base station. Other examples are possible as well.

When a WCD first enters into coverage of an access network, the WCD may then automatically scan the air interface in an effort to find the strongest available pilot signal, and the WCD may then register with the access network over the frequency channel associated with that pilot signal. For instance, the WCD may generally scan through various frequency channels and evaluate any pilot signals on those frequency channels in order to identify the frequency channel having the strongest pilot signal. In turn, the WCD may engage in registration signaling with the access network on that frequency channel in order to register with the access network. At some later time, the access network can then assign the WCD certain sub-resources on the frequency channel and begin exchanging bearer data with the WCD.

OVERVIEW

In access networks such as those described above, wireless service providers may also employ entities for restricting or otherwise managing use of communication services based on an account balance for a particular subscriber. In systems providing account balance services, a subscriber may first establish an account with a service provider and then prepay for communication services provided by the service provider by adding money to the subscriber's account. An account balance typically represents a measure, such as time or monetary value, of communication services that a subscriber is authorized to use. As the subscriber uses the service, the service provider may then continuously monitor and decrement the balance of the account. When the balance drops to a low threshold level, the service provider may notify the subscriber and allow the subscriber to add more money to the account. Then, once the account is exhausted, i.e., the balance drops to zero, the service provider may either refuse to provide further communication services to the subscriber or may begin charging the subscriber for excess use. Other arrangements are also possible.

In general, an account balance service can involve establishing or applying any type of account balance that serves as an actual or suggested limit on use of communications services. The account balance could represent a time limit such as minutes of use, a communication quantity limit such as

numbers of calls, number of messages communicated or units of data communicated, or a monetary limit such as dollars of use, for example. Further, the account balance that defines the actual or suggested limit on use need not necessarily come from a prepayment by a subscriber or other party. Rather, the account balance could simply represent an assigned limit on use, which the subscriber may or may not be allowed to exceed.

In order to provide account balance services such as those described above, an access network will typically include mechanisms for tracking communications, monitoring and adjusting a subscriber's account balance, and/or facilitating an appropriate action in response to detecting a low or zero balance. These mechanisms may take various forms.

For instance, to apply account balance services for WCD communications by a subscriber (such as communication of voice calls, SMS messages, instant messages, e-mail messages, or the like), the subscriber's serving access network may apply logic that queries the subscriber's account balance upon receipt of a request to transmit a message to or from the subscriber and that conditions allowance of the message communication on the existence of a sufficient balance to cover the communication. If sufficient balance exists, the access network would then allow the communication, but if sufficient balance does not exist, the access network may refuse to allow the communication and may instead provide a notice to the subscriber and invite the subscriber to replenish the balance.

As the subscriber uses communication services provided by the service provider, the access network may then continuously decrement the subscriber's account balance. In a typical implementation, the access network may carry out this decrementing based on a predefined rate for decrementing the account balance, such a rate for decrementing a monetary limit for the account such as dollars of use, as an example.

In some circumstances, however, it may be desirable for an access network to decrement a subscriber's account balance in different manners depending on the characteristics of the communication session between the access network and the subscriber's WCD, such as the particular air-interface resource(s) being used by the access network to serve the subscriber's WCD. For example, as noted above, an access network may be capable of serving the subscriber's WCD on one of several different frequency bands, and each of these frequency bands may provide a different capacity (e.g., the 2.5 GHz band may have more capacity than the 1.9 GHz band, the 1.9 GHz band may have more capacity than the 800 MHz band, etc.). As a result, there is decreased supply on those frequency bands having less capacity. Thus, the access network may wish to decrement the subscriber's account balance in different manners depending on the frequency band being used to serve the subscriber's WCD. Along similar lines, the access network may wish to decrement the subscriber's account balance in different manners depending on the particular frequency channel(s) being used to serve the subscriber's WCD, the particular sub-resource(s) assigned to the subscriber's WCD, etc.

Accordingly, disclosed herein are methods and systems for decrementing an account balance associated with a given WCD in different manners (e.g., in accordance with different rules that apply different rates) depending on the particular air-interface resource(s) presently being used to serve the given WCD.

One example embodiment of the disclosed methods may involve (a) at a gateway that provides connectivity between an access network and a transport network, receiving a message that was originated by a WCD being served by the access

network, (b) the gateway identifying a given air-interface resource on which the access network is serving the WCD, (c) after receiving the message, the gateway using the given air-interface resource to determine one or more rules for decrementing an account balance associated with the WCD, and (d) the gateway decrementing the account balance associated with the WCD in accordance with the determined one or more rules.

In line with the discussion above, the given air-interface resource identified by the gateway may take various forms. As one example, the given air-interface resource may be the particular frequency band on which the access network is serving the WCD. As another example, the given air-interface resource may be the frequency channel on which access network is serving the WCD, which may be identified by the carrier frequency of the frequency channel and/or an identifier of the coverage-area served by the frequency channel. As yet another example, the given air-interface resource may be a particular resource(s) assigned to the WCD on the frequency channel, such a particular LTE resource block, a particular 1xEV-DO timeslot and/or reverse-link channel, etc. Other examples are possible as well. It should also be understood that the given air-interface resource identified by the gateway could be a combination of two or more different air-interface resources being used to serve the given WCD (e.g., a frequency band and a frequency channel).

The one or more rules for decrementing the account balance associated with the given WCD may take various forms. As one example, the one or more rules for decrementing an account balance associated with the WCD comprise a respective rule corresponding to each of one or more frequency bands. For instance, a given WCD may decrement an account balance for the given WCD under a first set of rules if it is being served by the access network on the 1.9 GHz band, a second set of rules if it is being served by the access network on the 2.5 GHz band, and so on. Other examples are possible as well.

Another example embodiment of the disclosed methods may include (a) at an access network, serving a WCD with telecommunication service, wherein the access network maintains an account balance associated with the WCD, (b) the access network identifying a given air-interface resource on which the access network is serving the WCD, (c) the access network using the given air-interface resource to determine one or more rules for decrementing the account balance associated with the WCD, and (d) the access network decrementing the account balance associated with the WCD in accordance with the determined one or more rules.

Also disclosed herein are structures configured to facilitate implementation of the disclosed methods. One embodiment of the disclosed structures may take the form of a gateway that includes (a) a network communication interface configured to provide connectivity with an access network, (b) a processing unit, (c) data storage, and (d) program instructions stored in the data storage and executable by the processing unit to carry out functions such as those disclosed herein. Another embodiment of the disclosed structures may take the form of a non-transitory computer readable medium having instructions stored thereon that are executable by a processing unit to carry out functions such as those disclosed herein.

These and other aspects and advantages will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings. Further, it should be understood that this overview and other description through-

out this document is provided merely for purposes of example and is not intended to limit the scope of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified block diagram of an example network arrangement in which embodiments of the disclosed methods and entities can be implemented.

FIG. 2 is a simplified block diagram of another example network arrangement in which embodiments of the disclosed methods and entities can be implemented.

FIG. 3 is a flow chart depicting functions that can be carried out in accordance with example embodiment of the disclosed methods.

FIG. 4 is a simplified block diagram showing functional components that may be included in example gateway to facilitate implementation of the disclosed methods.

FIG. 5 is a simplified block diagram showing functional components that may be included in example base station to facilitate implementation of the disclosed methods.

DETAILED DESCRIPTION

The present method and corresponding system will now be described with reference to the figures. It should be understood, however, that numerous variations from the depicted arrangements and functions are possible while remaining within the scope and spirit of the claims. For instance, one or more elements may be added, removed, combined, distributed, substituted, re-positioned, re-ordered, and/or otherwise changed. Further, where this description refers to one or more functions being implemented on and/or by one or more devices, one or more machines, and/or one or more networks, it should be understood that one or more of such entities could carry out one or more of such functions by themselves or in cooperation, and may do so by application of any suitable combination of hardware, firmware, and/or software. For instance, one or more processors may execute one or more sets of programming instructions as at least part of carrying out of one or more of the functions described herein.

Referring to the drawings, as noted above, FIG. 1 is a simplified block diagram of an example network arrangement in which embodiments of the disclosed methods and entities can be implemented. As shown, the arrangement includes an access network 102 that functions to provide wireless communication devices (WCDs) with connectivity to one or more transport networks. In particular, the access network 102 is shown providing a representative WCD 104 with connectivity to a representative transport network 106. To facilitate providing this connectivity, the access network 102 may include one or more components that communicate with the WCD 104 and with the transport network 106 and that bridge those entities together to allow the WCD 104 to engage in communications with entities on the transport network 106.

The access network 102 may be structured to provide various types of connectivity, such as wireless, circuit-switched, and/or packet-switched, for various types of communications, such as voice and/or data for instance. As a specific example, the access network 102 may be cellular wireless network that includes (1) a wireless base station 108 arranged to serve the WCD 104 in accordance with an air-interface protocol such as OFDMA (e.g., LTE or WiMAX), CDMA, WIFI, or the like, and (2) a gateway 110 that connects with a transport network such as the PSTN or the Internet. Representative WCD 104 may then be a device such as a cell phone, wirelessly-equipped computer, embedded wireless module,

or the like, configured to be served wirelessly by such a base station and to engage in voice and/or data communication via the base station and the switch or gateway with entities on the PSTN or Internet. Other examples are possible as well.

The base station 108 may radiate to define one or more air-interface coverage areas, such as cells and cell sectors, in which the WCD 104 can operate and engage in air-interface communication with the base station 108. Within each air-interface coverage area, the base station 108 may operate on one or more carrier frequencies (or “carriers”). In a typical example, the base station’s 108 one or more carriers may each take the form of a particular frequency block (e.g., a 1.25 MHz, 5 MHz, or 10 MHz block) in a profile frequency band used by the wireless service provider, such as a 800 MHz band, a 1.9 GHz band, or a 2.5 GHz band. Each carrier in each coverage area may then define a separate frequency channel over which the base station 108 may communicate with WCDs. As such, the base station’s one or more frequency channels may each be identified based on a carrier frequency and an identifier of the coverage area in which the frequency channel is provided (e.g., a PN offset, sector ID, etc.). It should be understood, however, that a frequency channel may be identified in other manners as well.

The one or more frequency channels of the base station 108 may take various forms. In one example, each of the base station’s one or more frequency channels may be divided into a downlink (or forward link) for carrying communications from the base station 108 to the WCD 104 and an uplink (or reverse link) for carrying communications from the WCD 104 to the base station 108. For example, according to some air-interface protocols, each frequency channel may be divided over frequency into a first block of frequency for downlink communications and a second block of frequency for uplink communications. Alternatively, according to other air-interface protocols, each frequency channel may be divided over time into a first set of timeslots for carrying downlink communications and a second set of timeslots for carrying uplink communications. Other techniques for dividing a frequency channel into a downlink and uplink may exist as well.

Further, the agreed air-interface protocol may employ techniques such time-division multiplexing, frequency-division multiplexing, and/or code-division multiplexing to further divide a frequency channel’s downlink and/or uplink into discrete sub-resources (e.g., LTE resource blocks, 1xEV-DO forward-link timeslots and/or reverse-link channels, etc.), which may then be used to carry control and/or bearer data between the base station 108 and the WCD 104 on the frequency channel.

The gateway 110 may generally function to provide connectivity between the access network 102 and the transport network 106. As such, the gateway 110 may take any form that enables it to carry out this function.

In line with the discussion above, the access network 102 may provide a mechanism for restricting or otherwise managing use of communication services based on a measure of subscriber account balance. In such a system, a subscriber may first establish a prepaid account with the access network 102 and then pay for a duration of communication services on the communication network by adding money to the prepaid account. An account balance typically represents a measure, such as time or monetary value, of communication services that a subscriber is authorized to use. As the subscriber uses the service, the access network 102 may then decrement the balance of the prepaid account.

In accordance with this disclosure, the access network 102 may be arranged to decrement an account balance associated

with the WCD **104** in different manners depending on characteristics of a communication session between the access network **102** and the WCD **104**. To facilitate this, the access network **102** may be programmed with, have access to, or otherwise maintain rules that define the different manners in which the access network may decrement the account balance, and the access network **102** may then apply these rules as it serves the WCD **104**.

For instance, as shown in FIG. 1, the access network **102** may include a policy-subsystem **112** that is configured to maintain and apply rules for decrementing the account balance of the WCD **104**. This policy-subsystem **112** may take various forms. As one representative example, policy-subsystem **112** is shown as including (1) a policy decision point (PDP) **114** that generally functions to maintain a record of one or more rules for decrementing the account balance of the WCD **104** depending on characteristics of a communication session between the access network **102** and the WCD **104** and (2) a policy enforcement point (PEP) **116** that functions to apply these rules as the access network serves the WCD **104**. These entities may take various forms, and in some cases, may be implemented as functions of other access-network components (e.g., a controller or a gateway such as the gateway **110**). Other examples are possible as well.

FIG. 2 is next a more specific but still simplified depiction of a network arrangement in which embodiments of the disclosed methods and entities can be implemented. In particular, the representative system includes an LTE access network **202** and a CDMA access network **204**. It should be understood that these two types of access networks are just examples, and that the principles described can extend to apply with respect to any other types of access networks, such as wireless access networks operating in accordance with other air-interface protocols for instance.

As noted above, each of these access networks may include one or more base stations that radiate to provide one or more frequency channels on which to serve WCDs. By way of example, the LTE access network **202** is shown including one or more representative LTE base stations **206** known as eNodeBs, and the CDMA access network is shown including one or more representative CDMA base stations **208** known as base transceiver stations (BTSs). Further, by way of example, the LTE access network **202** is shown defining a number of frequency channels denoted as Channels 1, 2, . . . N, and the CDMA access network **204** is shown defining a single representative frequency channel. Other arrangements are possible as well.

The frequency channels provided by the LTE and CDMA access networks may take various forms. For instance, in one representative implementation of the LTE access network **202**, Channels 1, 2, . . . N may each include a downlink that takes the form of a 5 MHz, 10 MHz, or 20 MHz carrier-frequency channel, which is then further divided in both the time and frequency domains into "resource blocks," each taking the form of a timeslot having a duration of 0.5 milliseconds (ms) and spanning a set of twelve 15-kHz sub-carriers (for a total bandwidth of 180 kHz). These resource blocks may be assigned to particular WCDs such that each assigned resource block may carry control and/or bearer data intended for a particular WCD (or group of WCDs). Additionally, the resource blocks may also carry other information, such as shared control data (e.g., a reference signal for the given coverage area). Each frequency channel's uplink may then be configured in a similar manner. As noted above, in other implementations of LTE, the downlink and uplink may be divided in the time domain rather than the frequency domain.

Further, in one representative implementation of the CDMA network **204**, the frequency channel may include a 1.25 MHz carrier-frequency downlink that is divided in the time domain into timeslot resources, each having a length of 2048 chips and a duration of approximately 1.67 ms. Each downlink timeslot may then be further divided in the time domain into two 1024 chip half slots, each arranged to carry a 76 chip forward pilot channel, two 64 chip forward medium access control (MAC) channel segments, and two 400 chip forward data segments for carrying control and/or bearer data. These downlink timeslots may then be assigned to particular WCDs using MAC identifiers, such that each assigned timeslot may carry control and/or bearer data intended for a particular WCD (or group of WCDs). The frequency channel's uplink may be configured in a similar manner, although the uplink may alternatively be divided into code channels using "Walsh codes."

Each base station in the LTE and CDMA access networks may be configured to broadcast, on each of its frequency channels, a specification of the one or more frequency channels provided by the base station. This specification may take various forms, and may identify the base station's one or more frequency channels in various manners (e.g., using a combination of a carrier-frequency identifier and coverage-area identifier). For instance, in the LTE access network **202**, each eNodeB may broadcast a System Information Block #5 (SIBS) message that includes a frequency-channel list. And in the CDMA access network **204**, each BTS may broadcast a Channel List Message (CLM) that includes a frequency-channel list.

Each illustrated access network is shown as including other network infrastructure that helps enable the access network to serve WCDs. For example, the LTE access network **202** includes (1) a mobility management entity (MME) **210** that functions as a controller for the LTE access network **202**, and (2) a gateway system **212**. The gateway system **212** further includes (1) a serving gateway (SGW) **214** and (2) a packet gateway (PGW) **216**. The PGW **216** provides connectivity with a packet-switched network **218** such as the Internet. As shown, the MME **210** has an interface for communication with each of the eNodeBs **206** and an interface for communication with the gateway system **212**. With this arrangement, the MME **210** can manage registration of WCDs with the LTE access network **202**, paging of WCDs served by the LTE access network **202**, and setup of bearer tunnels for WCDs served by the LTE access network **202** to allow those WCDs to engage in packet data communication on packet-switched network **218**. The LTE access network **202** may further include a home subscriber server (HSS) **220** and a policy charging and rules function (PCRF) **222**, among other entities.

In line with the discussion above, the LTE access network **202** may also include a PDP and a PEP (or the like), which may be implemented in various manners. For instance, in one implementation, the HSS **220** may function as a PDP and the MME **210** may function as a PEP. According to this implementation, the HSS **220** may maintain a record of one or more rules for decrementing the account balance and may provide the MME **210** with the one or more rules when a representative WCD **230** is served by the LTE access network **202**. The MME **210** may then store the one or more rules and subsequently apply those rules as the LTE access network **202** serves the WCD **230**.

In another implementation, the PCRF **222** may function as a PDP and the PGW **216** may function as a PEP. According to this implementation, the PCRF **222** may maintain a record of one or more rules for decrementing the account balance and

may provide the PGW 216 with the one or more rules when the WCD 230 is served by the LTE access network 202. The PGW 216 may then store the one or more rules and subsequently apply those rules as the LTE access network 202 serves the WCD 230.

In yet another implementation, the MME 210, HSS 220, PGW 216, and/or PCRF 222 could package one or more such rules for decrementing the account balance and send the package to a provisioning server 224 sitting on the packet-switched network 218.

PGW 216 and PCRF 222 are shown in communication with account balance charging system 225, which may contain account balance data for various subscribers such as WCD 230. Although account balance charging system 225 is shown coupled directly to PGW 216 and PCRF 222 and external to access network 202, it could just as well be accessible via packet-switched network 218, or provided internally within provisioning server 224 or gateway system 212.

Account balance charging system 225 may contain information about account balances and account balance subscriptions of various subscribers users and/or WCDs, which PGW 216 may reference to facilitate account balance validation. For each WCD, the account balance charging system 225 may specify a client address, identifier or other data that might be indicated in (or determinable by) a content request or a content transmission to determine that the content is to be transmitted to and/or received by a particular WCD. In turn, the account balance charging system 225 may indicate for each WCD an existing account balance and a charge rate or other logic indicating how to apply the account balance in practice (such as on a per message, per minute, or per kilobyte basis or on some other basis). Account balance charging system 225 may further be part of a larger set of authentication and authorization data and/or logic for particular subscribers, which might define other conditions that need to be met (e.g., as part of the account balance validation process) before content is transmitted to the destination subscriber. The account balance may be arranged on a subscriber-by-subscriber basis (in which case a subscriber ID would correspond to a list of WCD IDs), or on a WCD-by-WCD basis (in which case a single WCD ID would correspond to a particular WCD).

CDMA access network 204, on the other hand, includes a mobile switching center (MSC) 226 that functions as a controller of the CDMA access network 204 and that also functions to provide connectivity with PSTN 228. As shown, MSC 226 has an interface for communication (typically through a base station controller or radio network controller (not shown)) with the BTS 208. With this arrangement, the MSC 226 can manage registration of WCDs with the CDMA access network 204, paging of WCDs served by the CDMA access network 204, and setup of PSTN calls for WCDs served by the CDMA access network 204.

The MSC 226 may also be in communication with a PEP and PDP that are configured to maintain and apply the rules for a given WCD, as discussed above. In addition, PSTN 228 may be in communication with the account balance charging system 225, and the account balance charging system 225 may contain information about account balances and account balance subscriptions of various users and/or WCDs, as discussed above.

Further shown in FIG. 2 is a representative WCD 230 positioned in coverage of both the LTE access network 202 and the CDMA access network 204. Such a WCD 230 may be capable being served concurrently by both the LTE access network 202 and the CDMA access network 204. For instance, the WCD 230 may be a dual-radio device, having

both an LTE radio that the WCD 230 can use to be served by the LTE access network 202, and a CDMA access network 204 that the WCD 230 can use concurrently to be served by the CDMA access network 204. Alternatively, the WCD 230 may include a single radio that supports both LTE service and CDMA service and that the WCD 230 can use to be served concurrently by both access networks. In another example, the WCD 230 may be configured to support being served exclusively by the LTE access network 202. Other configurations are possible as well.

Turning now to FIG. 3, a flow chart illustrating functions that can be carried out in accordance with an example embodiment of the disclosed methods is shown. These functions may be carried out by one or more components of an access network, such as the access networks of FIG. 1 and FIG. 2 above.

As shown in FIG. 3, the example embodiment may begin at block 302 with a base station of an access network serving a WCD on a given air-interface resource. As described above in relation to FIGS. 1 and 2, the given air-interface resource may be defined in various manners. For instance, the given air-interface resource may be defined based on a particular frequency band in which the base station is serving the WCD, a particular frequency channel within the particular frequency band on which the base station is serving the WCD (which may in turn be defined by the carrier frequency on which the frequency channel is employed and/or the particular coverage area in which the frequency channel is provided), and/or a particular sub-resource that has been assigned to the WCD on the frequency channel (e.g., an LTE resource block, a 1xEV-DO timeslot, a Walsh-coded channel, etc.). Other examples are possible as well.

The method continues at block 304 with a gateway receiving a message that was originated by the WCD. The message may take various routes from the WCD to the gateway. For example, with reference to the general network arrangement depicted in FIG. 1, the message may pass from the WCD to the base station, and then from the base station 108 to the gateway 110 (either directly or via one or more intermediate entities that are now shown). As another example, with reference to the LTE network arrangement depicted in FIG. 2, the message may pass from the WCD 230 to the eNodeB 206, from the eNodeB 206 to the SGW 214 (e.g., via an S1-U interface), and then from the SGW 214 to the PGW 216 (e.g., via an S5 interface or an S8 interface). Other examples are possible as well.

Further, the message may take various forms. The message may be a signaling message associated with the setup of a communication session (such as voice calls, SMS messages, instant messages, e-mail messages, or the like). In another example, the message may include a header and a payload. The header may include information such as an identifier of the WCD that originated the packet, the IP address of the destination of the message, among other information. The payload may include the part of the transmitted data which is the fundamental purpose of the transmission. For example, the payload may include the voice data of a cellular call, the text data in a text message, or other data transmitted to or from the WCD. The message may take other forms as well.

Further, a base station may receive the message from the WCD, and the base station may subsequently update the message to include the indication of the given air-interface resource, and then transmit the updated message for receipt by the gateway. In such an example, the feature of the base station updating the message to include an indication of the given air-interface resource may take various forms. In one example, this feature may comprise adding the indication of

the given air-interface resource to a header of the message. The header may take various forms, including a general packet radio service tunneling protocol (GTP-U) extension header, as an example. In another example, this feature may comprise adding the indication of the given air-interface resource to the payload of the message. Other examples are possible as well.

It should also be understood that the base station may not update each message it receives from the WCD with air-interface resource information. Rather, before updating, the base station may be configured to make a threshold determination of whether to update the received message. The base station may carry out this decision in various manners. For example, the base station may decide to include such an indication periodically (e.g., after a given amount of time has passed and/or a given number of messages have been received since last updating a message from the WCD to include such an indication). In another example, the base station may decide to include such an indication only in the first message received after the base station begins serving the WCD on a particular air-interface resource. Other examples are possible as well.

Next, the method continues at block 306 with the gateway identifying a given air-interface resource on which the access network is serving the WCD. The gateway may determine the given air-interface resource in various ways.

In one implementation, the gateway may identify the given air-interface resource based on an indication of the given air-interface resource that is included in the received message. The indication of the given air-interface resource may take various forms. In one example, the indication of the given air-interface resource may include an indication of a particular frequency band on which the access network is serving the WCD, such as one of the 800 MHz band, the 1.9 GHz band, and the 2.5 GHz band, as discussed above. In another example, the indication of the given air-interface resource may include an indication of at least one frequency channel on which the access network is serving the WCD (e.g., a carrier frequency and/or a coverage-area identifier). In yet another example, the indication of the given air-interface resource may include an indication of an uplink and/or downlink on which the base station is serving the WCD. In still another example, the indication of the given air-interface resource may include an indication of at least one sub-resource on which the access network is serving the WCD (e.g., an identifier of a resource block, timeslot, etc.). Other examples are possible as well.

In another example, the gateway may identify the given air-interface resource based on an attribute-value pair (AVP) that indicates the given air-interface resource on which the access network is presently serving the WCD, which the gateway may receive from an account balance charging system. The gateway may receive the AVP from the account balance charging system may at different times, such as the initial attachment of the WCD, or periodically, as examples. Further, the gateway may receive the AVP from the account balance charging system in various manners. For example, with reference to the LTE network arrangement depicted in FIG. 2, the PGW 216 may receive a CCA-I message that includes an AVP from the account balance charging system 225 (e.g., via a Gy interface) in response to sending the account balance charging system 225 a CCR-U message and/or a CCA-U message. Other examples are possible as well.

The method continues at block 308 with the gateway using the given air-interface resource to determine one or more rules for decrementing an account balance associated with the WCD. These rules may take various forms.

According to one implementation, the gateway may maintain sets of rules for decrementing an account balance associated with the WCD that are based on different frequency bands, such as a first set of rules for the 1.9 GHz band, a second set of rules for the 2.5 GHz band, etc. In this respect, in one representative example, the first set of rules may dictate that the account balance be decremented according to a first multiplier (e.g., one unit of account balance for every one unit of data communicated), and the second set of rules may dictate that the account balance be decremented according to a second multiplier (e.g., one half unit of balance for every unit of data communicated), etc. Further, if the gateway later determines that the access network has changed from serving the WCD in a first frequency band to serving the WCD a second frequency band (e.g., from the 1.9 GHz band to the 2.5 GHz band), the gateway may responsively adjust the one or more rules for decrementing the account balance from the first set of rules to the second set of rules.

In another implementation, the one or more rules may dictate that the account balance is to be decremented according to a particular rate, such as a rate for decrementing a monetary limit for the prepaid account. As another example, the one or more rules may define a multiplier for decrementing the account balance associated with the WCD, such as a multiplier for decrementing a time limit for the prepaid account, or a multiplier for decrementing a communication quantity limit for the prepaid account.

As another example, the rules may define an increase in available data usage for various air-interface resources. For example, a user may purchase 1 GB of data usage for a given WCD. The one or more rules may provide that when the given WCD is served by the access network on the 2.5 GHz band, the given WCD is entitled to a 10% increase in data usage, or 1.1 GB of data usage. Of course, many other examples of rules corresponding to different air-interface resources may exist as well.

In operation, the gateway may determine the set of rules for decrementing an account balance associated with the WCD in various manners. In one implementation, with reference to the LTE network arrangement depicted in FIG. 2, the PGW 216 may transmit the received message to the PCRF 222, which may maintain a record defining one or more rules for decrementing an account balance. The PCRF 222 may be configured to provide the PGW 216 with those rules when the WCD is served by the LTE access network.

In particular, in one example the PGW 216 may receive from the PCRF 222 a set of rules for the WCD, which may include different rules for different air-interface resources (e.g., different frequency bands or frequency channels). The PGW 216 may maintain a database of such rules locally (e.g., in a context record for the WCD) and may apply those rules as the PGW 216 receives the message from the SGW 214. In another example, the PGW 216 may query the PCRF 222 for a policy directive each time the PGW 216 learns of the air-interface resource on which the WCD is being served by the eNodeB 206. The PCRF 222 may then determine the appropriate set of rules to apply based at least in part on the given air-interface resource. The PCRF 222 may then provide a directive to the PGW 216 including the appropriate set of rules for decrementing an account balance associated with the WCD for the PGW 216 to implement.

In another example, the gateway may determine the set of rules for decrementing an account balance associated with the WCD by querying an account balance charging system. As discussed above, the account balance charging system may contain information about account balances and account balance subscriptions of various subscribers and/or WCDs. In

addition, the account balance may include the set of rules for decrementing the account balance associated with the WCD. In its query, the gateway may include identification information corresponding to the WCD and information indicating the given air-interface resource on which the WCD is being served by the access network. The account balance charging system may subsequently provide the set of rules for decrementing an account balance associated with the WCD based at least in part on the air-interface resource on which the WCD is being served. Other potential embodiments for determining the set of rules are possible as well.

The method continues at block 310 with the gateway decrementing the account balance associated with the WCD in accordance with the determined one or more rules. For example, if the determined one or more rules defines a rate for decrementing the account balance, then the gateway proceeds to decrement the account balance according to that rate by, e.g., decreasing the monetary balance by an amount that corresponds to the number of minutes or data used during the subsequent communication session.

FIG. 4 is next a simplified block diagram depicting components of an example gateway 400 that may be arranged to carry out various aspects of the disclosed methods. As shown in FIG. 4, gateway 400 includes a network communication interface 402, a processing unit 404, and data storage 406, all of which may be communicatively linked together by a system bus, network, or other connection mechanism 408.

In this example arrangement, network communication interface 402 functions to facilitate communication with various other entities of the system. As such, the interface may include a wired or wireless Ethernet module or other interface, depending on the manner in which communication will occur. Processing unit 404 may then comprise one or more general purpose processors (e.g., microprocessors) and/or one or more special purpose processors (e.g., application specific integrated circuits or digital signal processors). And data storage 406 may comprise one or more volatile and/or non-volatile storage components (non-transitory), such as magnetic, optical, flash, or organic storage components.

As shown, data storage 406 may contain reference data 410 and program logic 412. Reference data 410 may comprise various data usable by processing unit 404 to carry out various functions described herein. For example, reference data 410 may comprise one or more rules for decrementing an account balance for each of various air-interface resources and may thus define for each WCD one or more rules for decrementing an account balance based at least in part on the frequency on which the WCD is being served. Program logic 412, in turn, may then comprise machine language instructions or the like that are executable by the processing unit 404 to carry out various functions described herein, such as to receive a message that was originated by a given WCD and responsively provide one or more rules for decrementing an account balance for the given WCD based at least in part on the air-interface resource on which the given WCD is being served.

FIG. 5 is a simplified block diagram depicting components of an example base station 500 that may be arranged to carry out various aspects of the disclosed methods. As shown, the example base station 500 includes a wireless communication interface 502, a network communication interface 504, a processing unit 506, and data storage 508, all of which may be communicatively linked together by a system bus, network, or other connection mechanism 510.

In this example arrangement, wireless communication interface 502 generally functions to radiate to define one or more coverage areas in which WCDs can operate and engage in wireless communication with base station 500 over an air

interface. As such, wireless communication interface 502 may include one or more antenna structures arranged in various ways (e.g., one or more directional or sectorized antennas that are potentially tower mounted). Additionally, wireless communication interface 502 may include other associated components, such as a power amplifier and/or a modem for instance. Other configurations are also possible.

Network communication interface 504 generally functions to facilitate communication with one or more access networks, such as those discussed above for instance, and may thus take various forms to facilitate various types of communication such as wireless, landline, circuit-switched, and/or packet-switched communication. Network communication interface 504 may take any suitable form for carrying out this function, examples of which include an Ethernet interface, a serial bus interface (e.g., Firewire, USB 2.0, etc.), a chipset and antenna adapted to facilitate wireless communication, and/or any other interface that provides for wired and/or wireless communication. Network communication interface 504 may also include multiple interfaces. Other configurations are possible as well.

Processing unit 506 may comprise one or more general purpose processors (e.g., microprocessors) and/or one or more special purpose processors (e.g., application specific integrated circuits or digital signal processors), programmable-logic devices (e.g., a field programmable gate array), and/or any other processor components now known or later developed. Processing unit 506 may be integrated in whole or in part with other components of base station 500.

Data storage 508 may then comprise one or more volatile and/or non-volatile storage components (non-transitory), such as magnetic, optical, flash, or organic storage components. As shown, data storage 508 may be arranged to contain reference data 512 and program logic 514. Reference data 512 may comprise various data usable by processing unit 506 to carry out various functions described herein. Program logic 514 may then comprise machine language instructions or the like that may be executed or interpreted by processing unit 506 to carry out various functions described herein.

Exemplary embodiments have been described above. Those skilled in the art will appreciate, however, that many variations from the embodiments are possible while remaining within the spirit and scope of the claims.

What is claimed is:

1. A method comprising:

at a gateway that provides connectivity between an access network and a transport network, receiving a message that was originated by a wireless communication device (WCD) being served by the access network;

the gateway identifying a given air-interface resource on which the access network is serving the WCD, wherein the given air-interface resource is selected from the group consisting of a frequency band, at least one frequency channel, and at least one Orthogonal Frequency Division Multiple Access (OFDMA) resource block;

after receiving the message, the gateway using the given air-interface resource to determine one or more rules for decrementing an account balance associated with the WCD; and

the gateway decrementing the account balance associated with the WCD in accordance with the determined one or more rules.

2. The method of claim 1, wherein the message includes an indication of the given air-interface resource, and wherein identifying the given air-interface resource on which the access network is serving the WCD comprises identifying the given air-interface resource based on the indication.

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3. The method of claim 2, wherein the indication of the given air-interface resource is located in a header of the message.

4. The method of claim 3, wherein the header of the message comprises a general packet radio service tunneling protocol (GTP-U) extension header.

5. The method of claim 1, wherein the given air-interface resource comprises a given frequency band, wherein the one or more rules comprise a respective rule corresponding to each of one or more frequency bands, and wherein determining the one or more rules for decrementing the account balance associated with the WCD comprises matching the given frequency band with one of the one or more frequency bands.

6. The method of claim 1, wherein determining the one or more rules for decrementing the account balance associated with the WCD comprises using the given air-interface resource to obtain the one or more rules from a database of rules maintained by the gateway.

7. A method comprising:

at a gateway that provides connectivity between an access network and a transport network, receiving a message that was originated by a wireless communication device (WCD) being served by the access network;

the gateway identifying a given air-interface resource on which the access network is serving the WCD;

after receiving the message, the gateway using the given air-interface resource to determine one or more rules for decrementing an account balance associated with the WCD, wherein determining the one or more rules for decrementing the account balance associated with the WCD comprises (i) sending a request for the one or more rules to a policy charging and rules function (PCRF), wherein the request includes an indication of the given air-interface resource, and (ii) as a result of sending the request, receiving the one or more rules from the PCRF; and

the gateway decrementing the account balance associated with the WCD in accordance with the determined one or more rules.

8. The method of claim 1, further comprising:

the gateway detecting a change in the given air-interface resource on which the access network is serving the WCD from the given air-interface resource to a second air-interface resource; and

the gateway adjusting the one or more rules for decrementing the account balance of the WCD from a first set of rules associated with the given air-interface resource to a second set of rules associated with the second air-interface resource.

9. A method comprising:

at an access network, serving a wireless communication device (WCD) with telecommunication service, wherein the access network maintains an account balance associated with the WCD;

the access network identifying a given air-interface resource on which the access network is serving the WCD;

the access network using the given air-interface resource to determine one or more rules for decrementing the account balance associated with the WCD;

the access network decrementing the account balance associated with the WCD in accordance with the determined one or more rules;

the access network detecting a change in the given air-interface resource on which the access network is serv-

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ing the WCD from the given air-interface resource to a second air-interface resource; and

the access network adjusting the one or more rules for decrementing the account balance of the WCD from a first set of rules associated with the given air-interface resource to a second set of rules associated with the second air-interface resource.

10. The method of claim 9, wherein the given air-interface resource comprises a frequency band.

11. The method of claim 9, wherein the given air-interface resource comprises at least one frequency channel on which the access network is serving the WCD.

12. A gateway comprising:

a network communication interface configured to provide connectivity with an access network;

a processing unit;

data storage; and

program instructions stored in the data storage and executable by the processing unit to carry out functions comprising:

receiving a message that was originated by a wireless communication device (WCD) being served by the access network, wherein the message includes an indication of the given air-interface resource located in a header of the message;

identifying a given air-interface resource on which the access network is serving the WCD, wherein identifying the given air-interface resource on which the access network is serving the WCD comprises identifying the given air-interface resource based on the indication;

after receiving the message, using the given air-interface resource to determine one or more rules for decrementing an account balance associated with the WCD; and

decrementing the account balance associated with the WCD in accordance with the determined one or more rules.

13. The gateway of claim 12, wherein the given air-interface resource comprises a given frequency band, wherein the one or more rules comprise a respective rule corresponding to each of one or more frequency bands, and wherein determining the one or more rules for decrementing the account balance associated with the WCD comprises matching the given frequency band with one of the one or more frequency bands.

14. The gateway of claim 12, wherein determining the one or more rules for decrementing the account balance associated with the WCD comprises using the given air-interface resource to obtain the one or more rules from a database of rules maintained by the gateway.

15. The gateway of claim 12, wherein determining the one or more rules for decrementing the account balance associated with the WCD comprises:

sending a request for the one or more rules to a policy charging and rules function (PCRF), wherein the request includes an indication of the given air-interface resource; and

as a result of sending the request, receiving the one or more rules from the PCRF.

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