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Yang et al.

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(54) **MANAGING SYSTEM FRAME NUMBERS (SFNS) FOR CIRCUIT-SWITCHED FALLBACK (CSFB)**

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H04W 88/06 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 36/0022*** (2013.01); ***H04W 36/0066*** (2013.01); ***H04W 36/0088*** (2013.01); *H04W 88/06* (2013.01)

(58) **Field of Classification Search**
CPC H04W 36/0022; H04W 36/0006; H04W 36/0088; H04W 88/06
USPC 455/437; 370/338
See application file for complete search history.

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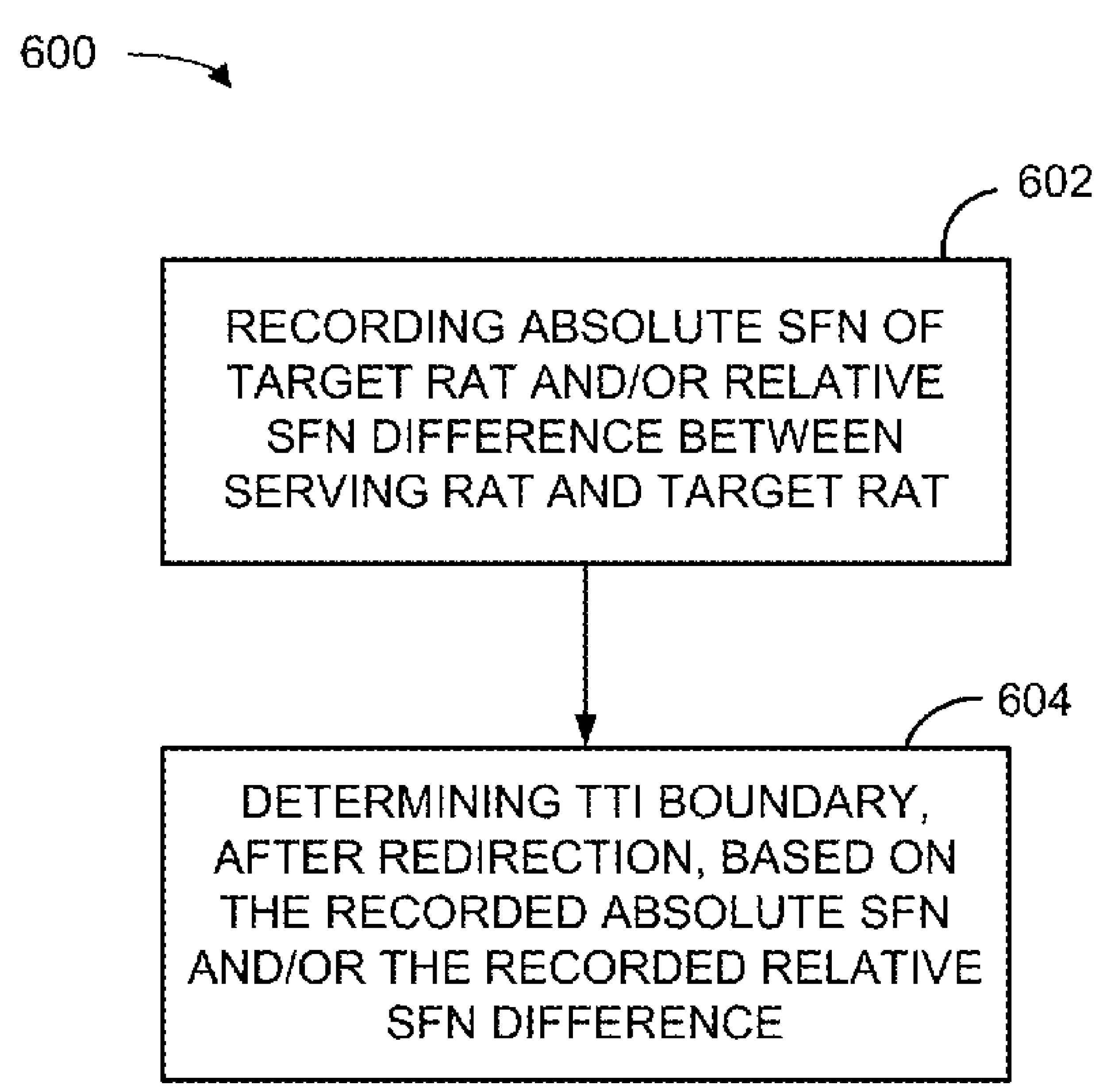
(57) **ABSTRACT**

A method of wireless communication includes recording an absolute system frame number (SFN) of a target radio access technology (RAT) and/or recording a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT. A transmission time interval (TTI) boundary, is determined after redirection, based at least in part on the recorded absolute frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

28 Claims, 7 Drawing Sheets



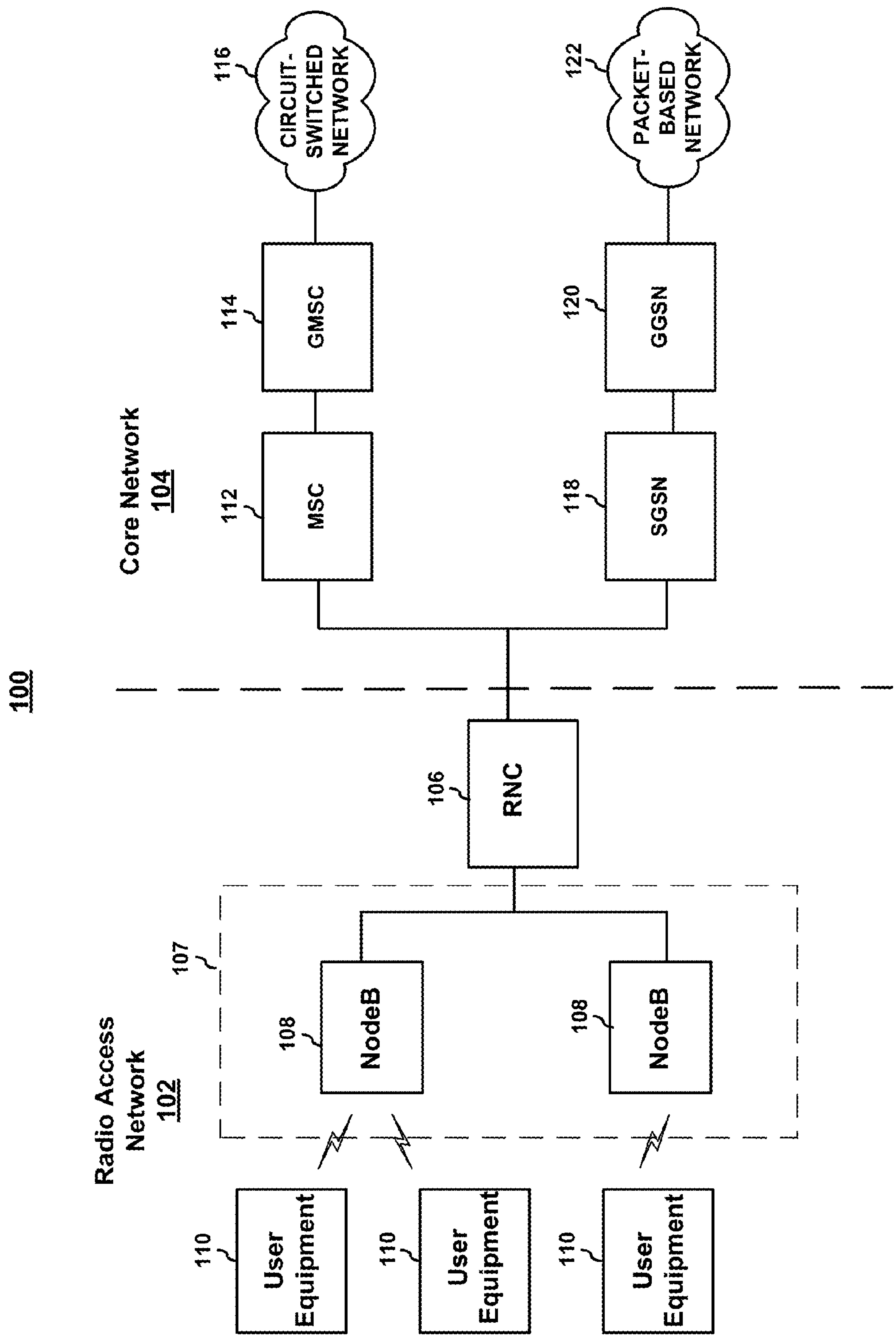

100
Core Network
104
Radio Access
Network
102
107
CIRCUIT-
SWITCHED
NETWORK
116
PACKET-
BASED
NETWORK
122
GMSC
114
GGSN
120
MSC
112
SGSN
118
RNC
106
NodeB
108
NodeB
108
User
Equipment
110
User
Equipment
110
User
Equipment
110

FIG. 1

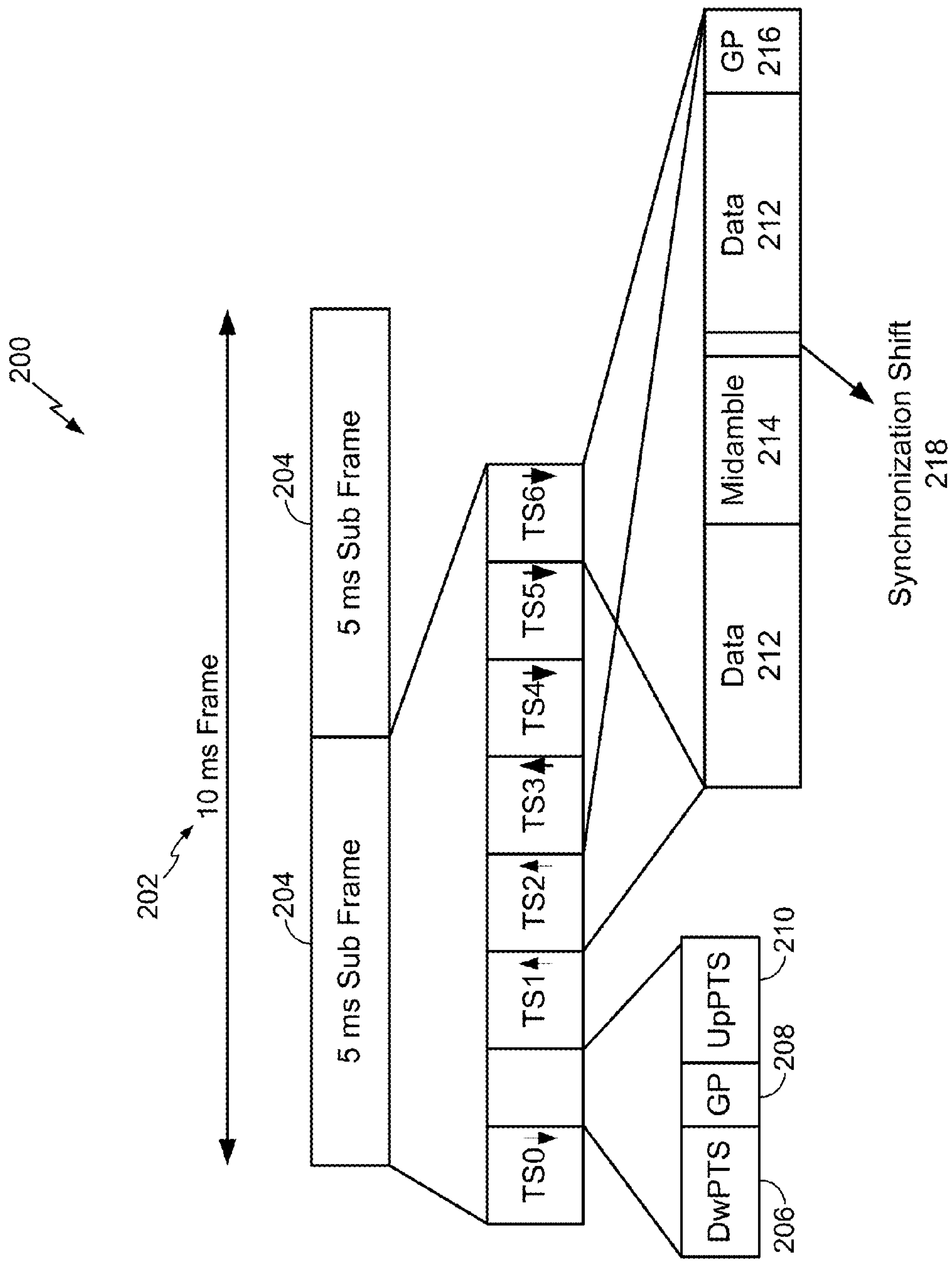

200
202
10 ms Frame
204
5 ms Sub Frame
204
5 ms Sub Frame
TS0
TS1
TS2
TS3
TS4
TS5
TS6
DwPTS
206
GP
208
UpPTS
210
Data
212
Midamble
214
Data
212
GP
216
Synchronization Shift
218

FIG. 2

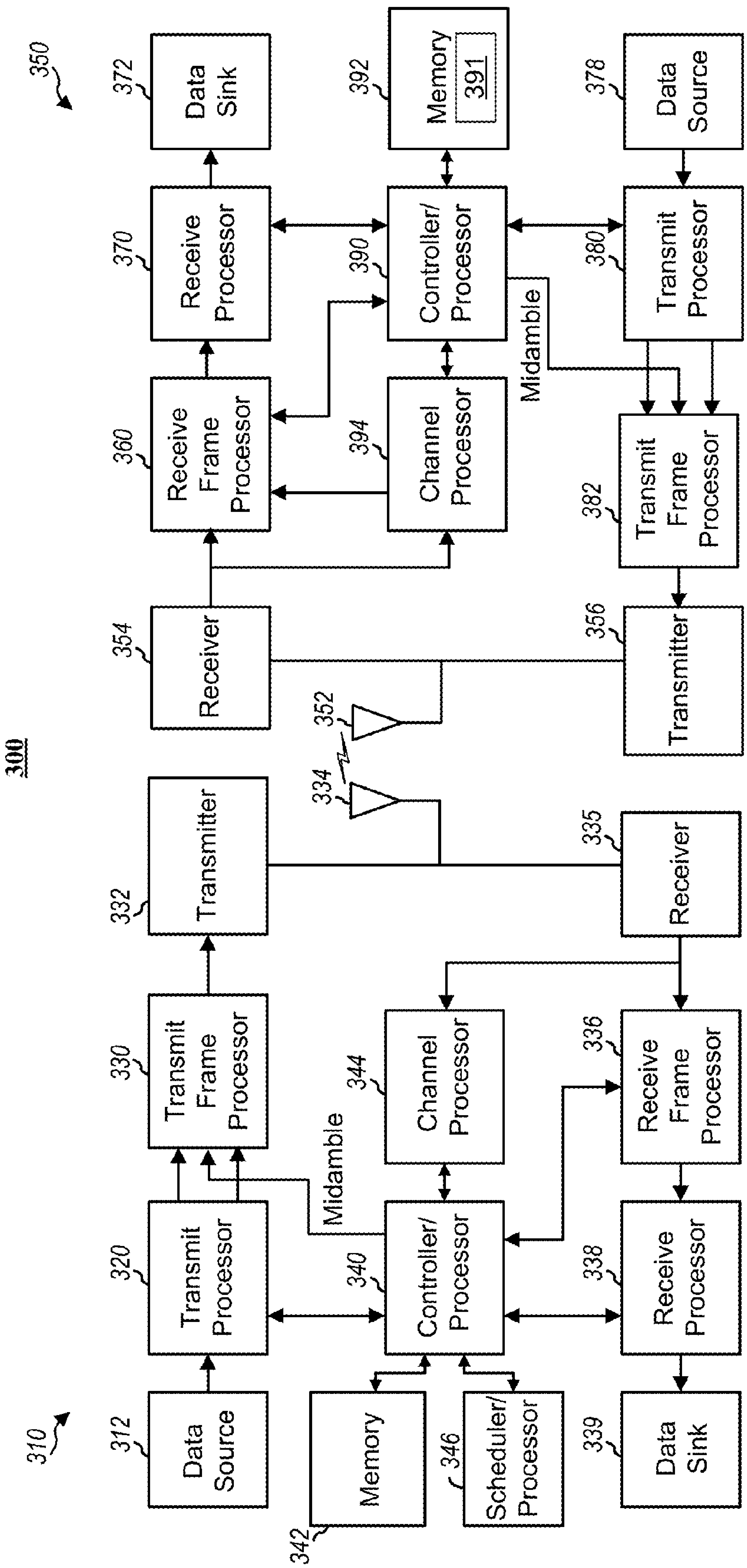

300
310
312
Data Source
320
Transmit Processor
330
Transmit Frame Processor
332
Transmitter
334
340
Controller/ Processor
342
Memory
346
Scheduler/ Processor
344
Channel Processor
Midamble
335
Receiver
336
Receive Frame Processor
338
Receive Processor
339
Data Sink
350
352
354
Receiver
360
Receive Frame Processor
370
Receive Processor
372
Data Sink
390
Controller/ Processor
392
Memory
391
394
Channel Processor
Midamble
356
Transmitter
382
Transmit Frame Processor
380
Transmit Processor
378
Data Source

FIG. 3

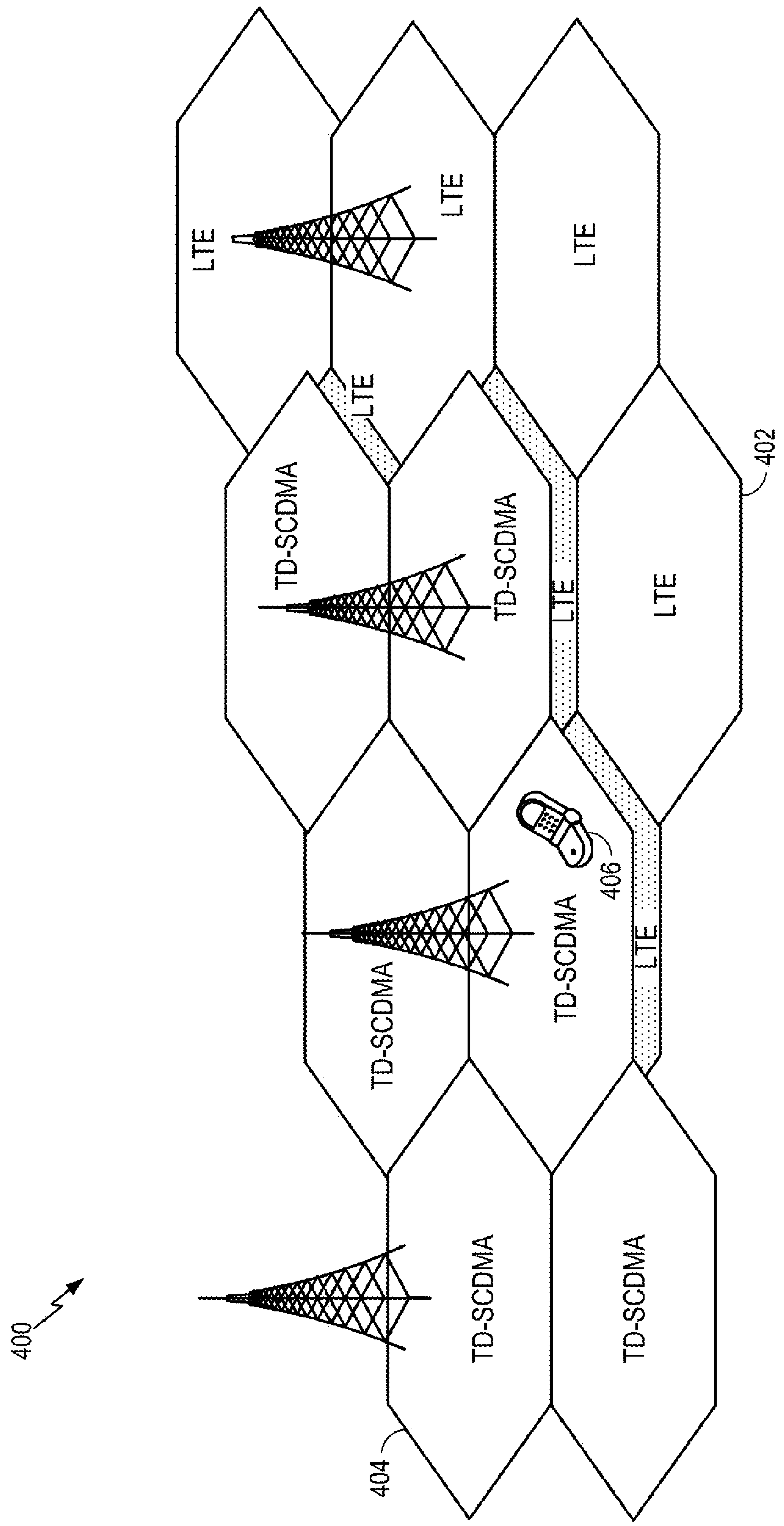

400
LTE
LTE
LTE
LTE
LTE
LTE
LTE
402
TD-SCDMA
TD-SCDMA
TD-SCDMA
TD-SCDMA
TD-SCDMA
TD-SCDMA
406
404

FIG. 4

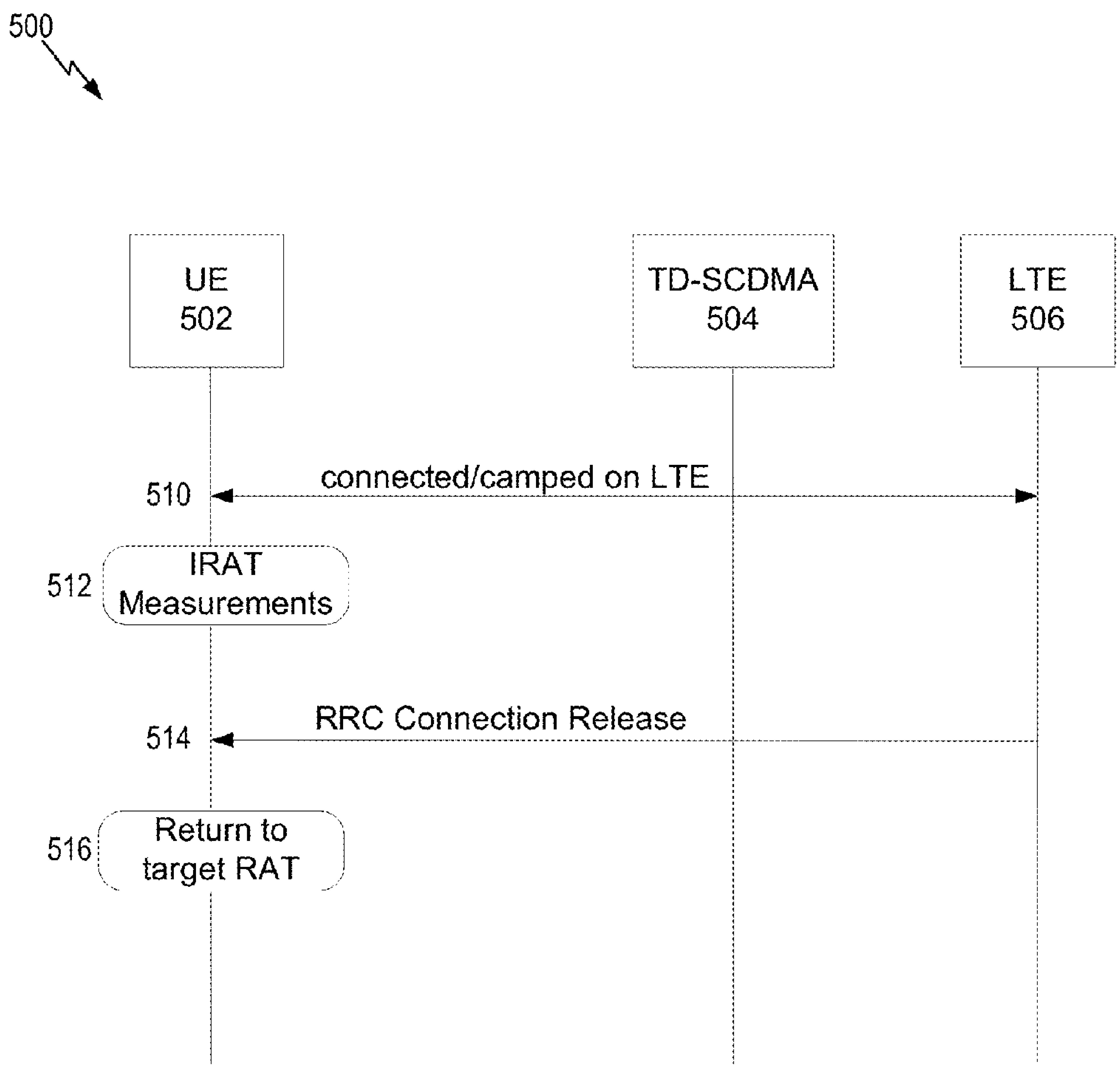

500
UE
502
TD-SCDMA
504
LTE
506
510
connected/camped on LTE
512
IRAT
Measurements
514
RRC Connection Release
516
Return to
target RAT

FIG. 5

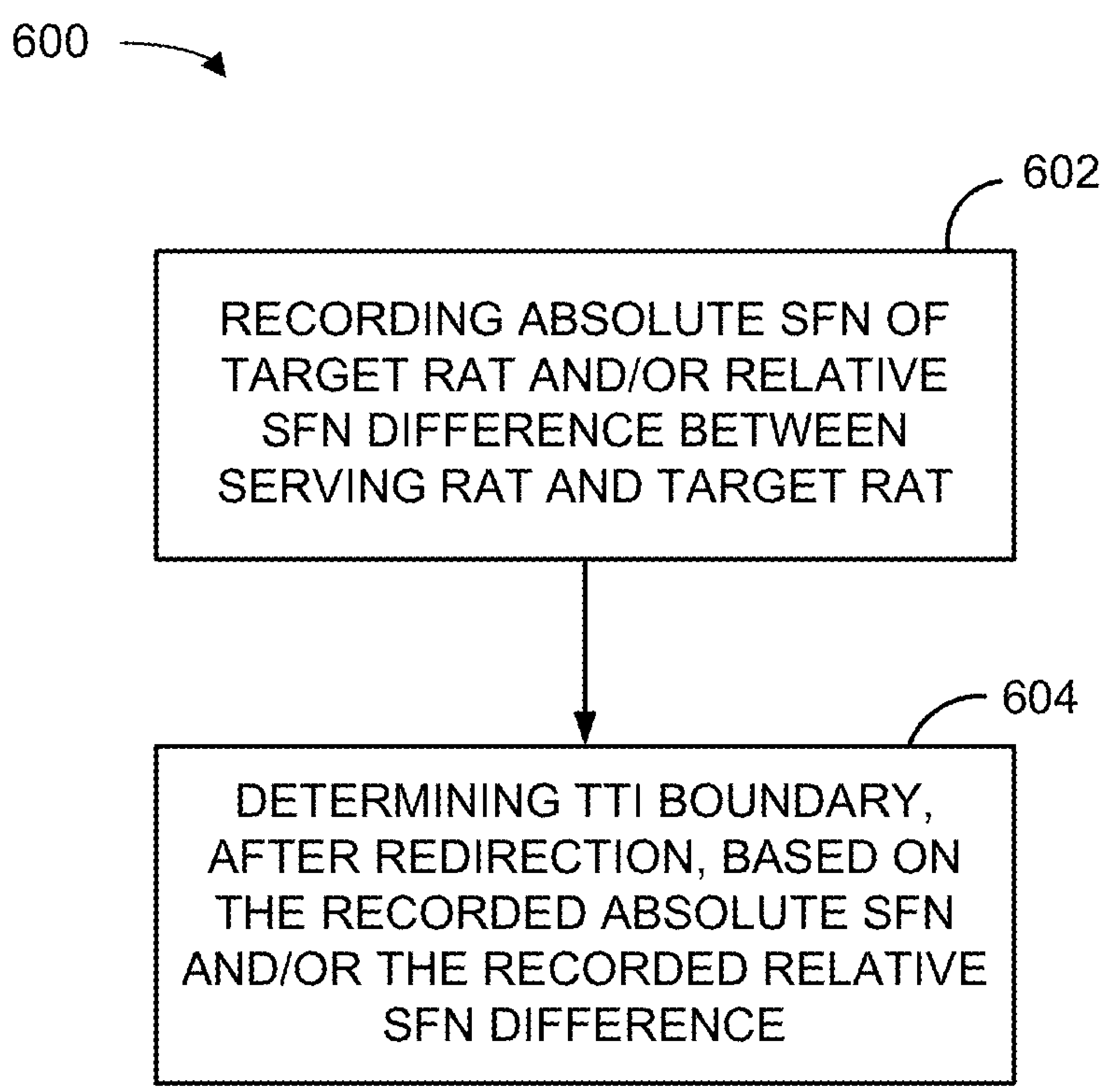

600
602
RECORDING ABSOLUTE SFN OF TARGET RAT AND/OR RELATIVE SFN DIFFERENCE BETWEEN SERVING RAT AND TARGET RAT
604
DETERMINING TTI BOUNDARY, AFTER REDIRECTION, BASED ON THE RECORDED ABSOLUTE SFN AND/OR THE RECORDED RELATIVE SFN DIFFERENCE

FIG. 6

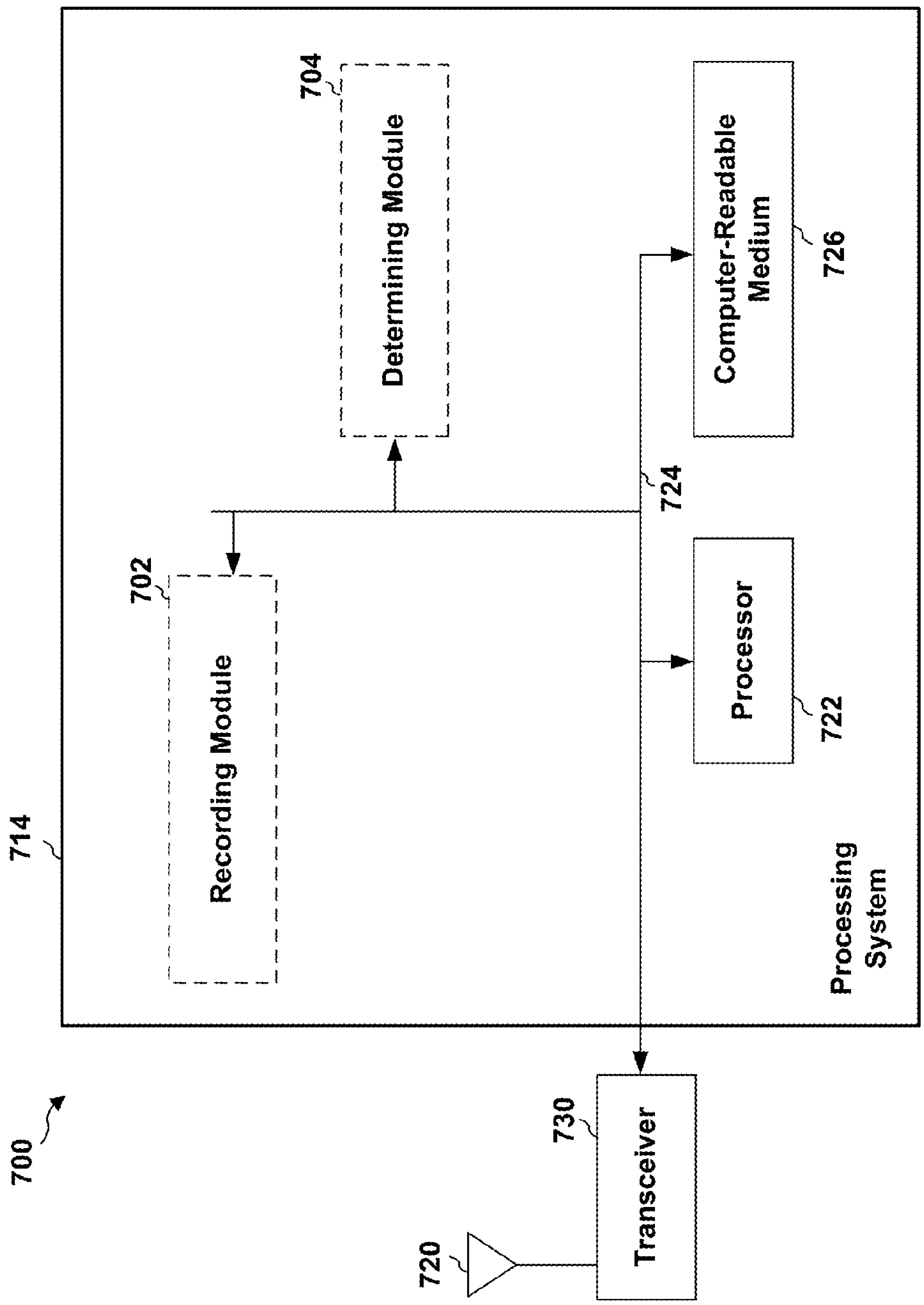

700
714
Recording Module
702
Determining Module
704
724
Computer-Readable Medium
726
Processor
722
Processing System
Transceiver
730
720

FIG. 7

MANAGING SYSTEM FRAME NUMBERS (SFNS) FOR CIRCUIT-SWITCHED FALLBACK (CSFB)

BACKGROUND

1. Field

Aspects of the present disclosure relate generally to wireless communication systems, and more particularly, to utilizing system frame numbers (SFNs) to determine a transmission time interval (TTI) boundary during redirection from one radio access technology (RAT) to another.

2. Background

Wireless communication networks are widely deployed to provide various communication services such as telephony, video, data, messaging, broadcasts, and so on. Such networks, which are usually multiple access networks, support communications for multiple users by sharing the available network resources. One example of such a network is the Universal Terrestrial Radio Access Network (UTRAN). The UTRAN is the radio access network (RAN) defined as a part of the Universal Mobile Telecommunications System (UMTS), a third generation (3G) mobile phone technology supported by the 3rd Generation Partnership Project (3GPP). The UMTS, which is the successor to Global System for Mobile Communications (GSM) technologies, currently supports various air interface standards, such as Wideband-Code Division Multiple Access (W-CDMA), Time Division-Code Division Multiple Access (TD-CDMA), and Time Division-Synchronous Code Division Multiple Access (TD-SCDMA). For example, China is pursuing TD-SCDMA as the underlying air interface in the UTRAN architecture with its existing GSM infrastructure as the core network. The UMTS also supports enhanced 3G data communications protocols, such as High Speed Packet Access (HSPA), which provides higher data transfer speeds and capacity to associated UMTS networks. HSPA is a collection of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), that extends and improves the performance of existing wideband protocols.

As the demand for mobile broadband access continues to increase, research and development continue to advance the UMTS technologies not only to meet the growing demand for mobile broadband access, but to advance and enhance the user experience with mobile communications.

SUMMARY

In one aspect, a method of wireless communication is disclosed. The method includes recording an absolute system frame number (SFN) of a target radio access technology (RAT) and/or a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT. A transmission time interval (TTI) boundary, after redirection, is then determined based at least in part on the recorded absolute frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

Another aspect discloses an apparatus including means for recording an absolute system frame number (SFN) of a target radio access technology (RAT) and/or a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT. Also included is a mean for determining a transmission time interval (TTI) boundary, after redirection, based at least in part on the recorded absolute frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

In another aspect, a computer program product for wireless communications in a wireless network having a non-transitory computer-readable medium is disclosed. The computer readable medium has non-transitory program code recorded thereon which, when executed by the processor(s), causes the processor(s) to perform operations of recording an absolute system frame number (SFN) of a target radio access technology (RAT) and/or recording a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT. The program code also causes the processor(s) to determine a transmission time interval (TTI) boundary, after redirection, based at least in part on the recorded absolute frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

Another aspect discloses wireless communication having a memory and at least one processor coupled to the memory. The processor(s) is configured to record an absolute system frame number (SFN) of a target radio access technology (RAT) and/or record a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT. The processor(s) is also configured to determine a transmission time interval (TTI) boundary, after redirection, is then determined based at least in part on the recorded absolute frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

This has outlined, rather broadly, the features and technical advantages of the present disclosure in order that the detailed description that follows may be better understood. Additional features and advantages of the disclosure will be described below. It should be appreciated by those skilled in the art that this disclosure may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present disclosure. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the teachings of the disclosure as set forth in the appended claims. The novel features, which are believed to be characteristic of the disclosure, both as to its organization and method of operation, together with further objects and advantages, will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, nature, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout.

FIG. **1** is a block diagram conceptually illustrating an example of a telecommunications system.

FIG. **2** is a block diagram conceptually illustrating an example of a frame structure in a telecommunications system.

FIG. **3** is a block diagram conceptually illustrating an example of a node B in communication with a UE in a telecommunications system.

FIG. **4** illustrates network coverage areas according to aspects of the present disclosure.

FIG. **5** is a call flow diagram illustrating an aspect of the present disclosure.

FIG. **6** is a block diagram illustrating a method for determining a transmission time interval according to one aspect of the present disclosure.

FIG. **7** is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system according to one aspect of the present disclosure.

DETAILED DESCRIPTION

The detailed description set forth below, in connection with the appended drawings, is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of the various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

Turning now to FIG. **1**, a block diagram is shown illustrating an example of a telecommunications system **100**. The various concepts presented throughout this disclosure may be implemented across a broad variety of telecommunication systems, network architectures, and communication standards. By way of example and without limitation, the aspects of the present disclosure illustrated in FIG. **1** are presented with reference to a UMTS system employing a TD-SCDMA standard. In this example, the UMTS system includes a (radio access network) RAN **102** (e.g., UTRAN) that provides various wireless services including telephony, video, data, messaging, broadcasts, and/or other services. The RAN **102** may be divided into a number of Radio Network Subsystems (RNSs) such as an RNS **107**, each controlled by a Radio Network Controller (RNC) such as an RNC **106**. For clarity, only the RNC **106** and the RNS **107** are shown; however, the RAN **102** may include any number of RNCs and RNSs in addition to the RNC **106** and RNS **107**. The RNC **106** is an apparatus responsible for, among other things, assigning, reconfiguring and releasing radio resources within the RNS **107**. The RNC **106** may be interconnected to other RNCs (not shown) in the RAN **102** through various types of interfaces such as a direct physical connection, a virtual network, or the like, using any suitable transport network.

The geographic region covered by the RNS **107** may be divided into a number of cells, with a radio transceiver apparatus serving each cell. A radio transceiver apparatus is commonly referred to as a node B in UMTS applications, but may also be referred to by those skilled in the art as a base station (BS), a base transceiver station (BTS), a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), an access point (AP), or some other suitable terminology. For clarity, two node Bs **108** are shown; however, the RNS **107** may include any number of wireless node Bs. The node Bs **108** provide wireless access points to a core network **104** for any number of mobile apparatuses. Examples of a mobile apparatus include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a notebook, a netbook, a smartbook, a personal digital assistant (PDA), a satellite radio, a global positioning system (GPS) device, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, or any other similar functioning device. The mobile apparatus is commonly referred to as user equipment (UE) in UMTS applications, but may also be referred to by those skilled in the art as a mobile station (MS), a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal (AT), a mobile terminal, a wireless terminal, a remote terminal, a handset, a terminal, a user agent, a mobile client, a client, or some other suitable terminology. For illustrative purposes, three UEs **110** are shown in communication with the node Bs **108**. The downlink (DL), also called the forward link, refers to the communication link from a node B to a UE, and the uplink (UL), also called the reverse link, refers to the communication link from a UE to a node B.

The core network **104**, as shown, includes a GSM core network. However, as those skilled in the art will recognize, the various concepts presented throughout this disclosure may be implemented in a RAN, or other suitable access network, to provide UEs with access to types of core networks other than GSM networks.

In this example, the core network **104** supports circuit-switched services with a mobile switching center (MSC) **112** and a gateway MSC (GMSC) **114**. One or more RNCs, such as the RNC **106**, may be connected to the MSC **112**. The MSC **112** is an apparatus that controls call setup, call routing, and UE mobility functions. The MSC **112** also includes a visitor location register (VLR) (not shown) that contains subscriber-related information for the duration that a UE is in the coverage area of the MSC **112**. The GMSC **114** provides a gateway through the MSC **112** for the UE to access a circuit-switched network **116**. The GMSC **114** includes a home location register (HLR) (not shown) containing subscriber data, such as the data reflecting the details of the services to which a particular user has subscribed. The HLR is also associated with an authentication center (AuC) that contains subscriber-specific authentication data. When a call is received for a particular UE, the GMSC **114** queries the HLR to determine the UE's location and forwards the call to the particular MSC serving that location.

The core network **104** also supports packet-data services with a serving GPRS support node (SGSN) **118** and a gateway GPRS support node (GGSN) **120**. GPRS, which stands for General Packet Radio Service, is designed to provide packet-data services at speeds higher than those available with standard GSM circuit-switched data services. The GGSN **120** provides a connection for the RAN **102** to a packet-based network **122**. The packet-based network **122** may be the Internet, a private data network, or some other suitable packet-based network. The primary function of the GGSN **120** is to provide the UEs **110** with packet-based network connectivity. Data packets are transferred between the GGSN **120** and the UEs **110** through the SGSN **118**, which performs primarily the same functions in the packet-based domain as the MSC **112** performs in the circuit-switched domain.

The UMTS air interface is a spread spectrum Direct-Sequence Code Division Multiple Access (DS-CDMA) system. The spread spectrum DS-CDMA spreads user data over a much wider bandwidth through multiplication by a sequence of pseudorandom bits called chips. The TD-SCDMA standard is based on such direct sequence spread spectrum technology and additionally calls for a time division duplexing (TDD), rather than a frequency division duplexing (FDD) as used in many FDD mode UMTS/W-CDMA systems. TDD uses the same carrier frequency for both the uplink (UL) and downlink (DL) between a node B **108** and a UE **110**, but divides uplink and downlink transmissions into different time slots in the carrier.

FIG. **2** shows a frame structure **200** for a TD-SCDMA carrier. The TD-SCDMA carrier, as illustrated, has a frame **202** that is 10 ms in length. The chip rate in TD-SCDMA is 1.28 Mcps. The frame **202** has two 5 ms subframes **204**, and each of the subframes **204** includes seven time slots, TS0 through TS6. The first time slot, TS0, is usually allocated for downlink communication, while the second time slot, TS1, is usually allocated for uplink communication. The remaining time slots, TS2 through TS6, may be used for either uplink or downlink, which allows for greater flexibility during times of higher data transmission times in either the uplink or downlink directions. A downlink pilot time slot (DwPTS) **206**, a guard period (GP) **208**, and an uplink pilot time slot (UpPTS) **210** (also known as the uplink pilot channel (UpPCH)) are located between TS0 and TS1. Each time slot, TS0-TS6, may allow data transmission multiplexed on a maximum of 16 code channels. Data transmission on a code channel includes two data portions **212** (each with a length of 352 chips) separated by a midamble **214** (with a length of 144 chips) and followed by a guard period (GP) **216** (with a length of 16 chips). The midamble **214** may be used for features, such as channel estimation, while the guard period **216** may be used to avoid inter-burst interference. Also transmitted in the data portion is some Layer **1** control information, including Synchronization Shift (SS) bits **218**. Synchronization Shift bits **218** only appear in the second part of the data portion. The Synchronization Shift bits **218** immediately following the midamble can indicate three cases: decrease shift, increase shift, or do nothing in the upload transmit timing. The positions of the SS bits **218** are not generally used during uplink communications.

FIG. **3** is a block diagram of a node B **310** in communication with a UE **350** in a RAN **300**, where the RAN **300** may be the RAN **102** in FIG. **1**, the node B **310** may be the node B **108** in FIG. **1**, and the UE **350** may be the UE **110** in FIG. **1**. In the downlink communication, a transmit processor **320** may receive data from a data source **312** and control signals from a controller/processor **340**. The transmit processor **320** provides various signal processing functions for the data and control signals, as well as reference signals (e.g., pilot signals). For example, the transmit processor **320** may provide cyclic redundancy check (CRC) codes for error detection, coding and interleaving to facilitate forward error correction (FEC), mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM), and the like), spreading with orthogonal variable spreading factors (OVSF), and multiplying with scrambling codes to produce a series of symbols. Channel estimates from a channel processor **344** may be used by a controller/processor **340** to determine the coding, modulation, spreading, and/or scrambling schemes for the transmit processor **320**. These channel estimates may be derived from a reference signal transmitted by the UE **350** or from feedback contained in the midamble **214** (FIG. **2**) from the UE **350**. The symbols generated by the transmit processor **320** are provided to a transmit frame processor **330** to create a frame structure. The transmit frame processor **330** creates this frame structure by multiplexing the symbols with a midamble **214** (FIG. **2**) from the controller/processor **340**, resulting in a series of frames. The frames are then provided to a transmitter **332**, which provides various signal conditioning functions including amplifying, filtering, and modulating the frames onto a carrier for downlink transmission over the wireless medium through smart antennas **334**. The smart antennas **334** may be implemented with beam steering bidirectional adaptive antenna arrays or other similar beam technologies.

At the UE **350**, a receiver **354** receives the downlink transmission through an antenna **352** and processes the transmission to recover the information modulated onto the carrier. The information recovered by the receiver **354** is provided to

a receive frame processor **360**, which parses each frame, and provides the midamble **214** (FIG. **2**) to a channel processor **394** and the data, control, and reference signals to a receive processor **370**. The receive processor **370** then performs the inverse of the processing performed by the transmit processor **320** in the node B **310**. More specifically, the receive processor **370** descrambles and despreads the symbols, and then determines the most likely signal constellation points transmitted by the node B **310** based on the modulation scheme. These soft decisions may be based on channel estimates computed by the channel processor **394**. The soft decisions are then decoded and deinterleaved to recover the data, control, and reference signals. The CRC codes are then checked to determine whether the frames were successfully decoded. The data carried by the successfully decoded frames will then be provided to a data sink **372**, which represents applications running in the UE **350** and/or various user interfaces (e.g., display). Control signals carried by successfully decoded frames will be provided to a controller/processor **390**. When frames are unsuccessfully decoded by the receive processor **370**, the controller/processor **390** may also use an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support retransmission requests for those frames.

In the uplink, data from a data source **378** and control signals from the controller/processor **390** are provided to a transmit processor **380**. The data source **378** may represent applications running in the UE **350** and various user interfaces (e.g., keyboard). Similar to the functionality described in connection with the downlink transmission by the node B **310**, the transmit processor **380** provides various signal processing functions including CRC codes, coding and interleaving to facilitate FEC, mapping to signal constellations, spreading with OVSFs, and scrambling to produce a series of symbols. Channel estimates, derived by the channel processor **394** from a reference signal transmitted by the node B **310** or from feedback contained in the midamble transmitted by the node B **310**, may be used to select the appropriate coding, modulation, spreading, and/or scrambling schemes. The symbols produced by the transmit processor **380** will be provided to a transmit frame processor **382** to create a frame structure. The transmit frame processor **382** creates this frame structure by multiplexing the symbols with a midamble **214** (FIG. **2**) from the controller/processor **390**, resulting in a series of frames. The frames are then provided to a transmitter **356**, which provides various signal conditioning functions including amplification, filtering, and modulating the frames onto a carrier for uplink transmission over the wireless medium through the antenna **352**.

The uplink transmission is processed at the node B **310** in a manner similar to that described in connection with the receiver function at the UE **350**. A receiver **335** receives the uplink transmission through the antenna **334** and processes the transmission to recover the information modulated onto the carrier. The information recovered by the receiver **335** is provided to a receive frame processor **336**, which parses each frame, and provides the midamble **214** (FIG. **2**) to the channel processor **344** and the data, control, and reference signals to a receive processor **338**. The receive processor **338** performs the inverse of the processing performed by the transmit processor **380** in the UE **350**. The data and control signals carried by the successfully decoded frames may then be provided to a data sink **339** and the controller/processor, respectively. If some of the frames were unsuccessfully decoded by the receive processor, the controller/processor **340** may also use an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support retransmission requests for those frames.

The controller/processors **340** and **390** may be used to direct the operation at the node B **310** and the UE **350**, respectively. For example, the controller/processors **340** and **390** may provide various functions including timing, peripheral interfaces, voltage regulation, power management, and other control functions. The computer readable media of memory **392** may store data and software for the UE **350**. For example, the memory **392** of the UE **350** may store a system frame number (SFN) management module **391** which, when executed by the controller/processor **390**, configures the UE **350** for recording a relative system frame number difference between a serving RAT and a target RAT during an IRAT measurement.

System Frame Number (SFN) Handling for Circuit-Switched Fallback (CSFB)

Some networks, such as a newly deployed network, may cover only a portion of a geographical area. Another network, such as an older more established network, may better cover the area, including remaining portions of the geographical area. FIG. **4** illustrates coverage of a newly deployed network, such as an LTE network and also coverage of a more established network, such as a TD-SCDMA network. A geographical area **400** may include LTE cells **402** and TD-SCDMA cells **404**. A user equipment (UE) **406** may move from one cell, such as a TD-SCDMA cell **404**, to another cell, such as an LTE cell **402**. The movement of the UE **406** may specify a handover or a cell reselection.

Handover from a first radio access technology (RAT) to a second RAT may occur for several reasons. First, the network may prefer to have the user equipment (UE) use the first RAT as a primary RAT and to use the second RAT for only a specific function, such as for only voice service(s). Second, there may be coverage holes in the network of one of the RATs. The handover from the first RAT to the second RAT may be based on measurement reporting.

Redirection from one RAT to another RAT commonly occurs, for example, to implement load balancing. Redirection may also be utilized to implement circuit-switched fallback (CSFB) from one RAT, such as Long Term Evolution (LTE) to a second RAT, such as Universal Mobile Telecommunications System (UMTS) frequency division duplex (FDD), UMTS time division duplex (TDD), or GSM.

Circuit-switched fallback is a feature that enables multimode UEs that have, for example, third generation (3G)/second generation (2G) network capabilities in addition to LTE capabilities, to have circuit switched (CS) voice services while being camped on an LTE network. A circuit-switched fallback capable UE may initiate a mobile-originated (MO) circuit-switched (CS) voice call while on LTE. This results in the UE being moved to a circuit-switched capable radio access network (RAN), such as a 3G or 2G network for CS voice call setup. A circuit-switched fallback capable UE may be paged for a mobile-terminated (MT) voice call while on LTE, resulting in the UE being moved to a 3G or 2G network for circuit-switched voice call setup.

Various methods are utilized in attempt to reduce latency that occurs during circuit-switched fallback call (CFSB) setup. For example, system information block (SIB) tunneling and deferred measurement control reading (DMCR) may be introduced to reduce latency for call setup. For CSFB to UTRAN, the delay related to call setup may increase due to additional signaling on both the LTE and UTRAN sides. A substantial part of the call setup delay results from reading system information on the UTRAN prior to the access.

The following describes exemplary SIB tunneling and DMCR implementations that may be utilized to meet operator indicator specifications for call setup delay. In particular, for the DMCR implementation, the UE only reads SIBs 1, 3, 5 and 7 prior to accessing the UTRAN cell for CSFB. The other SIBs, including SIB 11, 12 and 19, are not read prior to accessing the UTRAN for CSFB. These SIBs (e.g., SIBs 11, 12 and 19) are read again once the UE returns to an idle mode on the UTRAN cell after the circuit-switched call setup has been terminated or the circuit-switched call has ended.

For the SIB tunneling implementation, all of the TD-SCDMA SIBs are carried in a radio resource control (RRC) release message from the LTE network. In this implementation, the UE skips reading all of the SIBs from the TD-SCDMA network. After the UE is redirected to the TD-SCDMA network by the LTE network, and during TD-SCDMA cell acquisition, the UE is only aware of a 5 ms sub-frame boundary. The UE, however, has to find a 20-40 ms transmission time interval (TTI) boundary after the UE is redirected. Thus, the UE locates the transmission time interval (TTI) boundary by blindly decoding the broadcast control channel (BCCH) without knowledge of the BCCH boundary. However, it takes about 30 to 100 ms for the UE to locate a 40 ms TTI boundary, which delays initiating of a random access procedure in TD-SCDMA.

Aspects of the present disclosure are directed to determining the TTI boundary in a more efficient manner, thereby reducing latency. In particular, in one aspect of the disclosure, because the system frame number (SFN) is the same for all TD-SCDMA cells, the network may indicate a SFN relative difference in the radio resource control (RRC) release message from the LTE network. The UE can find the TD-SCDMA SFN based on the relative difference between the LTE SFN and TD-SCDMA SFN, and then determine the TTI boundary. This implementation reduces the latency of CSFB to TD-SCDMA setup based on the SIB tunneling implementation.

In other aspects of the disclosure, the UE records the relative difference between the TD-SCDMA SFN and the LTE SFN during an IRAT measurement. After the UE is redirected to the TD-SCDMA network, the UE determines the TTI boundary based on its record. In this aspect, the UE skips the blind decoding of the broadcast control channel (BCCH) of a target RAT to read an SFN in order to determine the TTI boundary. This implementation also reduces the latency of CSFB to TD-SCDMA setup based on the SIB tunneling implementation.

In another aspect, the UE records the absolute SFN of a target RAT. After redirection, the UE determines the TTI boundary based on the recorded absolute SFN. In another aspect, the UE records the absolute SFN and/or relative difference between the TD-SCDMA SFN and the LTE SFN. The UE then determines the TTI boundary based on the recorded absolute SFN and/or the recorded relative SFN difference. The relative difference may be recorded while the UE is camped in the target RAT. Optionally, the relative difference may be recorded during and IRAT measurement.

FIG. **5** is a call flow diagram **500** illustrating example communications of a UE **502** between a TD-SCDMA cell **504** and LTE cell **506**. At time **510**, the UE **502** is connected to/camped on the LTE cell **506** and is in an idle or connected mode. While in idle/connected mode, the UE **502** performs IRAT measurements, at time **512**.

In a first configuration, the UE records the TD-SCDMA SFN relative difference between the TD-SCDMA network and LTE network while performing the IRAT measurements.

At time **514**, the UE **502** receives an RRC connection release and is redirected to the TD-SCDMA network. In a second configuration, the RRC release message includes the SFN relative difference.

At time **516**, the UE **502** then returns to the TD-SCDMA cell **504** and determines the transmission time interval (TTI). In the first configuration, the determination is based on the recorded difference. In the second configuration, the determination is based on the relative difference signaled in the RRC connection release message.

FIG. **6** shows a wireless communication method **600** according to one aspect of the disclosure. A UE records an absolute system frame number (SFN) of a target radio access technology (RAT) and/or records the relative SFN difference between a serving RAT and a target RAT, at block **602**. The UE then determines a transmission time interval (TTI) boundary, after redirection, based the recorded absolute SFN and/or on the recorded relative difference, at block **604**.

FIG. **7** is a diagram illustrating an example of a hardware implementation for an apparatus **700** employing a processing system **714**. The processing system **714** may be implemented with a bus architecture, represented generally by the bus **724**. The bus **724** may include any number of interconnecting buses and bridges depending on the specific application of the processing system **714** and the overall design constraints. The bus **724** links together various circuits including one or more processors and/or hardware modules, represented by the processor **722** the modules **702**, **704**, and the non-transitory computer-readable medium **726**. The bus **724** may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

The apparatus includes a processing system **714** coupled to a transceiver **730**. The transceiver **730** is coupled to one or more antennas **720**. The transceiver **730** enables communication with various other apparatus over a transmission medium. The processing system **714** includes a processor **722** coupled to a non-transitory computer-readable medium **726**. The processor **722** is responsible for general processing, including the execution of software stored on the computer-readable medium **726**. The software, when executed by the processor **722**, causes the processing system **714** to perform the various functions described for any particular apparatus. The computer-readable medium **726** may also be used for storing data that is manipulated by the processor **722** when executing software.

The processing system **714** includes a recording module **702** for recording an absolute system frame number and/or recording relative system frame number difference. The processing system **714** includes a determining module **704** for determining a transmission time interval boundary based on the recording. The modules may be software modules running in the processor **722**, resident/stored in the computer-readable medium **726**, one or more hardware modules coupled to the processor **722**, or some combination thereof. The processing system **714** may be a component of the UE **350** and may include the memory **392**, and/or the controller/processor **390**.

In one configuration, an apparatus such as a UE is configured for wireless communication including means for recording. In one aspect, the recording means may be the controller/processor **390**, the memory **392**, the SFN management module **391**, recording module **702**, and/or the processing system **714** configured to perform the recording means. The UE is also configured to include means for determining. In one aspect, the determining means may be the controller/processor **390**, the memory **392**, SFN management module **391**, determining module **704** and/or the processing system **714** configured to perform the determining means. In one aspect the means functions recited by the aforementioned means. In another aspect, the aforementioned means may be a module or any apparatus configured to perform the functions recited by the aforementioned means.

Several aspects of a telecommunications system has been presented with reference to TD-SCDMA and LTE. As those skilled in the art will readily appreciate, various aspects described throughout this disclosure may be extended to other telecommunication systems, network architectures and communication standards. By way of example, various aspects may be extended to other UMTS systems such as W-CDMA, high speed downlink packet access (HSDPA), high speed uplink packet access (HSUPA), high speed packet access plus (HSPA+) and TD-CDMA. Various aspects may also be extended to systems employing Long Term Evolution (LTE) (in FDD, TDD, or both modes), LTE-Advanced (LTE-A) (in FDD, TDD, or both modes), CDMA2000, Evolution-Data Optimized (EV-DO), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Ultra-Wideband (UWB), Bluetooth, and/or other suitable systems. The actual telecommunication standard, network architecture, and/or communication standard employed will depend on the specific application and the overall design constraints imposed on the system.

Several processors have been described in connection with various apparatuses and methods. These processors may be implemented using electronic hardware, computer software, or any combination thereof. Whether such processors are implemented as hardware or software will depend upon the particular application and overall design constraints imposed on the system. By way of example, a processor, any portion of a processor, or any combination of processors presented in this disclosure may be implemented with a microprocessor, microcontroller, digital signal processor (DSP), a field-programmable gate array (FPGA), a programmable logic device (PLD), a state machine, gated logic, discrete hardware circuits, and other suitable processing components configured to perform the various functions described throughout this disclosure. The functionality of a processor, any portion of a processor, or any combination of processors presented in this disclosure may be implemented with software being executed by a microprocessor, microcontroller, DSP, or other suitable platform.

Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. The software may reside on a non-transitory computer-readable medium. A computer-readable medium may include, by way of example, memory such as a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., compact disc (CD), digital versatile disc (DVD)), a smart card, a flash memory device (e.g., card, stick, key drive), random access memory (RAM), read only memory (ROM), programmable ROM (PROM), erasable PROM (EPROM), electrically erasable PROM (EEPROM), a register, or a removable disk. Although memory is shown separate from the processors in the various aspects presented throughout this disclosure, the memory may be internal to the processors (e.g., cache or register).

Computer-readable media may be embodied in a computer-program product. By way of example, a computer-program product may include a computer-readable medium in packaging materials. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

It is to be understood that the specific order or hierarchy of steps in the methods disclosed is an illustration of exemplary processes. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the methods may be rearranged. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented unless specifically recited therein.

The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. A phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover: a; b; c; a and b; a and c; b and c; and a, b and c. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for."

What is claimed is:

1. A method of wireless communication, comprising:

Recording, by a user equipment (UE), an absolute system frame number (SFN) of a target radio access technology (RAT) and/or a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT; and

determining, by the UE, a transmission time interval (TTI) boundary, after redirection, based at least in part on the recorded absolute system frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

2. The method of claim **1**, further comprising skipping blind decoding of a broadcast control channel (BCCH) in the target RAT to read a SFN to determine the TTI boundary.

3. The method of claim **1**, in which the serving RAT is Long Term Evolution (LTE).

4. The method of claim **1**, in which the target RAT is time division-synchronous code division multiple access (TD-SCDMA).

5. The method of claim **1**, further comprising storing the recorded difference.

6. The method of claim **1**, in which recording the SFN difference occurs while camped in the target RAT.

7. The method of claim **1**, in which recording the SFN difference occurs during an inter-radio access technology (IRAT) measurement.

8. An apparatus for wireless communication, comprising:

means for recording an absolute system frame number (SFN) of a target radio access technology (RAT) and/or a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT; and

means for determining a transmission time interval (TTI) boundary, after redirection, based at least in part on the recorded absolute system frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

9. The apparatus of claim **8**, further comprising means for skipping blind decoding of a broadcast control channel (BCCH) in the target RAT to read a SFN to determine the TTI boundary.

10. The apparatus of claim **8**, in which the serving RAT is Long Term Evolution (LTE).

11. The apparatus of claim **8**, in which the target RAT is time division-synchronous code division multiple access (TD-SCDMA).

12. The apparatus of claim **8**, further comprising means for storing the recorded difference.

13. The apparatus of claim **8**, in which the means for recording the SFN difference occurs while camped in the target RAT.

14. The apparatus of claim **8**, in which the means for recording the SFN difference occurs during an inter-radio access technology (IRAT) measurement.

15. A non-transitory computer-readable medium having program code recorded thereon, the program code comprising:

program code to record an absolute system frame number (SFN) of a target radio access technology (RAT) and/or to record a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT; and

program code to determine a transmission time interval (TTI) boundary, after redirection, based at least in part on the recorded absolute system frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

16. The non-transitory computer-readable medium of claim **15**, further comprising program code to skip blind decoding of a broadcast control channel (BCCH) in the target RAT to read a SFN to determine the TTI boundary.

17. The non-transitory computer-readable medium of claim **15**, in which the serving RAT is Long Term Evolution (LTE).

18. The non-transitory computer-readable medium of claim **15**, in which the target RAT is time division-synchronous code division multiple access (TD-SCDMA).

19. The non-transitory computer-readable medium of claim **15**, further comprising program code to store the recorded difference.

20. The non-transitory computer-readable medium of claim **15**, in which the program code to record is further configured to record the SFN difference while a user equipment (UE) is camped in the target RAT.

21. The non-transitory computer-readable medium of claim **15**, in which the program code to record is further configured to record the SFN difference during an inter-radio access technology (IRAT) measurement.

22. An apparatus for wireless communication, comprising:

a memory; and

at least one processor coupled to the memory, the at least one processor being configured:

to record an absolute system frame number (SFN) of a target radio access technology (RAT) and/or to record a relative system frame number (SFN) difference between a serving radio access technology (RAT) and the target RAT; and

to determine a transmission time interval (TTI) boundary, after redirection, based at least in part on the recorded absolute system frame number (SFN) and/or the recorded relative system frame number (SFN) difference.

23. The apparatus of claim **22**, in which the at least one processor is further configured to skip blind decoding of a broadcast control channel (BCCH) in the target RAT to read a SFN to determine the TTI boundary.

24. The apparatus of claim **22**, in which the serving RAT is Long Term Evolution (LTE).

25. The apparatus of claim **22**, in which the target RAT is time division-synchronous code division multiple access (TD-SCDMA).

26. The apparatus of claim **22**, in which the at least one processor is further configured to store the recorded difference.

27. The apparatus of claim **22**, in which the at least one processor is configured to record the SFN difference occurs while a user equipment (UE) is camped in the target RAT.

28. The apparatus of claim **22**, in which the at least one processor is configured to record the SFN difference during an inter-radio access technology (IRAT) measurement.

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