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(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(72) Inventors; and
(71) Applicants *(for US only)*: **XIE, Ling** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121- 1714 (US). **GUO, Jiming** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **SHAH, Chintan Shirish** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **SIVANADYAN, Thiagarajan** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(74) Agent: **LEE AND LI - LEAVEN IPR AGENCY LTD.**; Unit 2202, Tower A, Beijing Marriott Center, No. 7, Jian Guo Men South Avenue, Dongcheng District, Beijing 100005 (CN).

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(54) **Title:** COMPONENT CARRIER SELECTION FOR TUNE-AWAYS IN MOBILE COMMUNICATION DEVICES

(57) **Abstract:** Various embodiments include methods implemented on a mobile communication device for performing a tune-away from a first subscription to a second subscription on a mobile communication device, in which the first subscription includes a plurality of component carriers. The methods may include determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away, determining a quality measure for each component carrier in the subset of component carriers before or during the scheduled tune-away, selecting a component carrier in the subset of component carriers having the lowest quality measure, and tuning away from the selected component carrier to the second subscription during the scheduled tune-away.

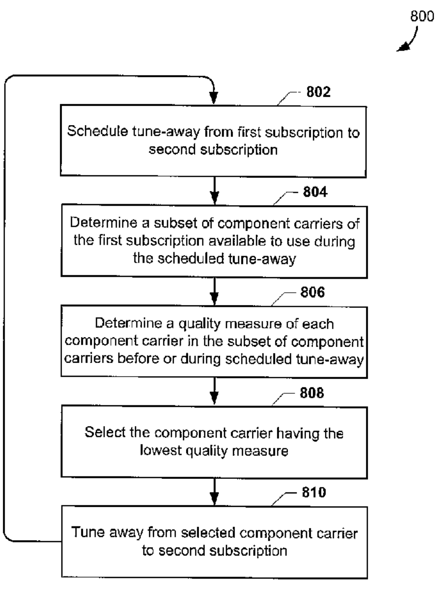

FIG. 8

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COMPONENT CARRIER SELECTION FOR TUNE-AWAYSIN MOBILE COMMUNICATION DEVICES

BACKGROUND

[0001] Some designs of mobile communication devices—such as smart phones, tablet computers, and laptop computers—contain one or more Subscriber Identity Module ("SIM') cards that provide users with access to multiple separate mobile telephony networks. Examples of mobile telephony networks include Third Generation (3G), Fourth Generation (4G), Long Term Evolution (LTE), Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Wideband CDMA (WCDMA), Time Division Synchronous CDMA (TD-SCDMA), Global System for Mobile Communications (GSM), Universal Mobile Telecommunications Systems (UMTS), evolved High Speed Packet Access (HSPA+), Dual-Cell High Speed Packet Access (DC-HSPA), Evolution Data-Optimized (EV-DO), Enhanced Data rates for GSM Evolution (EDGE), and single carrier Radio Transmission Technologies (lxRTT). A mobile communication device that includes one or more SIMs and connects to two or more separate mobile telephony networks using one or more shared radio frequency ("RF") resources/radios may be termed a multi-SIM mobile communication device. One example is a dual-SIM-dual-standby ("DSDS") communication device, which includes two SIM cards/subscriptions that are each associated with a separate radio access technology ("RAT"), and the separate RATs share one RF resource chain to communicate with two separate mobile telephony networks on behalf of their respective subscriptions. When one RAT is using the RF resource, the other RAT is in stand-by mode and is not able to communicate using the RF resource.

[0002] One consequence of having a plurality of RATs that maintain network connections is that the RATs may sometimes interfere with each other's communications. For example, two RATs on a DSDS communication device utilize a shared RF resource to communicate with their respective mobile telephony networks, and only one RAT may use the RF resource to communicate with the RAT's mobile network at a time. Even when a RAT is in an "idle-standby" mode, meaning that the RAT is not actively communicating with the network, the RAT may still need to periodically receive access to the shared RF resource in order to perform various network operations. For example, an idle RAT may need the shared RF resource at regular intervals to perform idle-mode operations to receive network paging messages in order to remain connected to the network, etc. on behalf of the RAT's subscription.

[0003] In conventional multi-SIM mobile communication devices, the RAT actively using an RF resource that is shared with an idle RAT may occasionally be forced to interrupt the active RAT's RF operations so that the idle RAT may use the shared RF resource to perform the idle RAT's idle-standby mode operations (e.g., paging monitoring and decoding, cell reselection, system information monitoring, etc.). This process of switching access of the shared RF resource from the active RAT to the idle RAT is sometimes referred to as a "tune-away," as the RF resource tunes away from the active RAT's frequency band or channel and tune to the idle RAT's frequency bands or channels. After the idle RAT has finished network communications, access to the RF resource may switch from the idle RAT to the active RAT via a "tune-back" operation.

[0004] Certain advanced RATs may have additional features. For example, an LTE mobile telephony network may be able to support more than one communications channel or transmit/receive chains using only one RF resource through carrier aggregation. A multi-SIM communication device may have an RF resource that supports a primary component carrier (PCC) and one or more secondary component carriers (SCC). The PCC may include an uplink carrier channel and a downlink carrier channel on a primary cell, and each SCC may be a downlink carrier channel on secondary cells. For example, a SIM with LTE category 6 ("CAT6") capability may include one PCC (uplink and downlink) and two SCCs, both used as downlink carriers, i.e., receive chains.

[0005] During a tune-away in such a device, the RF resource may select one of the SCC downlink or uplink component carriers of the LTE subscription to tune-away to the other subscription, which may be a GSM subscription or other 3G technologies. The selected SCC may not be able to receive data from the network during the tune-away. Currently the selection of which SCC to select in the tune-away to the other subscription does not take into account quality measures for the SCCs. For example, a first SCC of a LTE subscription may share a transceiver with a GSM subscription. The first SCC may have a higher downlink data throughput than a second SCC of the LTE subscription. However, because the first SCC shares a transceiver with the GSM subscription, the mobile communication device may by default tune away from the first SCC to the GSM subscription during a tune-away. This results in an overall lower data throughput on the LTE subscription during the tune-away because the SCC with the higher data throughput becomes unavailable during the tune-away.

SUMMARY

[0006] Various embodiments include methods implemented on a mobile communication device for performing a tune-away from a first subscription to a second subscription on a mobile communication device, in which the first subscription comprises a plurality of component carriers. Various embodiment methods may include determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away, determining a quality measure for each component carrier in the subset of component carriers before or during the scheduled tune-away, selecting a component carrier in the subset of component carriers having the lowest quality measure, and tuning away from the selected component carrier to the second subscription during the scheduled tune-away.

[0007] In some embodiments, the quality measure may include a historical data throughput before the scheduled tune-away. In such embodiments, the historical data throughput for a downlink component carrier may include a transport block size or a channel quality indicator while the historical data throughput for an uplink component carrier may include a transport block size or a modulation and coding scheme value.

[0008] In some embodiments, the quality measure may include a predicted data throughput during the scheduled tune-away. In such embodiments, the predicted data throughput for a downlink component carrier may be determined as SEj(k) * RBj (k) * (1 - ER_i) in which SEj (k) is a spectral efficiency of an ***i-th*** component carrier at sub-frame ***k,*** RBj (k) is a resource block size of the ***i-th*** component carrier at sub-frame ***k,*** and ERj is an error rate of the ***i-th*** component carrier. In such embodiments, the predicted data throughput for an uplink component carrier may be determined as instTBj (k) * (1 - ERj) in which instTBj (k) is an instant transport block size of an ***i-th*** component carrier at sub-frame ***k*** and ERj is an error rate of the ***i-th*** component carrier.

[0009] In some embodiments, determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away may include determining whether there are downlink component carriers in the plurality of component carriers that are not associated with any uplink component carriers, and selecting the downlink component carriers that are not associated with any uplink component carriers as the subset of component carriers in response to determining that there are downlink component carriers in the plurality of component carriers that are not associated with any uplink component carriers.

[0010] In some embodiments, determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away may include determining whether a transmitter and a receiver in the mobile communication device are bounded, and selecting the plurality of component carriers as the subset of component carriers in response to determining that the transmitter and the receiver in the mobile communication device are not bounded. In some embodiments, determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away may include determining whether data traffic on downlink component carriers in the plurality of component carriers is greater than data traffic on uplink component carriers in the plurality of component carriers, selecting the downlink component carriers as the subset of component carriers in response to determining that data traffic on the downlink component carriers is greater than data traffic on the uplink component carriers, and selecting the uplink component carriers as the subset of component carriers in response to determining that data traffic on the downlink component carriers is not greater than data traffic on the uplink component carriers.

[0011] In some embodiments, tuning away from the selected component carrier to the second subscription during the scheduled tune-away may include tuning away from both the selected component carrier and a component carrier associated with the selected component carrier during the scheduled tune-away.

[0012] Further embodiments include a mobile communication device including a processor configured with processor-executable instructions to perform operations of the embodiment methods described herein. Further embodiments include a non-transitory processor-readable storage medium having stored thereon processor-executable software instructions configured to cause a processor to perform operations of the embodiment methods described herein. Further embodiments include a mobile communication device that includes means for performing functions of the operations of the embodiment methods described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary aspects of the claims, and together with the general description and the detailed description given herein, serve to explain the features of the claims.

[0014] FIG. 1A is a communication system block diagram of a network suitable for use with various embodiments.

[0015] FIG. IB is system block diagram of an Evolved Packet System (EPS) suitable for use with various embodiments.

[0016] FIG. 2 is a block diagram illustrating a mobile communication device according to various embodiments.

[0017] FIG. 3 is a block diagram illustrating a communication subsystem in a mobile communication device according to various embodiments.

[0018] FIG. 4 is a timing diagram illustrating component carrier selection for tune-aways on a mobile communication device.

[0019] FIGS. 5A-5D are block diagrams illustrating configurations of component carriers of a subscription according to various embodiments.

[0020] FIG. 6 illustrates various quality measures for use in downlink component carrier selection for tune-aways on a mobile communication device according to various embodiments.

[0021] FIG. 7 illustrates various quality measures for use in uplink component carrier selection for tune-aways on a mobile communication device according to various embodiments.

[0022] FIG. 8 is a process flow diagram illustrating a method for performing a tune-away on a mobile communication device according to various embodiments.

[0023] FIG. 9 is a process flow diagram illustrating a method for determining a subset of component carriers available to use in a tune-away according to various embodiments.

[0024] FIG. 10 is a component diagram of an example mobile communication device suitable for use with various embodiments.

DETAILED DESCRIPTION

[0025] 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 claims.

[0026] As used herein, the terms "SIM," "SIM card," and "subscriber identification module" are used interchangeably to refer to a memory that may be an integrated circuit or embedded into a removable card, and that stores an International Mobile Subscriber Identity (IMSI), related key, and/or other information used to identify and/or authenticate a mobile communication device on a network and enable a communication service with the network. Because the information stored in a SIM enables the mobile communication device to establish a communication link for a particular communication service or services with a particular network, the term "SIM" is also be used herein as a shorthand reference to the communication service associated with and enabled by the information stored in a particular SIM as the SIM and the communication network, as well as the services and subscriptions supported by that network, correlate to one another. Similarly, the term SIM may also be used as a shorthand reference to the protocol stack and/or modem stack and communication processes used in establishing and conducting communication services with subscriptions and networks enabled by the information stored in a particular SIM.

[0027] As used herein, the terms "mobile communication device," "multi-SIM mobile communication device," "multi-SIM communication device," and "multi-SIM device" are used interchangeably to describe a mobile communication device that is configured with more than one SIM.

[0028] The terms "network," "wireless network," "cellular network," and "cellular wireless communication network" are used interchangeably herein to refer to a portion or all of a wireless network of a carrier associated with a mobile communication device and/or subscription on a mobile communication device.

[0029] Wireless communication networks are widely deployed to provide various communication services such as voice, packet data, broadcast, messaging, and so on. These wireless networks may be capable of supporting communications for multiple users by sharing the available network resources. Examples of such wireless networks include LTE, GSM, CDMA, TDMA, FDMA lxRTT, W-CDMA, CDMA2000, etc.

[0030] Modern mobile communication devices (e.g., smartphones) may each include one or more SIM cards containing SIMs that enable a user to connect to different mobile networks while using the same mobile communication device. Each SIM serves to identify and authenticate a subscriber using a particular mobile communication device, and each SIM is associated with only one subscription. For example, a SIM may be associated with a subscription to one of LTE, GSM, TD-SCDMA, CDMA2000, and WCDMA.

[0031] While specific receiver operations may be described herein with reference to a degree of two (i.e., two RF resources, two antennas, two RF chains, etc.), such references are used as example and are not meant to preclude embodiments using three or more RF resources. The terms "receiver" and/or "transmitter" may indicate an RF chain and/or portions of the RF receive chain in use for radio links. Such portions of the RF chain may include, without limitation, an RF front end, components of the RF front end (including a receiver unit and/or transmitter unit), antennas, etc. Portions of the RF chain may be integrated into a single chip, or distributed over multiple chips. Also, the RF resource, the RF chain, or portions of the RF chain may be integrated into a chip along with other functions of the mobile communication device. Further, in some embodiment wireless systems, the mobile communication device may be configured with more RF chains than spatial streams, thereby enabling receive and/or transmit diversity to improve signal quality.

[0032] A mobile communication device may have one RF resource that supports multiple SIMs. For example, in a dual-SIM-dual-standby (DSDS) device the mobile communication device supports two SIMs that share one RF resource. One SIM may support an advanced communications network such as an LTE subscription, while the other SIM may support a legacy communications network such as GSM, CDMA, or WCDMA. The RF resource may be capable of supporting carrier aggregation for the LTE subscription. That is, the LTE subscription may include a number of carriers, including a primary component carrier (PCC) and one or more secondary component carriers (SCC). The primary cell of the PCC includes a primary uplink and downlink carrier for the subscription, while the secondary cells of the SCCs may be used as additional receive chains (downlink carriers) or transmit chains (uplink carriers) in order to increase data throughput. The LTE subscription may support carrier aggregation in order to implement the multi-carrier communication features of the LTE subscription.

[0033] In mobile communication devices with multiple subscriptions sharing one RF resource, the RF resource may tune-away from an active subscription to the idle subscription so that the idle subscription can perform idle mode operations. For example, a mobile communication device with an active LTE subscription may periodically tune away to an idle GSM subscription. During a tune-away, one of the component carriers of the LTE subscription may be selected for the tune-away to the GSM subscription. The primary cell of the LTE subscription may still be active during the tune-away.

[0034] Each downlink or uplink component carrier may have associated quality measures that describe the data throughput capabilities of the component carrier at a certain period in time (e.g., sub-frames). One component carrier may have a higher quality measure than another component carrier during a scheduled tune-away. However, in conventional systems, the selection of the component carrier to use in the tune-away does not depend on any quality measures of the component carrier, but rather is based on certain default rules (e.g., the component carrier that shares the same transceiver as the other subscription, or alternating the selection between the component carriers). Thus, sometimes the component carrier that is selected for the tune-away may actually have a higher data throughput than other available component carriers. The component carrier with the lowest data throughput may be selected to use in the tune-away so that the overall data throughput of the carrier-aggregated subscription is maximized during the tune-away to another subscription.

[0035] Systems, methods, and devices of various embodiments enable a mobile communication device to select a component carrier for use in a tune-away based on quality measures of available component carriers, which may either be downlink carriers or uplink carriers. A mobile communication device processor may schedule a tune-away from a first subscription of the mobile communication device to a second subscription, in which the first subscription includes a plurality of downlink and uplink component carriers. For example, the first subscription may be capable of carrier aggregation, and thus have a PCC and two or more SCCs that may each include a downlink component carrier and/or an uplink component carrier.

[0036] The device processor may determine a subset of component carriers of the first subscription that are available to use in the scheduled tune-away (i.e., available to be given to the second subscription during the tune-away). The device processor may determine whether the first subscription has any downlink component carriers that are not associated with any uplink component carriers. For example, the first subscription may have a number of uplink and downlink component carriers, and some downlink component carriers may be associated with uplink component carriers while other downlink component carriers may not be associated with any uplink component carriers. Downlink component carriers that do not have any associated uplink component carriers may be included in the subset of component carriers of the first subscription that are available to use in the scheduled tune-away.

[0037] If each downlink component carrier is associated with an uplink component carrier, the device processor may determine whether the transmitter and receiver antennas of the RF resource are bounded. If the transmitter and receiver are not bounded together, the subset of component carriers available to use in the scheduled tune-away may include all downlink component carriers and uplink component carriers (if transmission during the tune-away is necessary) of the first subscription.

[0038] If the transmitter and receiver are bounded together, the device processor may determine whether the downlink data traffic of the first subscription is greater than the uplink data traffic. If the downlink data traffic is greater than the uplink data traffic, the subset of component carriers available to use in the scheduled tune-away may include all downlink component carriers of the first subscription because the downlink data traffic will be affected to a greater extent by the tune-away. If the uplink data traffic is greater than the downlink data traffic, the subset of component carriers available to use in the scheduled tune-away may include all uplink component carriers of the first subscription because the uplink data traffic will be affected to a greater extent by the tune-away.

[0039] The device processor may determine a quality measure for each of the component carriers in the subset of component carriers before or during the scheduled tune-away. The quality measure may be a historical data throughput of each component carrier before the scheduled tune-away, or a predicted data throughput of each component carrier during the scheduled tune-away. If the quality measure is historical data throughput of a downlink component carrier, the device processor may compare the transport block size of each downlink component carrier, in which a larger transport block size indicates a higher data throughput. If the transport block size of each downlink component carrier is equal, the device processor may compare the channel quality indicator (CQI) for each downlink component carrier, in which a larger CQI indicates a higher data throughput.

[0040] If the quality measure is a predicted data throughput of a downlink component carrier, the device processor may calculate the predicted data throughput as follows: SEj(k) * RBj (k) * (1 - ERj), in which SEj (k) is a spectral efficiency of an z-th downlink component carrier at sub-frame ***k*** (the sub-frame when the tune-away is scheduled), RBj (k) is a resource block size of an z-th downlink component carrier at sub-frame ***k,*** and ERj is an error rate of the z-th downlink component carrier. The error rate may either be a block error rate or a packet error rate.

[0041] If the quality measure is a historical data throughput of an uplink component carrier, the device processor may compare the transport block size of each uplink component carrier, in which a larger transport block size indicates a higher data throughput. If the transport block size of each uplink component carrier is equal, the device processor may compare a modulation and coding scheme (MCS) value for each uplink component carrier, in which a larger MCS value indicates a higher data throughput.

[0042] If the quality measure is a predicted data throughput of an uplink component carrier, the device processor may calculate the predicted data throughput as follows: instTBj (k) * (1 - ERj), in which instTBj (k) is an assigned instant transport block size of an z-th uplink component carrier at sub-frame ***k*** (the sub-frame when the tune-away is scheduled), and ERj is an error rate of the z-th uplink component carrier. The error rate may either be a block error rate or a packet error rate.

[0043] The device processor may tune away from the component carrier having the lowest quality measure to the second subscription during the scheduled tune-away. For example, when the first subscription includes first and second downlink carriers, the device processor may tune away from the second downlink carrier in response to determining that the quality measure of the first downlink carrier is higher than the quality measure of the second downlink carrier. Alternatively, the device processor may tune away from the first downlink carrier to the second subscription during the scheduled tune-away in response to determining that the quality measure of the first downlink carrier is not higher than the quality measure of the second downlink carrier. If the receiver and transmitter are bounded, both the selected component carrier and its associated component carrier (e.g., the downlink and uplink carriers of the same SCC) may be used to tune away to the second subscription. If the component carriers are not bounded but the second subscription will use both a downlink component carrier and an uplink component carrier during the tune-away, the device processor may make separate selections of a downlink component carrier and an uplink component carrier to give to the second subscription during the tune-away.

[0044] In the following descriptions of various embodiments, references made to a first subscription and a second subscription, and corresponding first carriers and second carriers. The references to the first and second subscriptions, or first and second carriers, are arbitrary and used merely for the purposes of describing the embodiments. The mobile communication device processor may assign any indicator, name or other designation to differentiate the subscriptions associated with one or more SIMs, and to differentiate the carriers used by a subscription. Further, embodiment methods apply the same regardless of which carrier channel, or receive chain, is being used to tune away from the high-speed (e.g., LTE) network. Further, while the high-speed network is referenced as an LTE network, various embodiments may be implemented for receiving data in any of a variety of high-speed networks (e.g., HSPA+, DC-HSPA, EV-DO, etc.).

[0045] Various embodiments may be implemented within a variety of communication systems, such as the example communication system 100 illustrated in FIG. 1A. The communication system 100 may include one or more mobile communication devices 102, a telephone network 104, and network servers 106 coupled to the telephone network 104 and to the Internet 108. In some embodiments, the network server 106 may be implemented as a server within the network infrastructure of the telephone network 104.

[0046] A typical telephone network 104 may include a plurality of cell base stations 110 coupled to a network operations center 112, which operates to connect voice and data calls between the mobile communication devices 102 (e.g., tablets, laptops, cellular phones, etc.) and other network destinations, such as via telephone land lines (e.g., a plain old telephone service (POTS) network, not shown) and the Internet 108. The telephone network 104 may also include one or more servers 116 coupled to or within the network operations center 112 that provide a connection to the Internet 108 and/or to the network servers 106. Communications between the mobile communication devices 102 and the telephone network 104 may be accomplished via two-way wireless communication links 114, such as GSM, UMTS, EDGE, 4G, 3G, CDMA, TD-SCDMA, TDMA, lxRTT, LTE, and/or other communication technologies.

[0047] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support one or more radio access technology, which may operate on one or more frequency (also referred to as a carrier, channel, frequency channel, etc.) in the given geographic area in order to avoid interference between wireless networks of different radio access technologies.

[0048] Upon power up, the mobile communication device 102 may search for wireless networks from which the mobile communication device 102 can receive communication service. In various embodiments, the mobile communication device 102 may be configured to prefer LTE networks when available by defining a priority list in which LTE frequencies occupy the highest spots. The mobile communication device 102 may perform registration processes on one of the identified networks (referred to as the serving network), and the mobile communication device 102 may operate in a connected mode to actively communicate with the serving network. Alternatively, the mobile communication device 102 may operate in an idle mode and camp on the serving network if active communication is not required by the mobile communication device 102. In the idle mode, the mobile communication device 102 may identify all radio access technologies in which the mobile communication device 102 is able to find a "suitable" cell in a normal scenario or an "acceptable" cell in an emergency scenario, as specified in the LTE standards, such as 3GPP TS 36.304 version 8.2.0 Release 8, entitled "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode."

[0049] The mobile communication device 102 may camp on a cell belonging to the RAT with the highest priority among all identified. The mobile communication device 102 may remain camped until either the control channel no longer satisfies a threshold signal strength or a cell of a higher priority RAT reaches the threshold signal strength. Such cell selection/reselection operations for the mobile communication device 102 in the idle mode are also described in 3GPP TS 36.304 version 8.2.0 Release 8.

[0050] FIG. IB illustrates a network architecture 150 that includes an Evolved Packet System (EPS). With reference to FIGS. 1A-1B, in the network architecture 150 to which the mobile communication device 102 may be connected to an LTE access network, for example, an Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) 152. In various embodiments, the E-UTRAN 152 may be a network of LTE base stations (i.e., eNodeBs) (e.g., 110 in FIG. 1A), which may be connected to one another via an X2 interface (e.g., backhaul) (not shown).

[0051] In various embodiments, each eNodeB 110 may provide to mobile communication devices an access point to an LTE core (e.g., an Evolved Packet Core). For example, the EPS in the network architecture 150 may further include an Evolved Packet Core (EPC) 154 to which the E-UTRAN 152 may connect. In various embodiments, the EPC 154 may include at least one Mobility Management Entity (MME) 162, a Serving Gateway (SGW) 160, and a Packet Data Network (PDN) Gateway (PGW) 163.

[0052] In various embodiments, the E-UTRAN 152 may connect to the EPC 154 by connecting to the SGW 160 and to the MME 162 within the EPC 154. The MME 162, which may also be logically connected to SGW 160, may handle tracking and paging of the mobile communication device 102 and security for E-UTRAN access on the EPC 154. The MME 162 may be linked to a Home Subscriber Server (HSS) 156, which may support a database containing user subscription, profile, and authentication information. Further, the MME 162 provides bearer and connection management for user Internet protocol (IP) packets, which are transferred through the SGW 160. In various embodiments, the SGW 160 may be connected to the PGW 163, which may provide IP address allocation to the mobile communication device 102, as well as other functions. The PGW 163 may be connected to the Operator's IP Services 158, which may include, for example, the Internet, an Intranet, an Internet protocol Multimedia Subsystem (IMS), a Packet switched Streaming Service (PSS), etc.

[0053] The network architecture 150 may also include circuit-switched (CS) and packet-switched (PS) networks. In some embodiments, the mobile communication device 102 may be connected to the CS and/or PS packet switched networks by connecting to a legacy 2G/3G access network 164, which may be one or more UTRAN, GSM EDGE Radio Access Network (GERAN), etc. In various embodiments, the 2G/3G access network 164 may include a network of base stations (e.g., base transceiver stations (BTSs), nodeBs, radio base stations (RBSs), etc.) (e.g., 110), as well as at least one base station controller (BSC) or radio network controller (RNC). In various embodiments, the 2G/3G access network 164 may connect to the circuit switched network via an interface with (or gateway to) a Mobile Switching Center (MSC) and associated Visitor Location Register (VLR), which may be implemented together as MSC/VLR 166. In the CS network, the MSC/VLR 166 may connect to a CS core 168, which may be connected to external networks (e.g., the public switched telephone network (PSTN)) through a Gateway MSC (GMSC) 170.

[0054] In various embodiments, the 2G/3G access network 164 may connect to the PS network via an interface with (or gateway to) a Serving GPRS support node (SGSN) 172, which may connect to a PS core 174. In the PS network, the PS core

174 may be connected to external PS networks, such as the Internet and the Operator's IP services 158 through a Gateway general packet radio service (GPRS) Support Node (GGSN) 176.

[0055] A number of techniques may be employed by LTE network operators to enable voice calls to the mobile communication device 102 when camped on the LTE network (e.g., EPS). The LTE network (e.g., EPS) may co-exist in mixed networks with the CS and PS networks, with the MME 162 serving the mobile communication device 102 for utilizing PS data services over the LTE network, the SGSN 172 serving the mobile communication device 102 for utilizing PS data services in non-LTE areas, and the MSC/VLR 166 serving the mobile communication device 102 for utilizing voice services. In various embodiments, the mobile communication device 102 may be able to use a single RF resource for both voice and LTE data services by implementing circuit-switched fallback (CSFB) to switch between accessing the E-UTRAN 152 and the legacy 2G/3G access network 164.

[0056] The mixed network may be enabled to facilitate CSFB via an interface between the MME 162 and the MSC/VLR 166. The interface enables the mobile communication device 102 to utilize a single RF resource to be both CS and PS registered while camped on the LTE network, which enables delivery CS pages via the E-UTRAN 152. A CS page may initiate the CSFB procedure, which may cause the mobile communication device to transition to the CS network and utilize the CS call setup procedures.

[0057] In various embodiments, modulation and multiple access schemes may be employed by a high speed access network (e.g., E-UTRAN 152), and may vary depending on the particular telecommunications standard being deployed. For example, in LTE applications, orthogonal frequency-division multiplexing (OFDM) may be used on the downlink, while single-carrier frequency-division multiple access (SC-FDMA) may be used on the uplink to support both frequency division duplexing (FDD) and time division duplexing (TDD). Those of ordinary skill in the art will appreciate that while various embodiments herein may be described with respect to LTE, such embodiments but may be extended to other telecommunication standards employing other modulation and multiple access techniques. By way of example, various embodiments may be extended EV-DO and/or Ultra Mobile Broadband (UMB), each of which are air interface standards promulgated by the 3rd Generation Partnership Project 2 (3GPP2) as part of the CDMA2000 family to provide broadband Internet access to mobile communication devices. Various embodiments may also be extended to Universal Terrestrial Radio Access (UTRA) employing WCDMA, GSM, Evolved UTRA (E-UTRA), UMB, Institute of Electrical and Electronics Engineers (IEEE) 802.1 1 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, and/or Flash-OFDM employing OFDM access (OFDMA). The actual wireless communication standard and the multiple access technology employed depend on the specific application and the overall design constraints imposed on the system.

[0058] In some embodiments, access network entities (e.g., eNodeBs) may have multiple antennas supporting multiple in multiple out (MIMO) technology, thereby enabling the eNodeBs to exploit the spatial domain to support spatial multiplexing, beamforming, and/or transmit diversity. Spatial multiplexing may be used to transmit different streams of data simultaneously on the same frequency. In some instances, the data steams may be transmitted to a single mobile communication device to increase the data rate, while in other instances the data streams may be transmitted to multiple mobile communication devices to increase the overall system capacity. Specifically, an eNodeB may spatially precode each data stream, and transmit each spatially precoded data stream through multiple transmit antennas on the downlink. The spatially precoded data streams may arrive at the one or more mobile communication device with different spatial signatures, enabling recovery of the one or more data streams destined for that device or antenna.

[0059] On the uplink, each mobile communication device may transmit a spatially precoded data stream, which enables the eNodeB to identify the source of each received data stream. In some embodiments, when channel conditions are unfavorable, beamforming may be used by the eNodeB to focus transmission energy in one or more directions. In various embodiments, beamforming may involve spatially precoding the data for transmission through multiple antennas. In some embodiments, to achieve good coverage at the edges of the cell, a single stream beamforming transmission may be used in combination with transmit diversity (e.g., sending the stream to the same source through multiple antennas).

[0060] Various embodiments may be implemented in LTE-Advanced wireless networks that have been deployed or that may be deployed in the future. LTE-Advanced communications typically use spectrum in up to 20 MHz bandwidths allocated in a carrier aggregation of up to a total of 100 MHz (5 component carriers) used for transmission in each direction. Such LTE-Advanced systems may utilize one or more of two types of carrier aggregation, non-continuous and continuous. Non-continuous carrier aggregation involves aggregating available component carriers (inter- or intra-band) that are separated in the frequency spectrum, while continuous carrier aggregation involves multiple available component carriers that are adjacent to each other. Both non-continuous and continuous carrier aggregation may aggregate multiple LTE/component carriers to serve a mobile communication device using the LTE-Advanced protocol.

[0061] FIG. 2 is a functional block diagram of an example multi-SIM communication device 200 that is suitable for implementing various embodiments. With reference to FIGS. 1A-2, the multi-SIM communication device 200 may be similar to one or more of the mobile communication devices 102. The multi-SIM communication device 200 may include a SIM interface 202, which may represent either one or two SIM interfaces. The SIM interface 202 may receive a first identity module SIM 204 that is associated with the first subscription. In some embodiments, the multi-SIM communication device 200 may also include a second SIM interface as part of the

SIM interface 202, which may receive a second identity module SIM 204 that is associated with a second subscription.

[0062] A SIM in various embodiments may be a Universal Integrated Circuit Card (UICC) that is configured with SIM and/or Universal SIM applications, enabling access to GSM and/or UMTS networks. The UICC may also provide storage for a phone book and other applications. Alternatively, in a CDMA network, a SIM may be a UICC removable user identity module (R-UIM) or a CDMA subscriber identity module (CSIM) on a card.

[0063] Each SIM 204 may have a central processing unit (CPU), read only memory (ROM), random access memory (RAM), electrically erasable programmable read only memory (EEPROM) and input/output (I/O) circuits. A SIM 204 used in various embodiments may contain user account information, an IMSI a set of SIM application toolkit (SAT) commands and storage space for phone book contacts. A SIM 204 may further store home identifiers (e.g., a System Identification Number (SID)/Network Identification Number (NID) pair, a Home Public Land Mobile Number (HPLMN) code, etc.) to indicate the SIM network operator provider. An Integrated Circuit Card Identity (ICCID) SIM serial number may be printed on the SIM card for identification.

[0064] The multi-SIM communication device 200 may include at least one controller, such as a general purpose processor 206, which may be coupled to a coder/decoder (CODEC) 208. The CODEC 208 may in turn be coupled to a speaker 210 and a microphone 212. The general purpose processor 206 may also be coupled to at least one memory 214. The memory 214 may be a non-transitory tangible computer readable storage medium that stores processor-executable instructions. For example, the instructions may include routing communication data relating to the first or second subscription though a corresponding baseband-RF resource chain. The memory 214 may store operating system (OS), as well as user application software and executable instructions. The memory 214 may also store quality measures for various carriers supported by the SIMs 204 and the RF resource 218.

[0065] The general purpose processor 206 and memory 214 may each be coupled to at least one baseband-modem processor 216. Each SIM 204 in the multi-SIM communication device 200 may be associated with a baseband-RF resource chain that includes a baseband-modem processor 216 and at least one receive block (e.g., RX1, RX2) of an RF resource 218. In various embodiments, baseband-RF resource chains may include physically or logically separate baseband modem processors (e.g., BB1, BB2).

[0066] The RF resource 218 may be coupled to antennas 220a, 220b, and may perform transmit/receive functions for the wireless services associated with each SIM 204 of the multi-SIM communication device 200. In some embodiments, the RF resource 218 may be coupled to wireless antennas 220a, 220b for sending and receiving RF signals for multiple SIMs 204 thereby enabling the multi-SIM communication device 200 to perform simultaneous communications with separate networks and/or service associated with the SIM(s) 204. The RF resource 218 may include separate receive and transmit functionalities, or may include a transceiver that combines transmitter and receiver functions. In various embodiments, the transmit functionalities of the resource 218 may be implemented by at least one transmit block (TX), which may represent circuitry associated with one or more radio access technologies/SIMs

[0067] In particular embodiments, the general purpose processor 206, memory 214, baseband-modem processors) 216, and RF resource 218 may be included in a system-on-chip device 222. The one or more SIMs 204 and corresponding interface(s) 202 may be external to the system-on-chip device 222. Further, various input and output devices may be coupled to components of the system-on-chip device 222, such as interfaces or controllers. Example user input components suitable for use in the multi-SIM communication device 200 may include, but are not limited to, a keypad 224 and a touch screen display 226.

[0068] In some embodiments, the keypad 224, touch screen display 226, microphone 212, or a combination thereof, may perform the function of receiving the request to initiate an outgoing call. For example, the touch screen display 226 may receive a selection of a contact from a contact list or receive a telephone number. In another example, either or both of the touch screen display 226 and microphone 212 may perform the function of receiving a request to initiate an outgoing call. For example, the touch screen display 226 may receive selection of a contact from a contact list or receive a telephone number. As another example, the request to initiate the outgoing call may be in the form of a voice command received via the microphone 212. Interfaces may be provided between the various software modules and functions in the multi-SIM communication device 200 to enable communication between them, as is known in the art.

[0069] The baseband-modem processor of a mobile communication device may be configured to execute software including at least one protocol stack associated with at least one SIM. SIMs and associated protocol stacks may be configured to support a variety of communication services that fulfill different user requirements. Further, a particular SIM may be provisioned with information to execute different signaling procedures for accessing a domain of the core network associated with these services and for handling data thereof.

[0070] In various embodiments, the RF resource 218 may be configured with receiver and transmitter circuitry to support multiple radio access technologies/wireless networks that operate according to different wireless communication protocols. Such circuitry may allow the RF resource 218 to process signals associated with different communication standards, and may include or provide connections to different sets of amplifiers, digital to analog converters, analog to digital converters, filters, voltage controlled oscillators (VCOs), etc. In some embodiments, a first receive block (RX1) and a transmit block (TX) may operate as a pair for transmission and reception of RF signals via a first antenna in accordance with a high-speed data network, such as an

LTE network. That is, various embodiments may include a first receive chain and a transmit chain that are each configured to primarily communicate with the LTE network. Further, a second receive block (RX2) may be coupled to a second antenna (i.e., forming a second receive chain), and may be configured to operate in cooperation with the transmit block and first receive block to provide dual receive capability (e.g., as used in MIMO reception). In various embodiments, the first and second receive blocks may be configured to utilize the same or different various radio receiver elements. For example, for MIMO communications, the first and second receive blocks may respectively use the first and second antennas to tune to and receive signals on the same LTE carrier frequency using a single VCO.

[0071] In some embodiments, the first and second receive blocks may respectively use the first and second antennas to tune to and receive signals on different carrier frequencies using separate VCOs. In some embodiments, a different carrier frequency may be an LTE carrier frequency in the same or in a different band, thereby providing support for an LTE wireless network that uses carrier aggregation to combine information transmitted on two or more carrier frequencies. In some embodiments in which two different carrier frequencies are received in a carrier aggregation mode, the first and second antennas may each be shared between the first and second receive blocks. In this manner, each antenna may be able to support two receive chains (i.e., one for each carrier frequency), thereby supporting antenna diversity on both carrier frequencies.

[0072] In other embodiments, the different carrier frequency may be a channel in another RAT (e.g., using a CDMA 2000 lx, UMTS, TD-SCDMA, lxRTT, GSM). In this manner, the additional receiver may achieve a downlink connection for a legacy network simultaneous to maintaining uplink and downlink communications on the LTE network. However, with only one receive chain allocated for LTE communication, MIMO communications is disabled for downlink communications on the LTE network. As a result the mobile communication device may provide a rank indicator (RI) value in a channel status report or to provide another signaling control message to the LTE wireless network indicating an inability to decode higher Modulation and Coding Scheme (MCS) downlink data.

[0073] FIG. 3 is a functional block diagram of an example communications subsystem 300 in a mobile communication device (such as multi-SIM communication device 200 in FIG. 2) that is suitable for implementing various embodiments. With reference to FIGS. 1A-3, the communications subsystem 300 may include a first SIM 302 and a second SIM 304. The first SIM 302 may be associated with a first subscription and a first RAT, such as LTE, that is capable of carrier aggregation and MIMO communication. The second SIM 304 may be associated with a second subscription and a second legacy RAT, such as GSM, CDMA, or WCDMA. The first SIM 302 and the second SIM 304 may be in communication with a modem processor 306. The modem processor 306 may be in communication with a first transceiver 308 and a second transceiver 310. The first transceiver 308 and the second transceiver 310 may be in communication with a RF front end 312, which may include one or more antennas used to communicate with mobile telephony networks.

[0074] The modem processor 306, the transceivers 308, 310, and the RF front end 312 may implement a number of uplink and downlink component carriers for subscriptions associated with the SIMs 302, 304. For example, the modem processor 306, the first transceiver 308, and the RF front end 312 may support a PCC 314 for the first SIM 302. The PCC 314 may include a primary uplink carrier Txl, a primary receive chain PRxl, and a diversity receive chain DRxl that is active when MIMO communication is enabled on the PCC 314. The modem processor 306, the first transceiver 308, and the RF front end 312 may also support a first SCC 316 for the first SIM 302. The first SCC 316 may operate as a downlink carrier with a primary receive chain PRx2 and a diversity receive chain DRx2 that is active when MIMO communication is enabled on the first SCC 316. The modem processor 306, the second transceiver 310, and the RF front end 312 may support a second SCC 318 for the first SIM 302. The second SCC 318 may operate as a downlink carrier with a primary receive chain PRx3 and a diversity receive chain DRx3 that is active when MIMO communication is enabled on the second SCC 318. Together, the PCC 314 and the SCCs 316, 318 form a first subscription 320 associated with the first SIM 302. In addition to downlink carriers, the first SCC 316 and the second SCC 318 may also have uplink carriers (not illustrated in the communications subsystem 300). The first subscription 320 may also have additional SCCs not illustrated the communications subsystem 300, and each SCC may include a downlink carrier and/or an uplink carrier.

[0075] The modem processor 306, the second transceiver 310, and the RF front end 312 may also support a second subscription 322 associated with the second SIM 304. The second subscription 322 may include an uplink carrier Tx Sub2. Resources for downlink communications by the second subscription 322 may be shared with one of the SCCs 316, 318 of the first subscription 320. For example, when the first subscription 320 is active, tune-aways to the second subscription 322 are occasionally conducted in order for the second subscription 322 to perform idle mode operations. The modem processor 306 may give RF resources assigned to the first SCC 316 to the second subscription 322 during a tune-away to the second subscription 322. Alternatively, the modem processor 306 may give RF resources assigned to the second SCC 318 to the second subscription 322 during a tune-away. The PCC 314 of the first subscription 320 may always be active, even during a tune-away from the first subscription 320 to the second subscription 322. The first subscription 320 may have additional downlink or uplink component carriers not illustrated in FIG. 3 that may be used in a tune-away to the second subscription 322.

[0076] FIG. 4 illustrates a timing diagram 400 for tune-aways performed on a mobile communication device. The mobile communication device may include a first subscription that is capable of carrier aggregation, for example a LTE subscription. The first subscription 420 may include a PCC uplink carrier 402, a PCC downlink carrier 404, a first SCC downlink carrier 406, and a second SCC downlink carrier 408.

The first subscription 420 may have additional uplink or downlink carriers not illustrated in the timing diagram 400. The second subscription 410 may be a legacy subscription, such as a GSM, CDMA, or WCDMA subscription.

[0077] When the first subscription 420 is active and the second subscription 410 is idle, each carrier of the first subscription 420 may be transmitting or receiving data. In particular, the first SCC 406 may be receiving data at a certain data throughput level 416. The second SCC 408 may initially be receiving data at a certain data throughput level 414a that is lower than the data throughput level 416 of the first SCC 406.

[0078] The mobile communication device may schedule a tune-away 412a from the first subscription 420 to the second subscription 410. During the tune-away 412a, the mobile communication device selects one of the SCCs 406, 408 of the first subscription 420 for the tune-away to the second subscription 410. In conventional systems, the selection conventionally does not take into account any quality measures for the SCCs 406 and 408, such as data throughput. Instead, the selection may be made using various default rules. For example, the mobile communication device may, as a default rule, select the second SCC 408 for the tune-away 412a (e.g., if the second SCC 408 and the second subscription 410 share a transceiver). During the tune-away 412a, the first SCC 406 is still active and receiving data at the data throughput level 416. The tune-away 412a may not significantly impact the overall data throughput of the first subscription 420 because the second SCC 408, which is now inactive, had a lower data throughput level 414a compared to the data throughput level 416 of the first SCC 406.

[0079] After the tune-away 412a ends, the data throughput of the second SCC 408 may increase to a new data throughput level 414b that is now higher than the data throughput level 416 of the first SCC 406. At a later time, the mobile communication device may schedule another tune-away 412b from the first subscription 420 to the second subscription 410. The mobile communication device may by default select the second SCC 408 for the tune-away 412b. However, during the tune-away 412b the overall data throughput of the first subscription 420 may be significantly impacted because the second SCC 408, which is now inactive, had a higher data throughput level 414b compared to the data throughput level 416 of the first SCC 406. The result is an inefficient method for selecting a component carrier of a carrier-aggregated subscription for use in a tune-away to another subscription. For example, the first SCC 406 may be used for the tune-away 412b rather than the second SCC 408 in order to maximize the overall data throughput of the first subscription 420.

[0080] Various embodiments resolve this inefficiency by selecting component carriers to use in a tune-away based various carrier link quality measures. The component carrier with the lowest quality measure during a scheduled tune-away is selected for the tune-away in order to minimize the impact on the active subscription during the tune-away. The quality measure used for the comparison may be a historical data throughput for each component carrier before the scheduled tune-away, or may be a predicted data throughput for each component carrier during the scheduled tune-away.

[0081] FIGS. 5A-5D illustrates block diagrams of various configurations of component carriers for a subscription in a mobile communication device according to various embodiments. With reference to FIGS. 1A-3 and 5A-5D, the subscription may be capable of carrier aggregation, such as the first subscriptions 320 (or 420 in FIG. 4). One or more of the component carriers of the subscription may be given to another subscription during a tune-away. A configuration 500 (FIG. 5A) for a subscription may include a PCC with an uplink component carrier, a downlink component carrier and four SCCs, numbered one through four, each with a downlink and uplink component carrier. In the configuration 500, all of the uplink component carriers are associated with the PCC downlink component carrier. Communication grants for all of the uplink component carriers may be included in the physical downlink control channel (PDCCH) for the PCC.

[0082] The configuration 500 may enable cross-carrier scheduling, in which the resources are scheduled on a different carrier as the grant is received. This allows a mobile communication device to balance loads across available component carriers. If the configuration 500 does not enable cross-carrier scheduling, data is transmitted only on the carrier to which the data is assigned. In the configuration 500, the transmitter antenna and receiver antenna may be bounded (i.e., the transmitter and antenna are utilized by the same SCC). If the transmitter and receiver are bounded, then both the uplink and downlink component carriers of the same SCC are given to another subscription during a tune-away. For a bounded RF resource, the mobile communication device may determine whether the uplink data traffic or the downlink data traffic on the mobile communication device is heavier, and select an SCC to give to the other subscription by looking at the quality measure of all of the downlink component carriers (if the downlink data traffic is heavier) or the quality measure of all of the uplink component carriers (if the uplink data traffic is heavier). If the transmitter and receiver are not bounded, then a downlink component carrier of one SCC may be given to another subscription during a tune-away, and an uplink component carrier of another SCC may be given to the other subscription if necessary. Thus, a mobile communication device may make the downlink and uplink selections separately.

[0083] In configuration 510, in each uplink component carrier is associated with a separate downlink component carrier with cross-carrier scheduling enabled. The cross-carrier scheduling may be conducted using the PCC PDCCH. In this case, uplink and downlink grants may be included in the PCC PDCCH. The transmitter and receiver antennas may be bounded or unbounded. If the transmitter and antenna are bounded, then both the uplink and downlink component carriers of the same SCC are given to another subscription during a tune-away. The mobile communication device may determine whether the uplink data traffic or the downlink data traffic on the mobile communication device is heavier, and then select a SCC to give to the other subscription by looking at the quality measure of all of the downlink component carriers (if the downlink data traffic is heavier) or the quality measure of all the uplink component carriers (if the uplink data traffic is heavier). If the transmitter and receiver are not bounded, then a downlink component carrier of one SCC may be given to another subscription during a tune-away, and an uplink component carrier of another SCC may be given to the other subscription if necessary.

[0084] In configuration 520, some downlink component carriers (e.g., downlink carriers for PCC and SCC2) may be associated with certain uplink component carriers while other downlink component carriers (e.g., downlink carriers for SCC1, SCC3, and SCC4) may not be associated with any uplink component carriers. In this case, the mobile communication device may select from only the unassociated downlink component carriers for a tune-away to another subscription so that none of the uplink component carriers are affected during the tune-away. For example, the mobile communication device may determine the quality measures for the downlink carriers of SCC1, SCC3, and SCC4 and select the carrier with the lowest quality measure to use in the tune-away. If only one downlink component carrier is unassociated, that carrier may always be selected for the tune-away.

[0085] In configuration 530, each uplink component carrier is associated with a separate downlink component carrier with no cross-carrier scheduling enabled. In this case, the uplink and downlink grants may be included in the PDCCH of each downlink component carrier. In the configuration 530, both the downlink and uplink component carriers of a SCC are given to another subscription during a tune-away. The mobile communication device may determine whether the uplink data traffic or the downlink data traffic on the mobile communication device is heavier, and select a SCC to give to the other subscription by looking at the quality measure of all of the downlink component carriers (if the downlink data traffic is heavier) or the quality measure of all of the uplink component carriers (if the uplink data traffic is heavier).

[0086] FIG. 6 illustrates a table 600 listing a number of measureable or determinable values that may be considered or used to calculate the quality measure for a downlink component carrier during a scheduled tune-away from the component carrier to another subscription. With reference to FIGS. 1A-3 and 5A-6, the measureable or determinable values in the table 600 may be indicative of historical or predicted data throughput of a downlink component carrier during the scheduled tune-away. The table 600 may include measureable or determinable values for a first SCC downlink carrier 602 and a second SCC downlink carrier 604 of a subscription in a mobile communication device (e.g., the mobile communication device 200) with carrier aggregation. The mobile communication device may have additional downlink or uplink carriers not shown in the table 600. The data shown in the table 600 may be stored in memory (e.g., the memory 214) on the mobile communication device. The data shown in the table 600 may be stored in any form and in various locations in memory, and is not limited to table form.

[0087] An example of a measureable or determinable value that may be used to calculate a quality measure for the downlink carriers 602, 604 is a channel quality indicator (CQI) value 606. The CQI value 606 may be expressed as CQIj(k), in which *i* represents the *i-th* component carrier (e.g., *i = l* for the first downlink carrier 602 and *i = 2* for the second downlink carrier 604), and *k* represents the sub-frame during which the tune-away occurs. The CQI value 606 may be a number ranging from zero to fifteen (0-15) that indicates the quality of the component carrier, with a value of zero indicating the lowest level of quality and a value of 15 indicating the highest level of quality. The CQI value 606 may be calculated by the mobile communication device periodically or in response to certain events, and may be reported to the network. The CQI value 606 may be indicative of the historical data throughput of a component carrier before sub-frame *k*.

[0088] Another example of a measureable or determinable value that may be used to calculate a quality measure for the downlink carriers 602, 604 is a downlink transport block (TB) size value 608. The TB size value 608 may be expressed as TBj(k), in which *i* represents the *i-th* component carrier and *k* represents the sub-frame during which the tune-away occurs. The TB size value represents the data size of the allocated payload in the physical layer of the mobile communication device. The mobile communication device may usually store a total instant TB size value TB(k) that represents the instant transport block size scheduled in sub-frame $\boldsymbol{k}$ using a cyclic redundancy check (CRC) pass decoding result. The TB size value 608 for a specific component carrier $TB_i(k)$ may be a filtered or averaged metric derived from the total instant TB size value TB(k) that may be determined as:

$$\boldsymbol{TB_i(k) = \alpha * TB(k) + (1 - \alpha)TBi(k - 1)}$$

in which **a** is a filter coefficient that denotes the weight of the total instant TB size value TB(k) in the calculation of $TB_i(k)$. The range of **a** may be between zero and one, and the value may be selected based on a number of factors such as channel condition and mobility. A smaller value for **a** indicates a smaller contribution from the total instant TB size value TB(k) and vice versa. The TB size value 608 may be indicative of the historical data throughput of a component carrier before sub-frame $\boldsymbol{k}$.

[0089] A mobile communication device may utilize the CQI value 606 and/or the TB size value 608 as quality measures indicative of historical data throughput for a downlink component carrier before a scheduled tune-away at sub-frame $\boldsymbol{k}$. For example, the mobile communication device may compare the TB size value TB^k) for the first downlink carrier 602 to the TB size value $TB_2(k)$ for the second downlink carrier 604 for the sub-frame $\boldsymbol{k}$ in which the tune-away occurs. A higher TB size value is indicative of higher data throughput and thus a higher quality measure. Whichever component carrier has the lowest TB size value may be selected for use in a tune-away to another subscription.

[0090] If the TB size value 608 for both component carriers are equal (i.e., TB^k) = $TB_2(k)$), the mobile communication device may compare the CQI value CQI^k) for the first downlink carrier 602 to the CQI value $CQI_2(k)$ for the second downlink carrier 604 for the sub-frame $\boldsymbol{k}$ in which the tune-away occurs. A higher CQI value is indicative of higher data throughput and thus a higher quality measure.

Whichever component carrier has the lowest CQI value may be selected for use in a tune-away to another subscription.

[0091] Another example of a measureable or determinable value that may be used to calculate a quality measure for the downlink carriers 602, 604 is a downlink resource block (RB) size value 610. The RB size value 610 may be expressed as RBi(k), in which *i* represents the *i-th* component carrier and *k* represents the sub-frame during which the tune-away occurs. The RB size value 610 may represent the number of resource blocks (resources represented in a time-frequency grid) that a network allocates to the mobile communication device. The mobile communication device may usually store a total instant RB size value RB(k) that represents the instant resource block size scheduled in sub-frame *k* using a cyclic redundancy check (CRC) pass decoding result. The RB size value 610 for a specific component carrier $RB_i(k)$ may be a filtered or averaged metric derived from the total instant RB size value RB(k) that may be determined as:

$$RB_i(k) = \alpha * RB(k) + (1 - \alpha)RB_i(k - 1)$$

in which a is a filter coefficient that denotes the weight of the total instant RB size value RB(k) in the calculation of RBi(k). The range of a may be between zero and one, and the value may be selected based on a number of factors such as channel condition and mobility. A smaller value for a indicates a smaller contribution from the total instant RB size value RB(k) and vice versa.. The RB size value 610 may be indicative of the predicted data throughput of a component carrier during a scheduled tune-away in sub-frame *k*.

[0092] Another example of a measureable or determinable value that may be used to calculate a quality measure for the downlink carriers 602, 604 is a block error rate (BLER) 612. The BLER 612 may be expressed as $BLER_i$ which represents the block error rate for the *i-th* component carrier. The BLER 612 may represent how successful a data transmission is at the transport block level. The BLER 612 may be defined as the ratio of the number of erroneous transport blocks received to the total number of transport blocks sent and may be determined by the mobile communication device using test transport blocks sent by the network. The BLER 612 may be indicative of the predicted data throughput of a component carrier during a scheduled tune-away in sub-frame ***k*.**

[0093] Another example of a measureable or determinable value that may be used to calculate a quality measure for the downlink carriers 602, 604 is a packet error rate (PER) 614. The PER 614 may be expressed as PERj which represents the packet error rate for the ***i-t*h** component carrier. The PER 614 may represent how successful a data transmission is at the packet level. The PER 614 may be defined as the ratio of the number of erroneous packets received to the total number of packets sent and may be determined by the mobile communication device using test packets sent from the network. The PER 614 may be indicative of the predicted data throughput of a component carrier during a scheduled tune-away in sub-frame ***k*.**

[0094] Another example of a measureable or determinable value that may be used to calculate a quality measure for the downlink carriers 602, 604 is a spectral efficiency (SE) value 616. The SE value 616 may be expressed as SEj(k), in which ***i*** represents the z-th component carrier and ***k*** represents the sub-frame during which the tune-away occurs. The SE value 616 may represent the information rate that can be transmitted over a given bandwidth in a specific communication system and may be a measure of how efficiently a frequency spectrum is utilized by the physical layer or medium access control (MAC) layer protocol. The SE value 616 may be measured in bits/second/Hertz. The SE value 616 may be associated with the CQI value 606 such that each CQI value may have an associated SE value. The SE value 616 may be indicative of the predicted data throughput of a component carrier during a scheduled tune-away in sub-frame ***k*.**

[0095] A mobile communication device may utilize the RB size value 610, the SE value 616, and either the BLER 612 or the PER 614 to calculate quality measures indicative of predicted data throughput for a downlink component carrier during a scheduled tune-away during sub-frame ***k***. For example, the mobile communication device may calculate the predicted data throughput for a downlink component carrier as follows:

$$T_i(k) = SE_i(k) * RB_i(k) * (1 - ER_i)$$

in which Tj(k) is the predicted data throughput for an ***i-th*** component carrier during a tune-away scheduled in sub-frame ***k***, SEj (k) is the spectral efficiency of the ***i-th*** component carrier at sub-frame ***k***, RBj (k) is the resource block size of the ***i-th*** component carrier at sub-frame ***k***, and ERj is the error rate of the ***i-th*** component carrier. The ERj value may either be the BLER 612 or the PER 614. Whichever downlink component carrier has the lowest Tj(k) may be selected for use in a tune-away to another subscription.

[0096] Thus, a mobile communication device may utilize the CQI value 606 and/or the TB size value 608 to determine a historical data throughput for a downlink component carrier, or may utilize the RB value 610, the SE value 616, and either the BLER 612 or the PER 614 to determine a predicted data throughput for a downlink component carrier. These data throughput calculations may be used by the mobile communication device to select a downlink component carrier to use in a tune-away to another subscription.

[0097] FIG. 7 illustrates a table 700 listing a number of measureable or determinable values that may be considered or used to calculate the quality measure for an uplink component carrier during a scheduled tune-away from the component carrier to another subscription. With reference to FIGS. 1A-3 and 5A-7, the values in the table 700 may be indicative of historical or predicted data throughput of an uplink component carrier during the scheduled tune-away. The table 700 may include values for a first SCC uplink carrier 702 and a second SCC uplink carrier 704 of a subscription in a mobile communication device (e.g., the mobile communication device 200) with carrier aggregation. The mobile communication device may have additional downlink or uplink carriers not shown in the table 700. The data shown in the table 700 may be stored in memory (e.g., the memory 214) on the mobile communication device. The data shown in the table 700 may be stored in any form and in various locations in memory, and is not limited to table form.

[0098] An example of a measureable or determinable value that may be used to calculate a quality measure for the uplink carriers 702, 704 is a modulation and coding scheme (MCS) value 706. The MCS value 706 may be expressed as MCSi(k), in which *i* represents the *i-th* component carrier (e.g., *i = l* for the first uplink carrier 702 and *i = 2* for the second uplink carrier 704), and *k* represents the sub-frame during which the tune-away occurs. The MCS value 706 may be a number that corresponds to various modulation and coding schemes assigned by a network to the component carrier. Different MCSs may have different associated data throughputs, and a higher MCS value may indicate higher data throughput allowed by the scheme. The MCS value 706 may be obtained from the network. The MCS value 706 may be indicative of the historical data throughput of an uplink component carrier before sub-frame *k*.

[0099] Another example of a measureable or determinable value that may be used to calculate a quality measure for the uplink carriers 702, 704 is an uplink transport block (TB) size value 708. The TB size value 708 may be expressed as $TB_i(k)$, in which *i* represents the *i-th* component carrier and *k* represents the sub-frame during which the tune-away occurs. As with the TB value 608 for downlink carriers, the TB size value 708 represents the data size of the allocated payload in the physical layer of the mobile communication device. The mobile communication device may usually store a total instant TB size value TB(k) that represents the instant transport block size scheduled in sub-frame *k* using a cyclic redundancy check (CRC) pass decoding result. The TB size value 708 for a specific component carrier $TB_i(k)$ may be a filtered or averaged metric derived from the total instant TB size value of the i-th component carrier ***instTBi(k)*** that may be determined as:

$$TB_i(k) = \alpha * instTB_i(k) + (1 - \alpha)TBi(k - 1)$$

in which **a** is a filter coefficient that denotes the weight of the total instant TB size value *instTBi(k)* in the calculation of TBi(k). The range of **a** may be between zero and one, and the value may be selected based on a number of factors such as channel condition and mobility. A smaller value for **a** indicates a smaller contribution from the total instant TB size value *instTBi(k)* and vice versa. The TB size value 708 may be indicative of the historical data throughput of a component carrier before sub-frame k.

[00100] A mobile communication device may utilize the MCS value 706 and/or the TB size value 708 as quality measures indicative of historical data throughput for an uplink component carrier before a scheduled tune-away at sub-frame ***k***. For example, the mobile communication device may compare the TB size value TB^k) for the first uplink carrier 702 to the TB size value $TB_2(k)$ for the second uplink carrier 704 for the sub-frame ***k*** in which the tune-away occurs. A higher TB size value is indicative of higher data throughput and thus a higher quality measure. Whichever component carrier has the lowest TB size value may be selected for use in a tune-away to another subscription.

[00101] If the TB size values 708 for both component carriers are equal (i.e., TB^k) = $TB_2(k)$), the mobile communication device may compare the MCS value MCSi(k) for the first uplink carrier 702 to the MCS value $MCS_2(k)$ for the second uplink carrier 704 for the sub-frame ***k*** in which the tune-away occurs. A higher MCS value is indicative of higher data throughput and thus a higher quality measure. Whichever component carrier has the lowest MCS value may be selected for use in a tune-away to another subscription.

[00102] Another example of a measureable or determinable value that may be used to calculate a quality measure for the uplink carriers 702, 704 is an uplink instant transport block (TB) size value 710. The instant TB size value 710 may be expressed as instTBi(k), in which ***i*** represents the ***i-th*** component carrier and ***k*** represents the sub-frame during which the tune-away occurs. Unlike the TB size value 708, the instant TB size value 710 is based on the instant TB size assigned by the network to the uplink component carrier. The instant TB size value 710 may be indicative of the predicted data throughput of a component carrier before sub-frame k.

[00103] Another example of a measureable or determinable value that may be used to calculate a quality measure for the uplink carriers 702, 704 is a block error rate (BLER) 712. The BLER 712 may be expressed as BLERj which represents the block error rate for the i-th component carrier. The BLER 712 may represent how successful a data transmission is at the transport block level. The BLER 712 may be defined as the ratio of the number of erroneous transport blocks received to the total number of transport blocks sent and may be determined using test transport blocks sent to the network. The BLER 712 may be indicative of the predicted data throughput of a component carrier during a scheduled tune-away in sub-frame k.

[00104] Another example of a measureable or determinable value that may be used to calculate a quality measure for the uplink carriers 702, 704 is a packet error rate (PER) 714. The PER 714 may be expressed as PERj which represents the packet error rate for the z-th component carrier. The PER 714 may represent how successful a data transmission is at the packet level. The PER 714 may be defined as the ratio of the number of erroneous packets received to the total number of packets sent and may be determined using test packets sent to the network. The PER 714 may be indicative of the predicted data throughput of a component carrier during a scheduled tune-away in sub-frame k.

[00105] A mobile communication device may utilize the instant TB value 710 and either the BLER 712 or the PER 714 to calculate quality measures indicative of predicted data throughput for an uplink component carrier during a scheduled tune-away during sub-frame k. For example, the mobile communication device may calculate the predicted data throughput for an uplink component carrier as follows:

$$T_i(k) = instTB_i(k) * (1 - ER_i)$$

in which Ti(k) is the predicted data throughput for an z-th component carrier during a tune-away scheduled in sub-frame ***k,*** instTBj (k) is the instant transport block size of the z-th component carrier at sub-frame ***k,*** and ERj is the error rate of the z-th component carrier. The ERj value may either be the BLER 712 or the PER 714. Whichever uplink component carrier has the lowest Tj(k) may be selected for use in a tune-away to another subscription.

[00106] Thus, a mobile communication device may utilize the MCS value 706 and/or the TB size value 708 to determine a historical data throughput for an uplink component carrier, or may utilize the instant TB size value 710 and either the BLER 712 or the PER 714 to determine a predicted data throughput for an uplink component carrier. These data throughput calculations may be used by the mobile communication device to select an uplink component carrier to use in a tune-away to another subscription.

[00107] FIG. 8 illustrates a method 800 for performing a tune-away on a mobile communication device according to various embodiments. With reference to FIGS. 1A-3 and 5A-8, the operations of the method 800 may be implemented by one or more processors of the mobile communication device 200, such as a general purpose processor 206, a baseband modem processor(s) 216, or a separate controller (not shown) that may be coupled to the memory 214 and to the baseband modem processor(s) 216.

[00108] In block 802, the device processor may schedule a tune-away from a first subscription of the mobile communication device to a second subscription. The first subscription may be capable of carrier aggregation and thus may support a PCC and a plurality of additional downlink or uplink component carriers (e.g., two SCCs). For example, the first subscription may communicate over a LTE RAT capable of carrier aggregation. The second subscription may communicate over a legacy RAT such as GSM, CDMA, or WCDMA. The first and second subscriptions may share a RF resource on the mobile communication device (e.g., a DSDS device). The first subscription may be the active subscription, and the scheduled tune-away allows the idle second subscription to perform idle mode operations. The RF resources of one of the component carriers of the first subscription may be given to the second subscription during the tune-away, and the selected component carrier loses the secondary cell connection during the tune-away.

[00109] In block 804, the device processor may determine a subset of component carriers of the first subscription that are available to use during the scheduled tune-way. The downlink or uplink component carriers that are available to use during the tune-away may depend on the configuration of the first subscription, such as the configurations 500, 510, 520, and 530 as described. For example, the subset of component carriers that may be given to the second subscription may depend on whether one or more downlink component carriers are associated with one or more uplink component carriers, whether cross-carrier scheduling is enabled, and whether the transmitter and receiver of the RF resource are bounded or unbounded. More detail on the selection of the subset of component carriers is described (e.g., with reference to FIG. 9).

[00110] In block 806, the device processor may determine a quality measure of each of the component carriers in the subset of component carriers at or near the time of the scheduled tune-away. The quality measure may either be a historical data throughput for each component carrier before the scheduled tune-away, or a predicted data throughput for each component carrier during the scheduled tune-away. The quality measure utilized may also depend on whether the device processor is comparing downlink or uplink component carriers. The historical data throughput for a downlink component carrier may be represented either by a CQI value or a TB size value that is calculated for each downlink component carrier. The historical data throughput for an uplink component carrier may be represented either by a MCS value or a TB size value that is calculated for each uplink component carrier.

[00111] The predicted data throughput for a downlink component carrier may be represented as:

$$Ti(k) = SEi(k) * RBi(k) * (1 - ER_t)$$

in which Tj(k) is the predicted data throughput for an ***i-th*** component carrier during a tune-away scheduled in sub-frame ***k***, SEj (k) is the spectral efficiency of the ***i-th*** component carrier at sub-frame ***k***, RBj (k) is the resource block size of the ***i-th*** component carrier at sub-frame ***k***, and ERj is the error rate of the ***i-th*** component carrier. The ERj value may either be the block error rate or the packet error rate.

[00112] The predicted data throughput for an uplink component carrier may be represented as:

$$Ti(k) = instTBiik) * (1 - ER_i)$$

in which Ti(k) is the predicted data throughput for an ***i-th*** component carrier during a tune-away scheduled in sub-frame ***k***, instTBi (k) is the instant transport block size of the ***i-th*** component carrier at sub-frame ***k***, and ER_i is the error rate of the ***i-th*** component carrier. The ERj value may either be the block error rate or the packet error rate.

[00113] In block 808, the device processor may select the component carrier having the lowest quality measure. If the quality measure is a historical data throughput of a downlink component carrier, the device processor may compare the CQI value or TB size value for each downlink component carrier and select the downlink component carrier that has the lowest CQI value or TB size value. In some embodiments, the device processor may compare the TB size values for each downlink component carrier first, and then compare the CQI value for each downlink component carrier if the TB size values for both carriers are equal. If the quality measure is a historical data throughput of an uplink component carrier, the device processor may compare the MCS value or TB size value for each uplink component carrier and select the uplink component carrier that has the lowest MCS value or TB size value. In some

embodiments, the device processor may compare the TB size values for each uplink component carrier first, and then compare the MCS value for each uplink component carrier if the TB size values for both carriers are equal. If the quality measure is a predicted data throughput for a downlink or uplink component carrier, the device processor may compare the calculated $T_i(k)$ value for each component carrier and select the component carrier that has the lowest $T_i(k)$ value.

[00114] The device processor may tune away from the selected component carrier to the second subscription during the scheduled tune-away, in block 810. For example, if the first subscription includes a first downlink carrier and a second downlink carrier, the device processor may select the downlink carrier with the lower quality measure and tune away from the selected downlink carrier to the second subscription. This preserves a higher overall data throughput on the first subscription during the scheduled tune-away. If the transmitter and receiver of the RF resource are bounded, then any component carriers associated with the selected component carrier are also given to the second subscription during the tune-away. For example, if a selected downlink component carrier is associated with an uplink component carrier, the device process may tune away from both the downlink and uplink component carriers to the second subscription. If the transmitter and receiver of the RF resource are not bounded, the device processor may select a downlink component carrier and an unassociated uplink component carrier (if necessary) for the tune-away to the second subscription. If there is only one component carrier in the subset of component carriers, that carrier may be automatically selected for the tune-away.

[00115] If the quality measures for all component carriers are equal, the device processor may select a default component carrier for use in the scheduled tune-away. In this manner, the method 800 may maximize the overall data throughput of a first subscription when the RF resources of one component carrier of the first subscription are given to a second subscription during a tune-away.

[00116] The method 800 may be extendable to any number of downlink or uplink component carriers supported by the first subscription. Further, the method 800 may be repeated in a loop so that tune-aways are performed from the carrier with the lowest quality measure as the carrier link conditions vary (e.g., as the mobile communication device moves).

[00117] FIG. 9 illustrates a method 900 for determining a subset of component carriers available to use in a tune-away according to various embodiments. With reference to FIGS. 1A-3 and 5A-9, the operations of the method 900 may be implemented by one or more processors of the mobile communication device 200, such as a general purpose processor 206, a baseband modem processor(s) 216, or a separate controller (not shown) that may be coupled to the memory 214 and to the baseband modem processor(s) 216.

[00118] The device processor may perform the method 900 when determining a subset of component carriers of a first subscription that are available to use in a tune-away to a second subscription in the mobile communication device (i.e., block 804 in the method 800). In determination block 902, the device processor may determine whether there are any downlink component carriers in the first subscription that are not associated with any uplink component carriers. Some downlink component carriers in the first subscription may be associated with one or more uplink component carriers. However, if a downlink component carrier is not associated with any uplink component carriers, then selecting such a carrier for a tune-away would not have any effect on the uplink capabilities of the first subscription during the tune-away. Thus, unassociated downlink component carriers may be used for the tune-away.

[00119] In response to determining that at least one downlink component carrier is not associated with any uplink component carriers (i.e., determination block 902 = "Yes"), the device processor may include all downlink component carriers not associated with any uplink component carriers in the subset of component carriers, in block 904. The device processor may then calculate a quality measure for each component carrier in the subset of component carriers, in block 806 of the method 800.

[00120] In response to determining that all downlink component carriers are associated with at least one uplink component carrier (i.e., determination block 902 = "No"), the device processor may determine whether the receiver and transmitter antennas of the RF resource in the mobile communication device are bounded, in determination block 906. When the receiver and transmitter are bounded, both the uplink and downlink component carriers of the same SCC are given to another subscription during a tune-away. If the transmitter and antenna are not bounded, a downlink component carrier of one SCC may be given the second subscription during the tune-away, and an uplink component carrier of another SCC may be given to the second subscription if necessary. Thus, device processor may make the quality measure selection for the downlink and uplink carriers separately.

[00121] In response to determining that the receiver and the transmitter antennas are not bounded (i.e., determination block 906 = "No"), the device processor may include all component carriers, both downlink and uplink, of the first subscription to the subset of component carriers, in block 908. If the second subscription does not need to transmit data during the tune-away, the uplink component carriers may not need to be added to the subset of component carriers. The device processor may then calculate a quality measure for each downlink component carrier (and uplink component carrier, if necessary) in the subset of component carriers, in block 806 of the method 800.

[00122] In response to determining that the receiver and the transmitter antennas are bounded (i.e., determination block 906 = "Yes"), the device processor may determine whether the downlink data traffic is greater than the uplink data traffic on the first subscription, in determination block 910.

[00123] In response to determining that the downlink data traffic is not greater than the uplink data traffic (i.e., determination block 910 = "No"), the device processor may include all uplink component carriers of the first subscription in the subset of component carriers, in block 912. For example, if the first subscription is transmitting more data than it is receiving, the tune-away would affect the uplink data traffic more than the downlink data traffic. In this case, the selection of a component carrier to use in the tune-away may be based on quality measures of the uplink component carriers. The device processor may then calculate a quality measure for the subset of component carriers, in block 806 of the method 800.

[00124] In response to determining that the downlink data traffic is greater than the uplink data traffic (i.e., determination block 910 = "Yes"), the device processor may include all downlink component carriers of the first subscription in the subset of component carriers, in block 914. For example, if the first subscription is receiving more data than it is transmitting, the tune-away would affect the downlink data traffic more than the uplink data traffic. In this case, the selection of a component carrier to use in the tune-away should be based on quality measures of the downlink component carriers. The device processor may then calculate a quality measure for the subset of component carriers, in block 806 of the method 800. In this manner, the method 900 provides a way to determine the subset of component carriers of a subscription that are available to use for a tune-away.

[00125] Various embodiments may be implemented in any of a variety of computing devices, an example of which (e.g., mobile communication device 1000) is illustrated in FIG. 10. According to various embodiments, the mobile communication device 1000 may be similar to the mobile communication devices 102 as described with reference to FIGS. 1A and IB, as well as multi-SIM communication device 200 as described with reference to FIG. 2. As such, the mobile communication device 1000 may implement the methods 800 and 900.

[00126] With reference to FIGS. 1-3 and 5A-10, a mobile communication device 1000 may include a processor 1002 coupled to a touchscreen controller 1004 and an internal memory 1006. The processor 1002 may be one or more multi-core integrated circuits designated for general or specific processing tasks. The internal memory 1006 may be volatile or non-volatile memory, and may also be secure and/or encrypted memory, or unsecure and/or unencrypted memory, or any combination thereof. The touchscreen controller 1004 and the processor 1002 may also be coupled to a touchscreen panel 1012, such as a resistive-sensing touchscreen, capacitive-sensing touchscreen, infrared sensing touchscreen, etc. Additionally, the display of the mobile communication device 1000 need not have touch screen capability.

[00127] The mobile communication device 1000 may have one or more cellular network transceivers 1008 coupled to the processor 1002 and to one or more antennas 1010 and configured for sending and receiving cellular communications. The one or more transceivers 1008 and the one or more antennas 1010 may be used with the herein-mentioned circuitry to implement various embodiment methods. The mobile communication device 1000 may include one or more SIM cards 1016 coupled to the one or more transceivers 1008 and/or the processor 1002 and may be configured as described herein.

[00128] The mobile communication device 1000 may also include speakers 1014 for providing audio outputs. The mobile communication device 1000 may also include a housing 1020, constructed of a plastic, metal, or a combination of materials, for containing all or some of the components discussed herein. The mobile communication device 1000 may include a power source 1022 coupled to the processor 1002, such as a disposable or rechargeable battery. The rechargeable battery may also be coupled to the peripheral device connection port to receive a charging current from a source external to the mobile communication device 1000. The mobile communication device 1000 may also include a physical button 1024 for receiving user inputs. The mobile communication device 1000 may also include a power button 1026 for turning the mobile communication device 1000 on and off.

[00129] 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 operations of various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the order of operations 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 operations; 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.

[00130] While the terms "first" and "second" are used herein to describe data transmission associated with a SIM and data receiving associated with a different SIM, such identifiers are merely for convenience and are not meant to limit various embodiments to a particular order, sequence, type of network or carrier.

[00131] The various illustrative logical blocks, modules, circuits, and algorithm operations 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 operations have been described herein 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 claims.

[00132] The hardware used to implement the various illustrative logics, logical blocks, modules, and circuits described in connection with the aspects 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 operations or methods may be performed by circuitry that is specific to a given function.

[00133] In one or more exemplary aspects, 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 or non-transitory processor-readable medium. The operations of a method or algorithm disclosed herein may be embodied in a processor-executable software module which may reside on a non-transitory computer-readable or processor-readable storage medium. Non-transitory 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 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, digital versatile disc (DVD), floppy disk, and Blu-ray disc in which disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the storage media are also included within the scope of non-transitory 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

processor-readable medium and/or computer-readable medium, which may be incorporated into a computer program product.

[00134] The preceding description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the claims. 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 scope of the claims. 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.

CLAIMS

What is claimed is:

1. A method of performing a tune-away from a first subscription to a second subscription on a mobile communication device, wherein the first subscription comprises a plurality of component carriers, the method comprising:

determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away;

determining a quality measure for each component carrier in the subset of component carriers before or during the scheduled tune-away;

selecting a component carrier in the subset of component carriers having the lowest quality measure; and

tuning away from the selected component carrier to the second subscription during the scheduled tune-away.

2. The method of claim 1, wherein the quality measure comprises a historical data throughput before the scheduled tune-away.

3. The method of claim 2, wherein the historical data throughput for a downlink component carrier comprises a transport block size or a channel quality indicator.

4. The method of claim 2, wherein the historical data throughput for an uplink component carrier comprises a transport block size or a modulation and coding scheme value.

5. The method of claim 1, wherein the quality measure comprises a predicted data throughput during the scheduled tune-away.

6. The method of claim 5, wherein the predicted data throughput for a downlink component carrier is determined as SEi(k) * RBj (k) * (1 - ERj) in which SEj (k) is a spectral efficiency of an z-th component carrier at sub-frame ***k*,** RBj (k) is a resource block size of the z-th component carrier at sub-frame ***k*,** and ERj is an error rate of the z-th component carrier.

7. The method of claim 5, wherein the predicted data throughput for an uplink component carrier is determined as instTBj (k) * (1 - ERj) in which instTBj (k) is an instant transport block size of an z-th component carrier at sub-frame ***k*** and ERj is an error rate of the z-th component carrier.

8. The method of claim 1, wherein determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away comprises:

determining whether there are downlink component carriers in the plurality of component carriers that are not associated with any uplink component carriers; and

selecting the downlink component carriers that are not associated with any uplink component carriers as the subset of component carriers in response to determining that there are downlink component carriers in the plurality of component carriers that are not associated with any uplink component carriers.

9. The method of claim 1, wherein determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away comprises:

determining whether a transmitter and a receiver in the mobile communication device are bounded; and

selecting the plurality of component carriers as the subset of component carriers in response to determining that the transmitter and the receiver in the mobile communication device are not bounded.

10. The method of claim 9, wherein determining a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away comprises

determining whether data traffic on downlink component carriers in the plurality of component carriers is greater than data traffic on uplink component carriers in the plurality of component carriers;

selecting the downlink component carriers as the subset of component carriers in response to determining that data traffic on the downlink component carriers is greater than data traffic on the uplink component carriers; and

selecting the uplink component carriers as the subset of component carriers in response to determining that data traffic on the downlink component carriers is not greater than data traffic on the uplink component carriers.

11. The method of claim 1, wherein tuning away from the selected component carrier to the second subscription during the scheduled tune-away comprises tuning away from both the selected component carrier and a component carrier associated with the selected component carrier during the scheduled tune-away.

12. A mobile communication device, comprising:

a radio frequency (RF) resource; and

a processor coupled to the RF resource and configured to connect to a first SIM associated with a first subscription and a second SIM associated with a second subscription, wherein the first subscription comprises a plurality of component carriers, and configured with processor-executable instructions to:

determine a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away;

determine a quality measure for each component carrier in the subset of component carriers before or during the scheduled tune-away;

select a component carrier in the subset of component carriers having the lowest quality measure; and

tune away from the selected component carrier to the second subscription during the scheduled tune-away.

13. The mobile communication device of claim 12, wherein the quality measure comprises a historical data throughput before the scheduled tune-away.

14. The mobile communication device of claim 13, wherein the historical data throughput for a downlink component carrier comprises a transport block size or a channel quality indicator.

15. The mobile communication device of claim 13, wherein the historical data throughput for an uplink component carrier comprises a transport block size or a modulation and coding scheme value.

16. The mobile communication device of claim 12, wherein the quality measure comprises a predicted data throughput during the scheduled tune-away.

17. The mobile communication device of claim 16, wherein the predicted data throughput for a downlink component carrier is determined as $SEi(k) * RB_i(k) * (1 - ER_i)$ in which $SE_i(k)$ is a spectral efficiency of an ***i-th*** component carrier at sub-frame ***k,*** $RB_i(k)$ is a resource block size of the ***i-th*** component carrier at sub-frame ***k,*** and ER_i is an error rate of the ***i-th*** component carrier.

18. The mobile communication device of claim 16, wherein the predicted data throughput for an uplink component carrier is determined as $instTB_i(k) * (1 - ER_i)$ in which $instTB_i(k)$ is an instant transport block size of an ***i-th*** component carrier at sub-frame ***k*** and ER_i is an error rate of the ***i-th*** component carrier.

19. The mobile communication device of claim 12, wherein the processor is further configured with processor-executable instructions to determine a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away by:

determining whether there are downlink component carriers in the plurality of component carriers that are not associated with any uplink component carriers; and

selecting the downlink component carriers that are not associated with any uplink component carriers as the subset of component carriers in response to determining that there are downlink component carriers in the plurality of component carriers that are not associated with any uplink component carriers.

20. The mobile communication device of claim 12, wherein the processor is further configured with processor-executable instructions to determine a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away by:

determining whether a transmitter and a receiver in the mobile communication device are bounded; and

selecting the plurality of component carriers as the subset of component carriers in response to determining that the transmitter and the receiver in the mobile communication device are not bounded.

21. The mobile communication device of claim 20, wherein the processor is further configured with processor-executable instructions to determine a subset of component carriers from the plurality of component carriers available to use in a scheduled tune-away by:

determining whether data traffic on downlink component carriers in the plurality of component carriers is greater than data traffic on uplink component carriers in the plurality of component carriers;

selecting the downlink component carriers as the subset of component carriers in response to determining that data traffic on the downlink component carriers is greater than data traffic on the uplink component carriers; and

selecting the uplink component carriers as the subset of component carriers in response to determining that data traffic on the downlink component carriers is not greater than data traffic on the uplink component carriers.

22. The mobile communication device of claim 12, wherein the processor is further configured with processor-executable instructions to tune away from the selected component carrier to the second subscription during the scheduled tune-away by tuning away from both the selected component carrier and a component carrier associated with the selected component carrier during the scheduled tune-away.

23. A non-transitory processor-readable medium having stored thereon processor-executable instructions configure to cause a processor of a mobile communication device to perform operations comprising:

determining a subset of component carriers from a plurality of component carriers of a first subscription on the mobile communication device that are available to use in a scheduled tune-away to a second subscription on the mobile communication device;

determining a quality measure for each component carrier in the subset of component carriers before or during the scheduled tune-away;

selecting a component carrier in the subset of component carriers having the lowest quality measure; and

tuning away from the selected component carrier to the second subscription during the scheduled tune-away.

24. The non-transitory processor-readable medium of claim 23, wherein the quality measure comprises a historical data throughput before the scheduled tune-away.

25. The non-transitory processor-readable medium of claim 23, wherein the quality measure comprises a predicted data throughput during the scheduled tune-away.

26. A mobile communication device, comprising:

means for determining a subset of component carriers from a plurality of component carriers of a first subscription on the mobile communication device that are available to use in a scheduled tune-away to a second subscription on the mobile communication device;

means for determining a quality measure for each component carrier in the subset of component carriers before or during the scheduled tune-away;

means for selecting a component carrier in the subset of component carriers having the lowest quality measure; and

means for tuning away from the selected component carrier to the second subscription during the scheduled tune-away.

27. The mobile communication device of claim 26, wherein the quality measure comprises a historical data throughput before the scheduled tune-away.

28. The mobile communication device of claim 26, wherein the quality measure comprises a predicted data throughput during the scheduled tune-away.

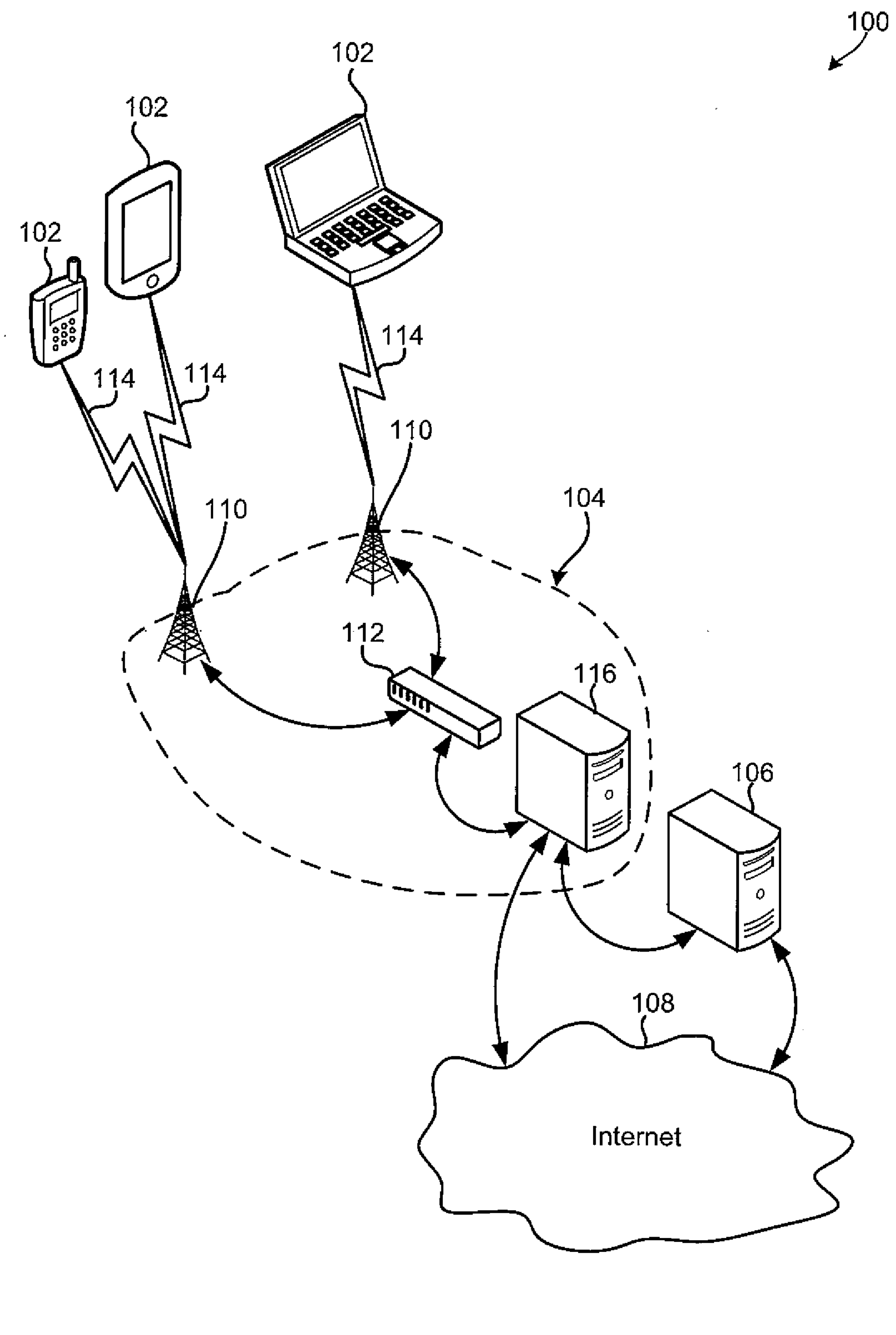
100
102
102
102
114
114
114
110
110
104
112
116
106
108
Internet

FIG. 1A

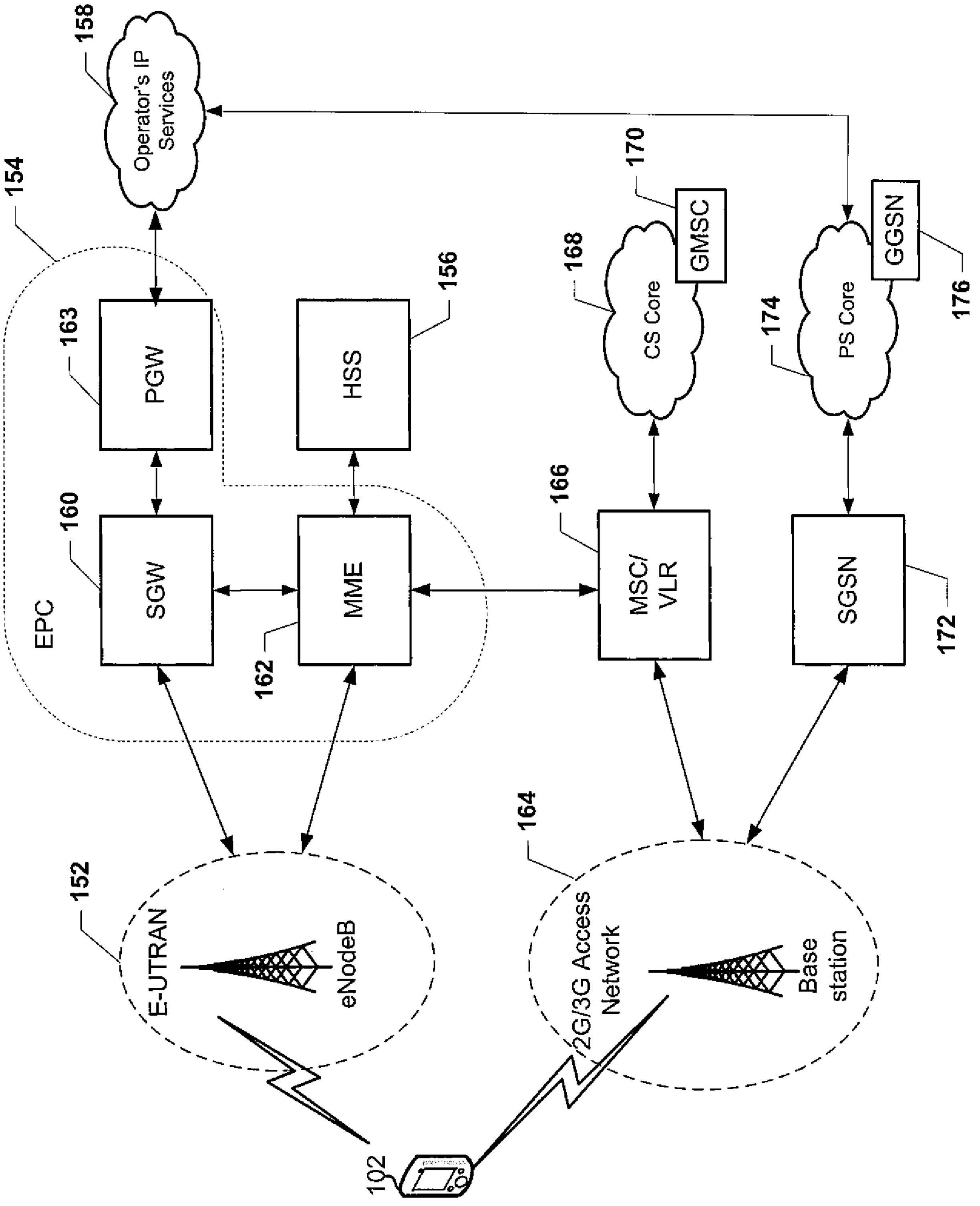
150
102
E-UTRAN
eNodeB
152
2G/3G Access Network
Base station
164
EPC
154
SGW
160
MME
162
PGW
163
HSS
156
Operator's IP Services
158
MSC/ VLR
166
CS Core
168
GMSC
170
SGSN
172
PS Core
174
GGSN
176

FIG. 1B

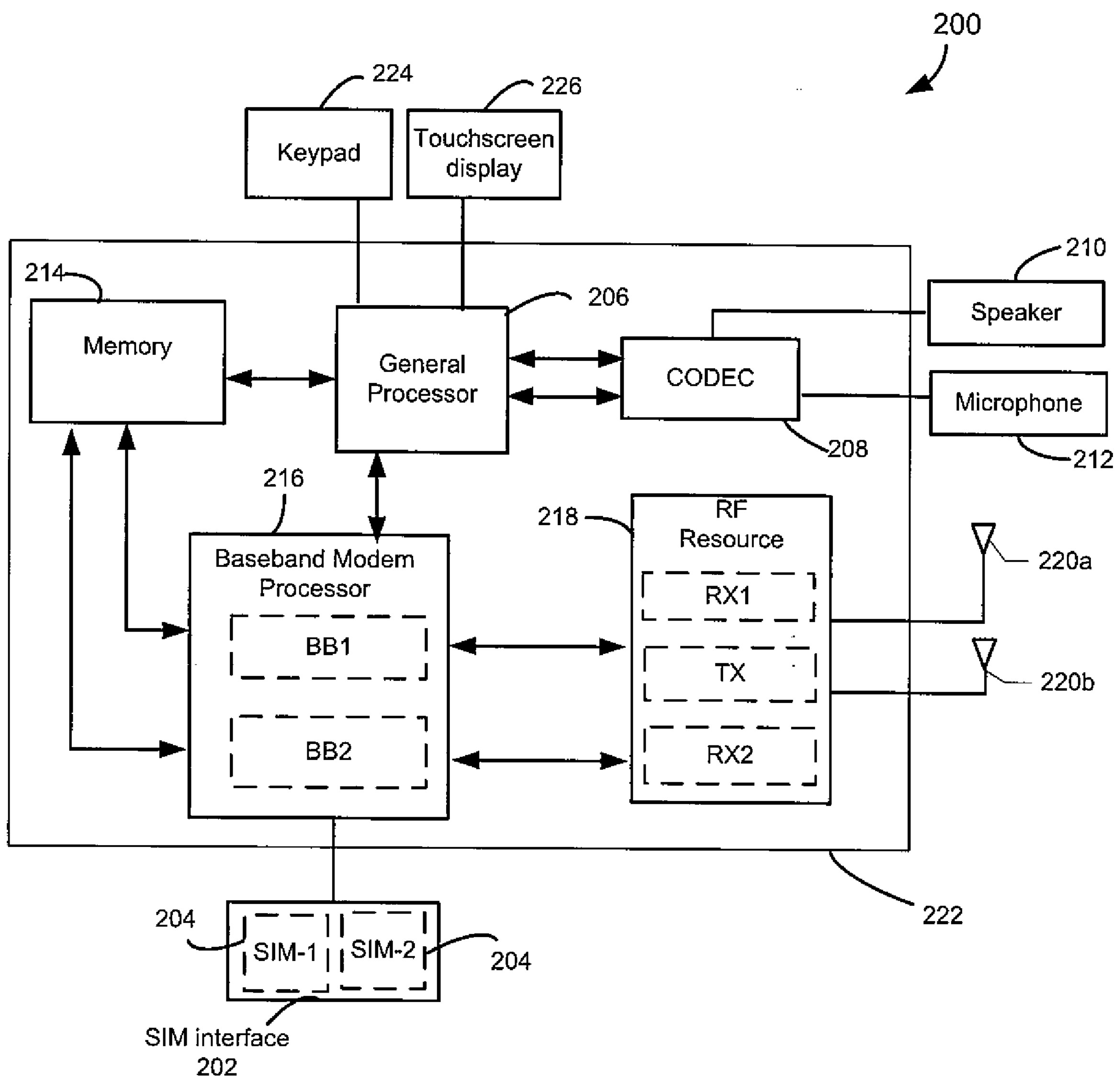
200
224
226
Keypad
Touchscreen display
214
Memory
206
General Processor
CODEC
210
Speaker
Microphone
208
212
216
218
RF Resource
Baseband Modem Processor
RX1
220a
BB1
TX
220b
BB2
RX2
222
204
SIM-1
SIM-2
204
SIM interface 202

FIG. 2

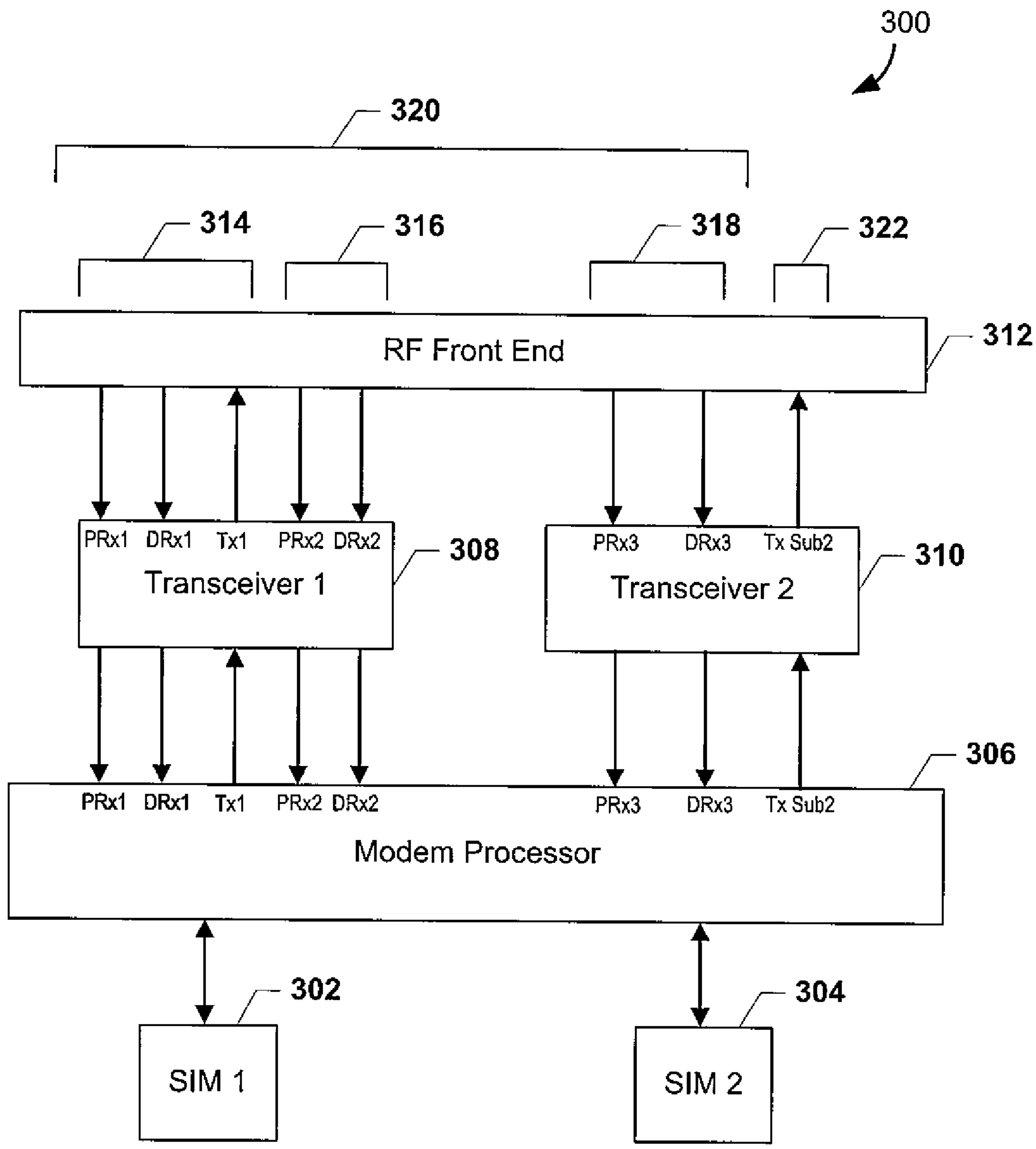
300
320
314
316
318
322
RF Front End
312
PRx1 DRx1 Tx1 PRx2 DRx2
Transceiver 1
308
PRx3 DRx3 Tx Sub2
Transceiver 2
310
306
PRx1 DRx1 Tx1 PRx2 DRx2
PRx3 DRx3 Tx Sub2
Modem Processor
302
304
SIM 1
SIM 2

FIG. 3

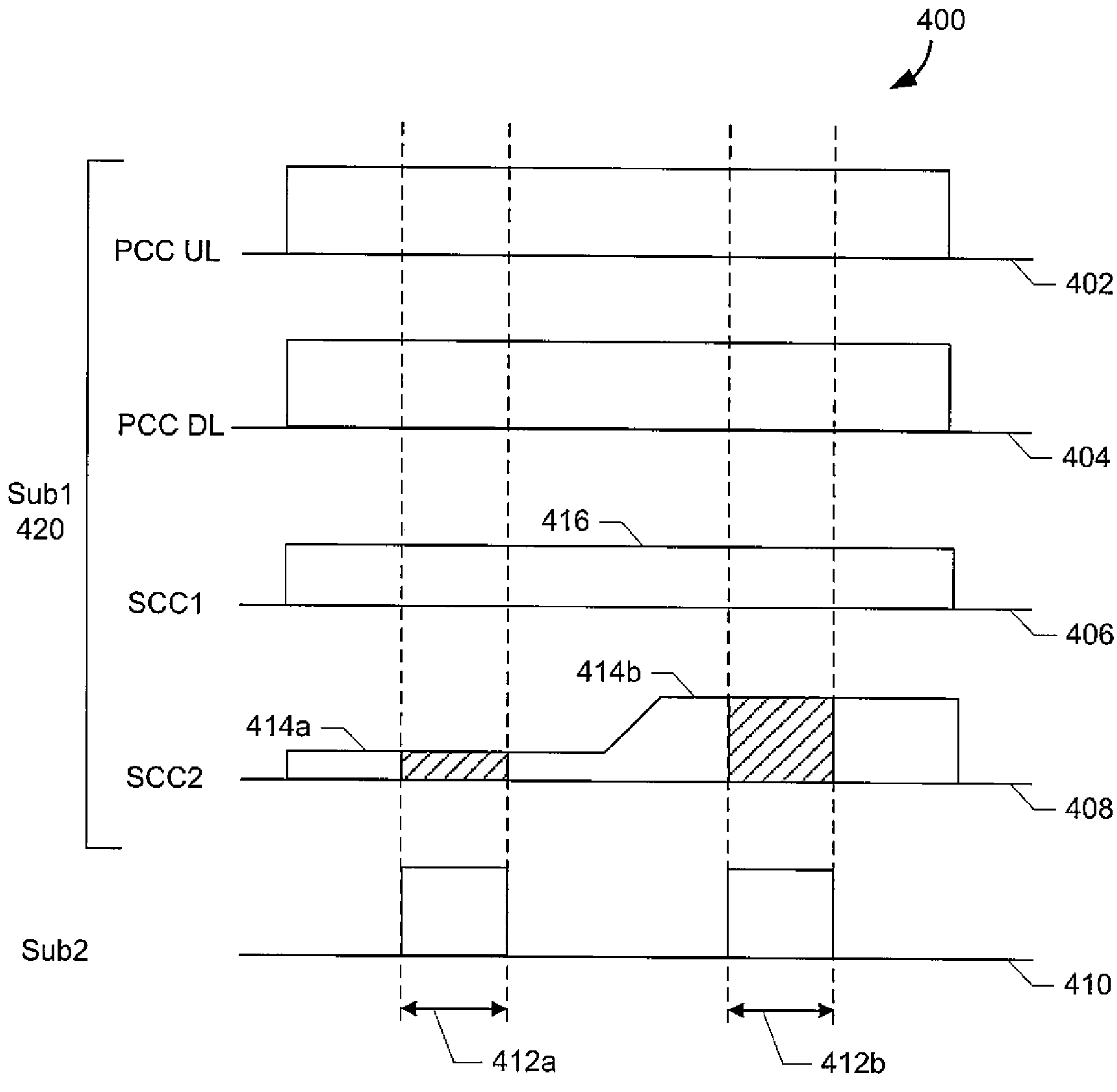
400
PCC UL
402
PCC DL
404
Sub1
420
416
SCC1
406
414b
414a
SCC2
408
Sub2
410
412a
412b

FIG. 4

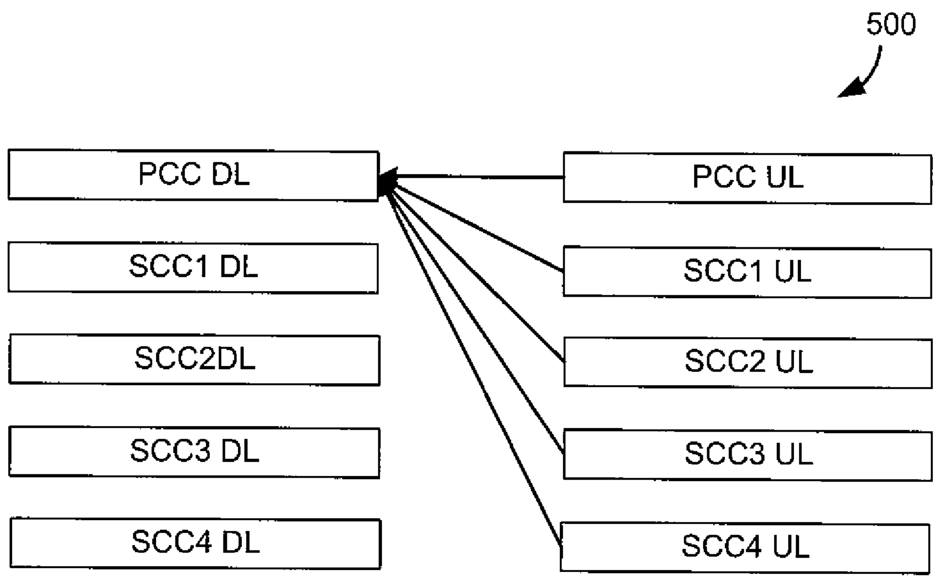
500
PCC DL
SCC1 DL
SCC2DL
SCC3 DL
SCC4 DL
PCC UL
SCC1 UL
SCC2 UL
SCC3 UL
SCC4 UL

FIG. 5A

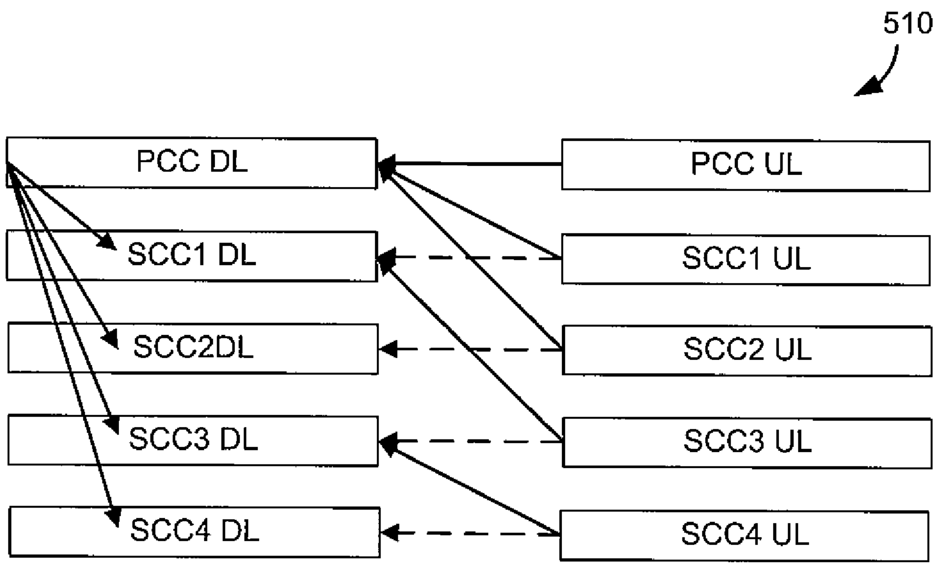
510
PCC DL
SCC1 DL
SCC2DL
SCC3 DL
SCC4 DL
PCC UL
SCC1 UL
SCC2 UL
SCC3 UL
SCC4 UL

FIG. 5B

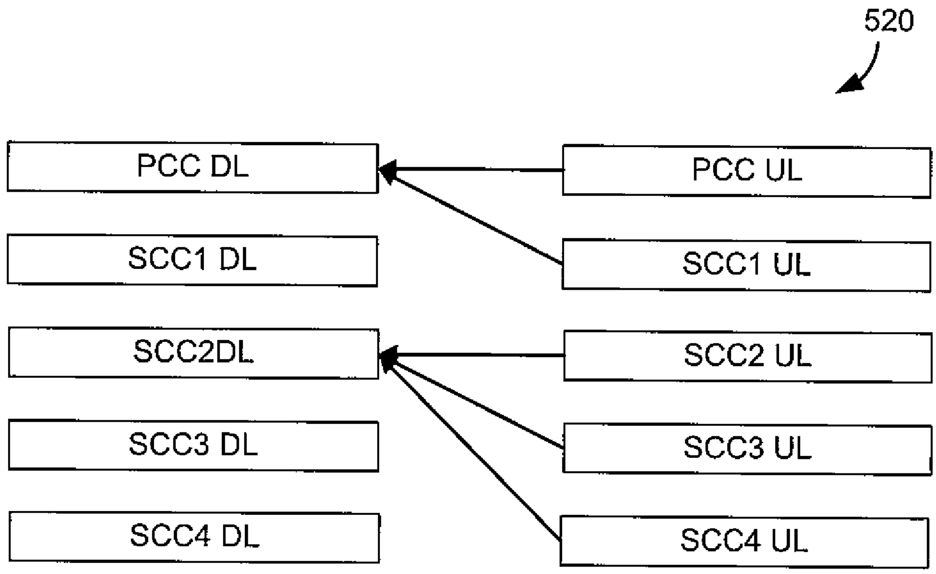
520
PCC DL
SCC1 DL
SCC2DL
SCC3 DL
SCC4 DL
PCC UL
SCC1 UL
SCC2 UL
SCC3 UL
SCC4 UL

FIG. 5C

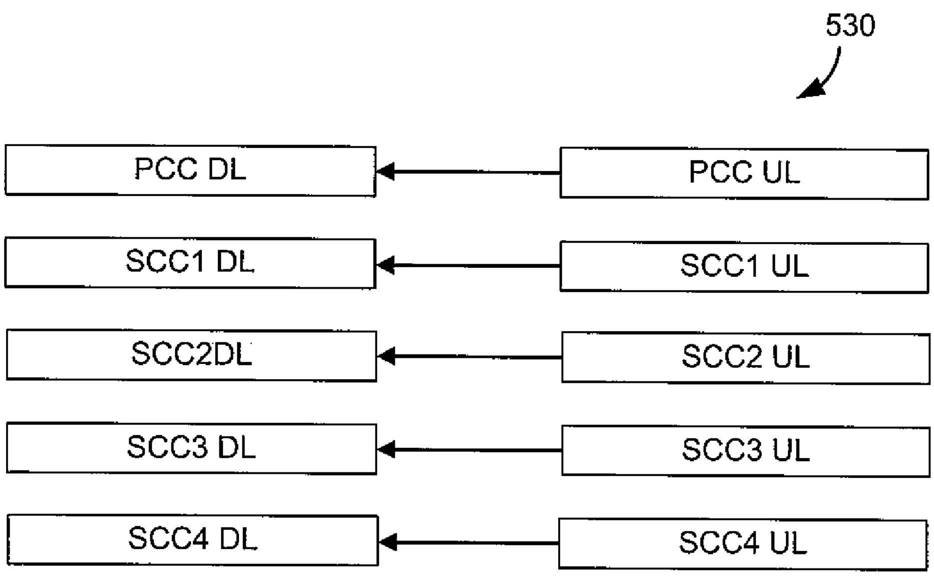
530
PCC DL
SCC1 DL
SCC2DL
SCC3 DL
SCC4 DL
PCC UL
SCC1 UL
SCC2 UL
SCC3 UL
SCC4 UL

FIG. 5D

600

		602	604
		SCC1 DL	SCC2 DL
606	$CQI_i(k)$	$CQI_1(k)$	$CQI_2(k)$
608	$TB_i(k)$	$TB_1(k)$	$TB_2(k)$
610	$RB_i(k)$	$RB_1(k)$	$RB_2(k)$
612	$BLER_i$	$BLER_1$	$BLER_2$
614	PER_i	PER_1	PER_2
616	$SE_i(k)$	$SE_1(k)$	$SE_2(k)$

FIG. 6

700

		702	704
		SCC1 UL	SCC2 UL
706	$MCS_i(k)$	$MCS_1(k)$	$MCS_2(k)$
708	$TB_i(k)$	$TB_1(k)$	$TB_2(k)$
710	$instTB_i(k)$	$instTB_1(k)$	$instTB_2(k)$
712	$BLER_i$	$BLER_1$	$BLER_2$
714	PER_i	PER_1	PER_2

FIG. 7

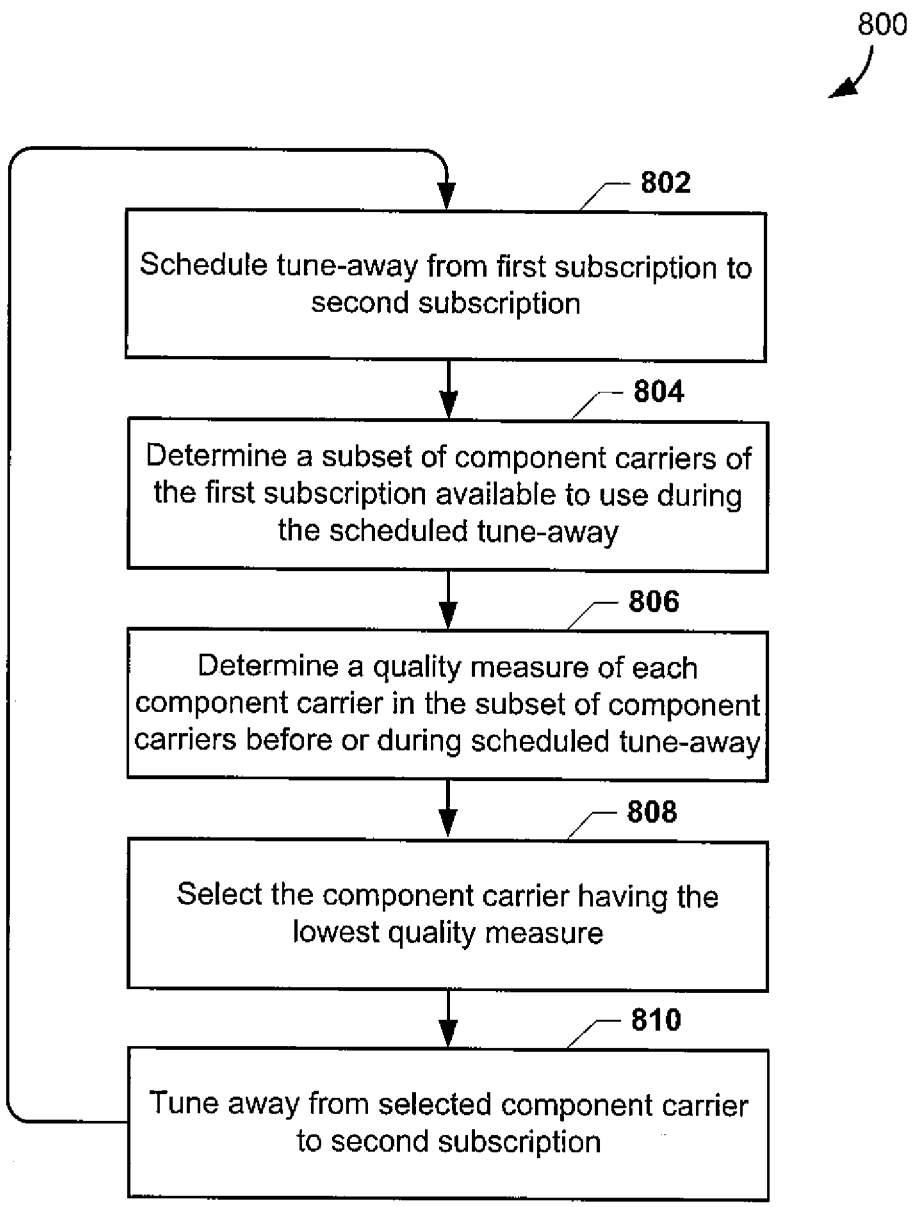
800
802
Schedule tune-away from first subscription to second subscription
804
Determine a subset of component carriers of the first subscription available to use during the scheduled tune-away
806
Determine a quality measure of each component carrier in the subset of component carriers before or during scheduled tune-away
808
Select the component carrier having the lowest quality measure
810
Tune away from selected component carrier to second subscription

FIG. 8

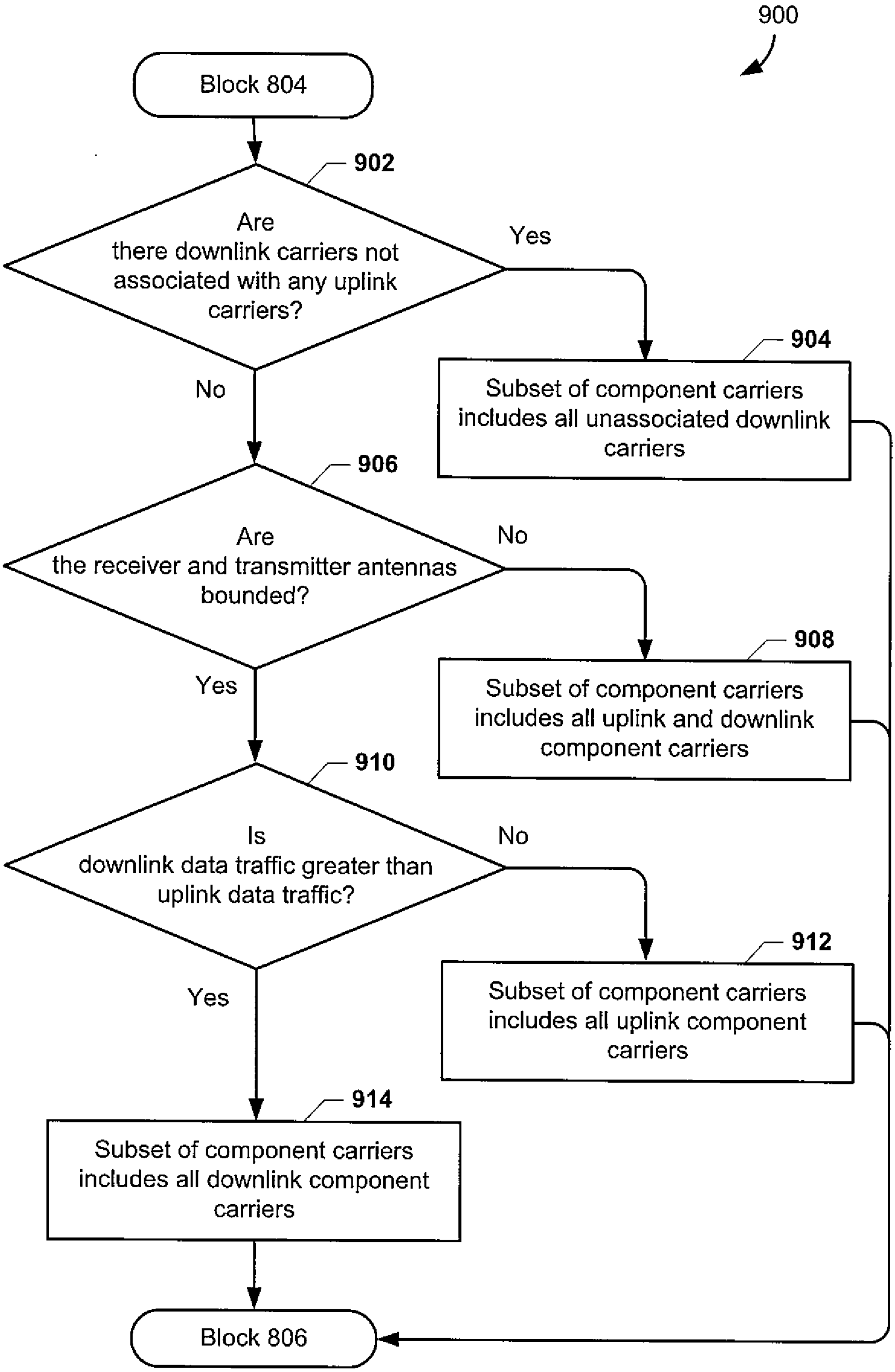
900
Block 804
902
Are there downlink carriers not associated with any uplink carriers?
Yes
No
904
Subset of component carriers includes all unassociated downlink carriers
906
Are the receiver and transmitter antennas bounded?
No
Yes
908
Subset of component carriers includes all uplink and downlink component carriers
910
Is downlink data traffic greater than uplink data traffic?
No
Yes
912
Subset of component carriers includes all uplink component carriers
914
Subset of component carriers includes all downlink component carriers
Block 806

FIG. 9

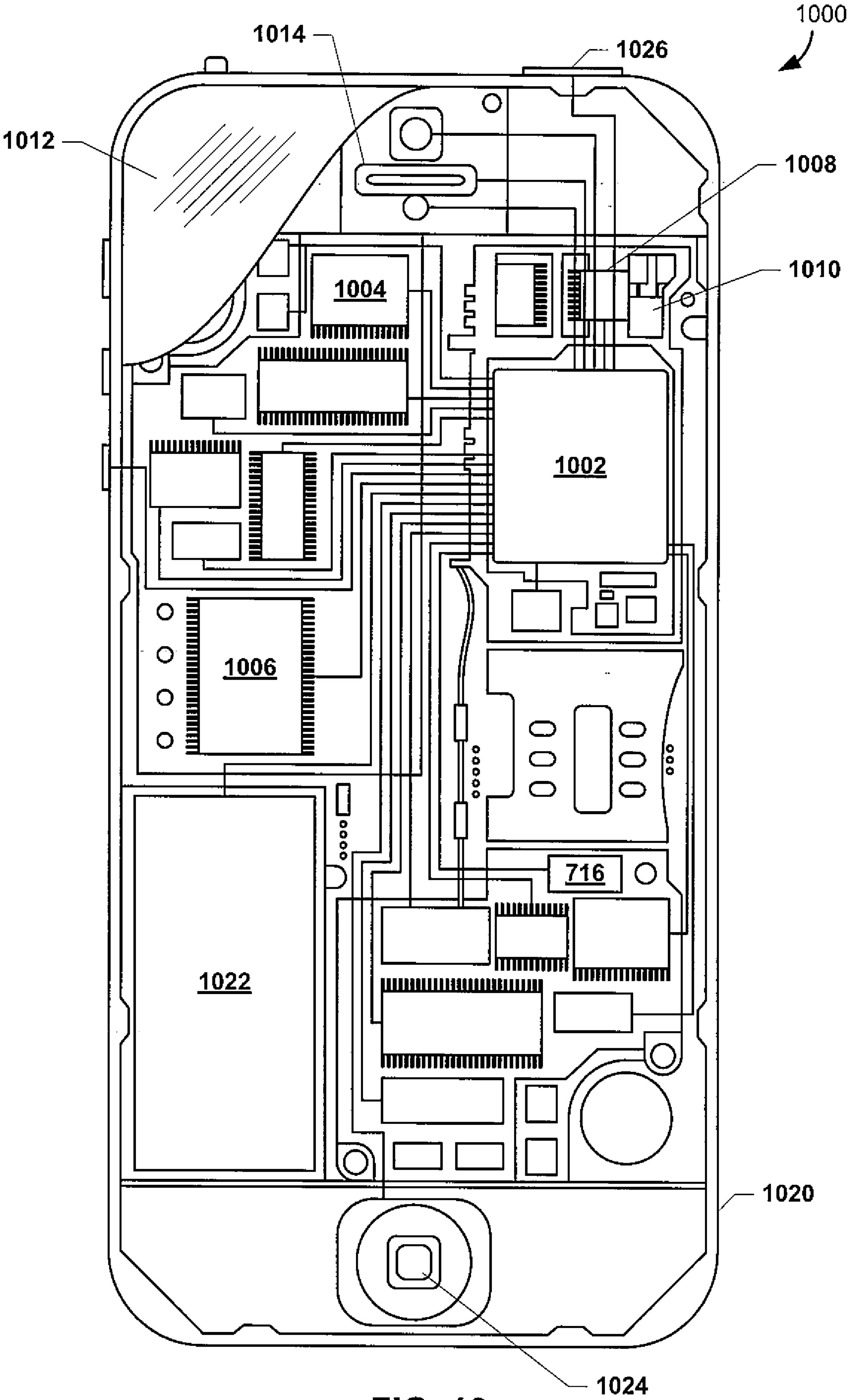
1000
1014
1026
1012
1008
1010
1004
1002
1006
716
1022
1020
1024

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/084471

A. CLASSIFICATION OF SUBJECT MATTER

H04W 76/04(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04Q; H04B

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

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

CNPAT,CNKI,WPI,EPODOC: tune w away, CQI, TB, RB, BLER, PER, RAT, LTE, SIM, RF, DSDS, downlink, uplink, carrier, channel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013337861 A1 (QUALCOMM INC.) 19 December 2013 (2013-12-19) paragraphs 50-52 in the description	1-28
A	US 2013303240 A1 (QUALCOMM INC.) 14 November 2013 (2013-11-14) the whole document	1-28
A	US 2012264390 A1 (INFINEON TECHNOLOGIES AG) 18 October 2012 (2012-10-18) the whole document	1-28
A	CN 103416101 A (QUALCOMM INC.) 27 November 2013 (2013-11-27) the whole document	1-28
A	CN 102123466 A (HUAWEI TECHNOLOGIES CO., LTD.) 13 July 2011 (2011-07-13) the whole document	1-28

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 April 2016	**28 April 2016**

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China

Facsimile No. **(86-10)62019451**

Authorized officer

GUOJing

Telephone No. **(86-10)010-82246956**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/084471

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2013337861 A1	19 December 2013	WO 2013192171 A1	27 December 2013
		EP 2862395 A1	22 April 2015
		CN 104380812 A	25 February 2015
US 2013303240 A1	14 November 2013	JP 2015517766 A	22 June 2015
		WO 2013170255 A1	14 November 2013
		CN 104272824 A	07 January 2015
		US 2015057046	26 February 2015
US 2012264390 A1	18 October 2012	CN 102740461 A	17 October 2012
		DE 102012102953 A1	18 October 2012
CN 103416101 A	27 November 2013	EP 2668815 A1	04 December 2013
		WO 2012103034 A1	02 August 2012
		KR 20130118965 A	30 October 2013
		US 2012190362 A1	26 July 2012
		JP 2014504125 A	13 February 2014
CN 102123466 A	13 July 2011	WO 2012097736 A1	26 July 2012
		US 2013303235 A1	14 November 2013