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(54) **Title**: SERVICE CONTINUITY FOR GROUP COMMUNICATIONS OVER EVOLVED MULTIMEDIA BROADCAST MULTICAST SERVICE

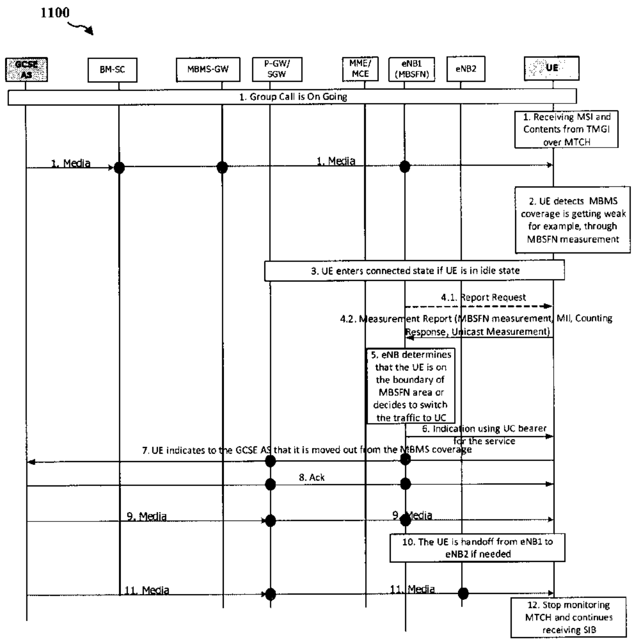

FIG. 11

(57) **Abstract**: A method, a user equipment (UE), and a computer program product for maintaining continuity of evolved multimedia broadcast multicast service (e MBMS) broadcast service at the user equipment (UE) are disclosed. The UE detects insufficient eMBMS coverage at the UE, where the UE is receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service. The UE receives at least one MBSFN threshold from the network and at least one MBSFN measurement from the network, and determines whether to switch from broadcast to unicast for continued reception of the eMBMS broadcast content based on the at least one MBSFN threshold and the at least one MBSFN measurement.

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SERVICE CONTINUITY FOR GROUP COMMUNICATIONS OVER EVOLVED MULTIMEDIA BROADCAST MULTICAST SERVICE

BACKGROUND

Field

[0001] The present disclosure relates generally to communication systems, and more particularly, to service continuity for group communications over evolved multimedia broadcast multicast service (eMBMS).

Background

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power). Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example of an emerging telecommunication standard is Long Term Evolution (LTE). LTE is a set of enhancements to the Universal Mobile Telecommunications System (UMTS) mobile standard promulgated by Third Generation Partnership Project (3GPP). It is designed to better support mobile broadband Internet access by improving spectral efficiency, lowering costs, improving services, making use of new spectrum, and better integrating with other open standards using OFDMA on the downlink (DL), SC-FDMA on the uplink (UL), and multiple-input multiple-output (MIMO) antenna technology. However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in LTE technology. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0004] Methods, apparatuses, and computer program products for maintaining continuity of group communications over evolved multimedia broadcast multicast service (eMBMS) broadcast service are disclosed.

[0005] In one aspect, the apparatus may be a UE. The UE detects insufficient eMBMS coverage at the UE, where the UE is receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service. The UE receives at least one MBSFN threshold from the network and at least one MBSFN measurement from the network, and determines whether to switch from broadcast to unicast for continued reception of the eMBMS broadcast content based on the at least one MBSFN threshold and the at least one MBSFN measurement.

[0006] In another aspect, the apparatus may be a network element, such as a base station of a network within an MFSFN area supporting the eMBMS broadcast service. The base station receives at least one parameter from a UE, while the UE is in a connected state. The base station determines whether the UE should switch from broadcast to unicast for continued reception of eMBMS broadcast service content, based on the at least one parameter. The base station indicates to the UE to switch to a unicast reception mode to continue receiving the content, and transmits the content over a unicast channel through the base station. In one configuration, the base station, prior to receiving the at least one parameter, triggers the UE to enter the connected state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a diagram illustrating an example of a network architecture.

[0008] FIG. 2 is a diagram illustrating an example of an access network.

[0009] FIG. 3 is a diagram illustrating an example of a DL frame structure in LTE.

[0010] FIG. 4 is a diagram illustrating an example of an UL frame structure in LTE.

[0011] FIG. 5 is a diagram illustrating an example of a radio protocol architecture for the user and control planes.

[0012] FIG. 6 is a diagram illustrating an example of an evolved Node B and user equipment in an access network.

[0013] FIG. 7A is a diagram illustrating an example of an evolved Multimedia Broadcast Multicast Service channel configuration in a Multicast Broadcast Single Frequency Network.

[0014] FIG. 7B is a diagram illustrating a format of a Multicast Channel Scheduling Information Media Access Control control element.

[0015] FIG. 8 is a diagram illustrating an example of a network architecture including a group communication service enabler (GCSE) application server.

[0016] FIG. 9A is a diagram illustrating a first case of a broadcast to broadcast scenario wherein a same frequency is used for both eMBMS cell and non-eMBMS cell.

[0017] FIG. 9B is a diagram illustrating a second case of a broadcast-to-broadcast scenario wherein a same frequency is used for different eMBMS service.

[0018] FIG. 10 is a call flow diagram illustrating a baseline solution for BC-to-UC service continuity when a UE is moving out of eMBMS coverage.

[0019] FIG. 11 is a call flow diagram illustrating a make-before-break, UE-assisted network based solution for maintaining service continuity when moving out from eMBMS coverage.

[0020] FIG. 12 is a call flow diagram illustrating a make-before-break, full network based solution for maintaining service continuity when moving out from eMBMS coverage.

[0021] FIG. 13 is a call flow diagram illustrating a make-before-break solution for maintaining service continuity when moving out from eMBMS coverage with the anchor at the BM-SC.

[0022] FIG. 14 is a flow chart of a method of wireless communication.

[0023] FIG. 15 is a conceptual data flow diagram illustrating the data flow between different modules/means/components in an exemplary apparatus.

[0024] FIG. 16 is a diagram illustrating an example of a hardware implementation for an apparatus employing a processing system.

DETAILED DESCRIPTION

[0025] 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 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.

[0026] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, modules, components, circuits, steps, processes, algorithms, etc. (collectively referred to as "elements"). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0027] By way of example, an element, or any portion of an element, or any combination of elements may be implemented with a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. 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.

[0028] Accordingly, in one or more exemplary embodiments, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), compact disk ROM (CD-ROM) or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Disk and disc, as used herein, includes CD, laser disc, optical disc, digital versatile disc (DVD), and floppy disk where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media.

[0029] FIG. 1 is a diagram illustrating an LTE network architecture 100. The LTE network architecture 100 may be referred to as an Evolved Packet System (EPS) 100. The EPS 100 may include one or more user equipment (UE) 102, an Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) 104, an Evolved Packet Core (EPC) 110, and an Operator's Internet Protocol (IP) Services 122. The EPS can interconnect with other access networks, but for simplicity those entities/interfaces are not shown. As shown, the EPS provides packet-switched services, however, as those skilled in the art will readily appreciate, the various concepts presented throughout this disclosure may be extended to networks providing circuit-switched services.

[0030] The E-UTRAN includes the evolved Node B (eNB) 106, other eNBs 108, and a Multicast Coordination Entity (MCS) 128. The eNB 106 provides user and control planes protocol terminations toward the UE 102. The eNB 106 may be connected to the other eNBs 108 via a backhaul (e.g., an X2 interface). The MCE 128 allocates time/frequency radio resources for evolved Multimedia Broadcast Multicast Service (MBMS) (eMBMS), and determines the radio configuration (e.g., a modulation and coding scheme (MCS)) for the eMBMS. The MCE 128 may be a separate entity or part of the eNB 106. The eNB 106 may also be referred to as a base station, a Node B, an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), or some other suitable terminology. The eNB 106 provides an access point to the EPC 110 for a UE 102. Examples of UEs 102 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, or any other similar functioning device. The UE 102 may also be referred to by those skilled in the art as a mobile station, 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, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0031] The eNB 106 is connected to the EPC 110. The EPC 110 may include a Mobility Management Entity (MME) 112, a Home Subscriber Server (HSS) 120, other MMEs 114, a Serving Gateway 116, a Multimedia Broadcast Multicast Service (MBMS) Gateway 124, a Broadcast Multicast Service Center (BM-SC) 126, and a Packet Data Network (PDN) Gateway 118. The MME 112 is the control node that processes the signaling between the UE 102 and the EPC 110. Generally, the MME 112 provides bearer and connection management. All user IP packets are transferred through the Serving Gateway 116, which itself is connected to the PDN Gateway 118. The PDN Gateway 118 provides UE IP address allocation as well as other functions. The PDN Gateway 118 and the BM-SC 126 are connected to the IP Services 122. The IP Services 122 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service (PSS), and/or other IP services. The BM-SC 126 may provide functions for MBMS user service provisioning and delivery. The BM-SC 126 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a PLMN, and may be used to schedule and deliver MBMS transmissions. The MBMS Gateway 124 may be used to distribute MBMS traffic to the eNBs (e.g., 106, 108) belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

[0032] FIG. 2 is a diagram illustrating an example of an access network 200 in an LTE network architecture. In this example, the access network 200 is divided into a number of cellular regions (cells) 202. One or more lower power class eNBs 208 may have cellular regions 210 that overlap with one or more of the cells 202. The lower power class eNB 208 may be a femto cell (e.g., home eNB (HeNB)), pico cell, micro cell, or remote radio head (RRH). The macro eNBs 204 are each assigned to a respective cell 202 and are configured to provide an access point to the EPC 110 for all the UEs 206 in the cells 202. There is no centralized controller in this example of an access network 200, but a centralized controller may be used in alternative configurations. The eNBs 204 are responsible for all radio related functions including radio bearer control, admission control, mobility control, scheduling, security, and connectivity to the serving gateway 116. An eNB may support one or multiple (e.g., three) cells (also referred to as a sector). The term "cell" can refer to the smallest coverage area of an eNB and/or an eNB subsystem serving are particular coverage area. Further, the terms "eNB," "base station," and "cell" may be used interchangeably herein.

[0033] The modulation and multiple access scheme employed by the access network 200 may vary depending on the particular telecommunications standard being deployed. In LTE applications, OFDM is used on the DL and SC-FDMA is used on the UL to support both frequency division duplex (FDD) and time division duplex (TDD). As those skilled in the art will readily appreciate from the detailed description to follow, the various concepts presented herein are well suited for LTE applications. However, these concepts may be readily extended to other telecommunication standards employing other modulation and multiple access techniques. By way of example, these concepts may be extended to Evolution-Data Optimized (EV-DO) or Ultra Mobile Broadband (UMB). EV-DO and UMB are air interface standards promulgated by the 3rd Generation Partnership Project 2 (3GPP2) as part of the CDMA2000 family of standards and employs CDMA to provide broadband Internet access to mobile stations. These concepts may also be extended to Universal Terrestrial Radio Access (UTRA) employing Wideband-CDMA (W-CDMA) and other variants of CDMA, such as TD-SCDMA; Global System for Mobile Communications (GSM) employing TDMA; and Evolved UTRA (E-UTRA), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, and Flash-OFDM employing OFDMA. UTRA, E-UTRA, UMTS, LTE and GSM are described in documents from the 3GPP organization. CDMA2000 and UMB are described in documents from the 3GPP2 organization. The actual wireless communication standard and the multiple access technology employed will depend on the specific application and the overall design constraints imposed on the system.

[0034] The eNBs 204 may have multiple antennas supporting MIMO technology. The use of MIMO technology enables the eNBs 204 to exploit the spatial domain to support spatial multiplexing, beamforming, and transmit diversity. Spatial multiplexing may be used to transmit different streams of data simultaneously on the same frequency. The data streams may be transmitted to a single UE 206 to increase the data rate or to multiple UEs 206 to increase the overall system capacity. This is achieved by spatially precoding each data stream (i.e., applying a scaling of an amplitude and a phase) and then transmitting each spatially precoded stream through multiple transmit antennas on the DL. The spatially precoded data streams arrive at the UE(s) 206 with different spatial signatures, which enables each of the UE(s) 206 to recover the one or more data streams destined for that UE 206. On the UL, each UE 206 transmits a spatially precoded data stream, which enables the eNB 204 to identify the source of each spatially precoded data stream.

[0035] Spatial multiplexing is generally used when channel conditions are good. When channel conditions are less favorable, beamforming may be used to focus the transmission energy in one or more directions. This may be achieved by spatially precoding the data for transmission through multiple antennas. To achieve good coverage at the edges of the cell, a single stream beamforming transmission may be used in combination with transmit diversity.

[0036] In the detailed description that follows, various aspects of an access network will be described with reference to a MIMO system supporting OFDM on the DL. OFDM is a spread-spectrum technique that modulates data over a number of subcarriers within an OFDM symbol. The subcarriers are spaced apart at precise frequencies. The spacing provides "orthogonality" that enables a receiver to recover the data from the subcarriers. In the time domain, a guard interval (e.g., cyclic prefix) may be added to each OFDM symbol to combat inter-OFDM-symbol interference. The UL may use SC-FDMA in the form of a DFT-spread OFDM signal to compensate for high peak-to-average power ratio (PAPR).

[0037] FIG. 3 is a diagram 300 illustrating an example of a DL frame structure in LTE. A frame (10 ms) may be divided into 10 equally sized subframes. Each subframe may include two consecutive time slots. A resource grid may be used to represent two time slots, each time slot including a resource block. The resource grid is divided into multiple resource elements. In LTE, a resource block contains 12 consecutive subcarriers in the frequency domain and, for a normal cyclic prefix in each OFDM symbol, 7 consecutive OFDM symbols in the time domain, or 84 resource elements. For an extended cyclic prefix, a resource block contains 6 consecutive OFDM symbols in the time domain and has 72 resource elements. Some of the resource elements, indicated as R 302, 304, include DL reference signals (DL-RS). The DL-RS include Cell-specific RS (CRS) (also sometimes called common RS) 302 and UE-specific RS (UE-RS) 304. UE-RS 304 are transmitted only on the resource blocks upon which the corresponding physical DL shared channel (PDSCH) is mapped. The number of bits carried by each resource element depends on the modulation scheme. Thus, the more resource blocks that a UE receives and the higher the modulation scheme, the higher the data rate for the UE.

[0038] FIG. 4 is a diagram 400 illustrating an example of an UL frame structure in LTE. The available resource blocks for the UL may be partitioned into a data section and a control section. The control section may be formed at the two edges of the system bandwidth and may have a configurable size. The resource blocks in the control section may be assigned to UEs for transmission of control information. The data section may include all resource blocks not included in the control section. The UL frame structure results in the data section including contiguous subcarriers, which may allow a single UE to be assigned all of the contiguous subcarriers in the data section.

[0039] A UE may be assigned resource blocks 410a, 410b in the control section to transmit control information to an eNB. The UE may also be assigned resource blocks 420a, 420b in the data section to transmit data to the eNB. The UE may transmit control information in a physical UL control channel (PUCCH) on the assigned resource blocks in the control section. The UE may transmit only data or both data and control information in a physical UL shared channel (PUSCH) on the assigned resource blocks in the data section. A UL transmission may span both slots of a subframe and may hop across frequency.

[0040] A set of resource blocks may be used to perform initial system access and achieve UL synchronization in a physical random access channel (PRACH) 430. The PRACH 430 carries a random sequence and cannot carry any UL data/signaling. Each random access preamble occupies a bandwidth corresponding to six consecutive resource blocks. The starting frequency is specified by the network. That is, the transmission of the random access preamble is restricted to certain time and frequency resources. There is no frequency hopping for the PRACH. The PRACH attempt is carried in a single subframe (1 ms) or in a sequence of few contiguous subframes and a UE can make only a single PRACH attempt per frame (10 ms).

[0041] FIG. 5 is a diagram 500 illustrating an example of a radio protocol architecture for the user and control planes in LTE. The radio protocol architecture for the UE and the eNB is shown with three layers: Layer 1, Layer 2, and Layer 3. Layer 1 (L1 layer) is the lowest layer and implements various physical layer signal processing functions. The L1 layer will be referred to herein as the physical layer 506. Layer 2 (L2 layer) 508 is above the physical layer 506 and is responsible for the link between the UE and eNB over the physical layer 506.

[0042] In the user plane, the L2 layer 508 includes a media access control (MAC) sublayer 510, a radio link control (RLC) sublayer 512, and a packet data convergence protocol (PDCP) 514 sublayer, which are terminated at the eNB on the network side. Although not shown, the UE may have several upper layers above the L2 layer 508 including a network layer (e.g., IP layer) that is terminated at the PDN gateway 118 on the network side, and an application layer that is terminated at the other end of the connection (e.g., far end UE, server, etc.).

[0043] The PDCP sublayer 514 provides multiplexing between different radio bearers and logical channels. The PDCP sublayer 514 also provides header compression for upper layer data packets to reduce radio transmission overhead, security by ciphering the data packets, and handover support for UEs between eNBs. The RLC sublayer 512 provides segmentation and reassembly of upper layer data packets, retransmission of lost data packets, and reordering of data packets to compensate for out-of-order reception due to hybrid automatic repeat request (HARQ). The MAC sublayer 510 provides multiplexing between logical and transport channels. The MAC sublayer 510 is also responsible for allocating the various radio resources (e.g., resource blocks) in one cell among the UEs. The MAC sublayer 510 is also responsible for HARQ operations.

[0044] In the control plane, the radio protocol architecture for the UE and eNB is substantially the same for the physical layer 506 and the L2 layer 508 with the exception that there is no header compression function for the control plane. The control plane also includes a radio resource control (RRC) sublayer 516 in Layer 3 (L3 layer). The RRC sublayer 516 is responsible for obtaining radio resources (e.g., radio bearers) and for configuring the lower layers using RRC signaling between the eNB and the UE.

[0045] FIG. 6 is a block diagram of an eNB 610 in communication with a UE 650 in an access network. In the DL, upper layer packets from the core network are provided to a controller/processor 675. The controller/processor 675 implements the functionality of the L2 layer. In the DL, the controller/processor 675 provides header compression, ciphering, packet segmentation and reordering, multiplexing between logical and transport channels, and radio resource allocations to the UE 650 based on various priority metrics. The controller/processor 675 is also responsible for HARQ operations, retransmission of lost packets, and signaling to the UE 650.

[0046] The transmit (TX) processor 616 implements various signal processing functions for the L1 layer (i.e., physical layer). The signal processing functions include coding and interleaving to facilitate forward error correction (FEC) at the UE 650 and 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)). The coded and modulated symbols are then split into parallel streams. Each stream is then mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 674 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 650. Each spatial stream may then be provided to a different antenna 620 via a separate transmitter 618TX. Each transmitter 618TX may modulate an RF carrier with a respective spatial stream for transmission.

[0047] At the UE 650, each receiver 654RX receives a signal through its respective antenna 652. Each receiver 654RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 656. The RX processor 656 implements various signal processing functions of the L1 layer. The RX processor 656 may perform spatial processing on the information to recover any spatial streams destined for the UE 650. If multiple spatial streams are destined for the UE 650, they may be combined by the RX processor 656 into a single OFDM symbol stream. The RX processor 656 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the eNB 610. These soft decisions may be based on channel estimates computed by the channel estimator 658. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the eNB 610 on the physical channel. The data and control signals are then provided to the controller/processor 659.

[0048] The controller/processor 659 implements the L2 layer. The controller/processor can be associated with a memory 660 that stores program codes and data. The memory 660 may be referred to as a computer-readable medium. In the UL, the controller/processor 659 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover upper layer packets from the core network. The upper layer packets are then provided to a data sink 662, which represents all the protocol layers above the L2 layer. Various control signals may also be provided to the data sink 662 for L3 processing. The controller/processor 659 is also responsible for error detection using an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support HARQ operations.

[0049] In the UL, a data source 667 is used to provide upper layer packets to the controller/processor 659. The data source 667 represents all protocol layers above the L2 layer. Similar to the functionality described in connection with the DL transmission by the eNB 610, the controller/processor 659 implements the L2 layer for the user plane and the control plane by providing header compression, ciphering, packet segmentation and reordering, and multiplexing between logical and transport channels based on radio resource allocations by the eNB 610. The controller/processor 659 is also responsible for HARQ operations, retransmission of lost packets, and signaling to the eNB 610.

[0050] Channel estimates derived by a channel estimator 658 from a reference signal or feedback transmitted by the eNB 610 may be used by the TX processor 668 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 668 may be provided to different antenna 652 via separate transmitters 654TX. Each transmitter 654TX may modulate an RF carrier with a respective spatial stream for transmission.

[0051] The UL transmission is processed at the eNB 610 in a manner similar to that described in connection with the receiver function at the UE 650. Each receiver 618RX receives a signal through its respective antenna 620. Each receiver 618RX recovers information modulated onto an RF carrier and provides the information to a RX processor 670. The RX processor 670 may implement the L1 layer.

[0052] The controller/processor 675 implements the L2 layer. The controller/processor 675 can be associated with a memory 676 that stores program codes and data. The memory 676 may be referred to as a computer-readable medium. In the UL, the control/processor 675 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover upper layer packets from the UE 650. Upper layer packets from the controller/processor 675 may be provided to the core network. The controller/processor 675 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0053] FIG. 7A is a diagram 750 illustrating an example of an evolved MBMS (eMBMS) channel configuration in an MBSFN. The eNBs 752 in cells 752' may form a first MBSFN area and the eNBs 754 in cells 754' may form a second MBSFN area. The eNBs 752, 754 may each be associated with other MBSFN areas, for example, up to a total of eight MBSFN areas. A cell within an MBSFN area may be designated a reserved cell. Reserved cells do not provide multicast/broadcast content, but are time-synchronized to the cells 752', 754' and have restricted power on MBSFN resources in order to limit interference to the MBSFN areas. Each eNB in an MBSFN area synchronously transmits the same eMBMS control information and data. Each area may support broadcast, multicast, and unicast services. A unicast service is a service intended for a specific user, e.g., a voice call. A multicast service is a service that may be received by a group of users, e.g., a subscription video service. A broadcast service is a service that may be received by all users, e.g., a news broadcast. Referring to FIG. 7A, the first MBSFN area may support a first eMBMS broadcast service, such as by providing a particular news broadcast to UE 770. The second MBSFN area may support a second eMBMS broadcast service, such as by providing a different news broadcast to UE 760. Each MBSFN area supports a plurality of physical multicast channels (PMCH) (e.g., 15 PMCHs). Each PMCH corresponds to a multicast channel (MCH). Each MCH can multiplex a plurality (e.g., 29) of multicast logical channels. Each MBSFN area may have one multicast control channel (MCCH). As such, one MCH may multiplex one MCCH and a plurality of multicast traffic channels (MTCHs) and the remaining MCHs may multiplex a plurality of MTCHs.

[0054] A UE can camp on an LTE cell to discover the availability of eMBMS service access and a corresponding access stratum configuration. In a first step, the UE may acquire a system information block (SIB) 13 (SIB13). In a second step, based on the SIB13, the UE may acquire an MBSFN Area Configuration message on an MCCH. In a third step, based on the MBSFN Area Configuration message, the UE may acquire an MCH scheduling information (MSI) MAC control element. The SIB13 indicates (1) an MBSFN area identifier of each MBSFN area supported by the cell; (2) information for acquiring the MCCH such as an MCCH repetition period (e.g., 32, 64, …, 256 frames), an MCCH offset (e.g., 0, 1, …, 10 frames), an MCCH modification period (e.g., 512, 1024 frames), a signaling modulation and coding scheme (MCS), subframe allocation information indicating which subframes of the radio frame as indicated by repetition period and offset can transmit MCCH; and (3) an MCCH change notification configuration. There is one MBSFN Area Configuration message for each MBSFN area. The MBSFN Area Configuration message indicates both (1) a temporary mobile group identity (TMGI) and an optional session identifier of each MTCH identified by a logical channel identifier within the PMCH, (2) allocated resources (i.e., radio frames and subframes) for transmitting each PMCH of the MBSFN area and the allocation period (e.g., 4, 8, …, 256 frames) of the allocated resources for all the PMCHs in the area, and (3) an MCH scheduling period (MSP) (e.g., 8, 16, 32, …, or 1024 radio frames) over which the MSI MAC control element is transmitted.

[0055] FIG. 7B is a diagram 790 illustrating the format of an MSI MAC control element. The MSI MAC control element may be sent once each MSP. The MSI MAC control element may be sent in the first subframe of each scheduling period of the PMCH. The MSI MAC control element can indicate the stop frame and subframe of each MTCH within the PMCH. There may be one MSI per PMCH per MBSFN area.

[0056] FIG. 8 is a diagram illustrating an example of a network architecture including a group communication service enabler (GCSE) application server. A GCSE is a 3GPP feature enabling an application layer functionality to provide group communication service over E-UTRAN. A group communication service is intended to provide a fast and efficient mechanism to distribute the same content, to multiple users in a controlled manner through "group communication." Group communication corresponds to communication from transmitter group members to receiver group members. A transmitter group member is a group member of a GCSE group that is authorized to transmit ongoing or future group communications for that GCSE group. A receiver group member is a group member of a GCSE group that has expressed interest in receiving ongoing or future group communications of that GCSE group. As an example, the concept of group communications may be used in the operation of classical Land Mobile Radio (LMR) systems for, but not limited to, public safety organizations.

[0057] Group communication may have three service continuity scenarios. In a first scenario, referred to as a broadcast (BC) to unicast (UC) scenario, the UE is moving out of broadcast, e.g., eMBMS, coverage of a group communication which may be identified by a temporary mobile group identity (TMGI). In the broadcast-to-unicast scenario, the UE may be switched to a unicast, e.g., EPS, bearer, in order to continue receiving group communication.

[0058] In a second scenario, referred to as a BC-to-BC scenario, the UE moves from one eMBMS cell to a new eMBMS cell. The new eMBMS cell should support the TMGI of the UE's ongoing group communication. In this particular scenario, two special cases warrant consideration:

[0059] FIG. 9A is a diagram illustrating a first case of a broadcast-to-broadcast scenario wherein a same frequency is used for both an eMBMS cell and a non-eMBMS cell. In this case, a UE is moving from a first eMBMS cell transmitting eMBMS services associated with service area identification (SAI) 1 on a frequency F1, to a second cell transmitting non-eMBMS services on frequency F1.

[0060] FIG. 9B is a diagram illustrating a second case of a broadcast-to-broadcast scenario wherein a same frequency is used for different eMBMS services. In this case, a UE is moving from a first eMBMS cell transmitting an eMBMS service associated with service area identification (SAI) 1 on a frequency F1, to a second eMBMS cell transmitting another eMBMS service associated with service area identification (SAI) 2 on a frequency F1.

[0061] In a third scenario, referred to as a UC-to-BC scenario, the UE is moving into a broadcast coverage area of a group communication service. In the UC-to-BC scenario, the UE may be switched to a broadcast, e.g., eMBMS, bearer, in order to continue receiving the group communication.

[0062] Disclosed herein are improvements for BC-to-UC service continuity for group communications. Improvements for BC-to-BC service continuity for group communications are also disclosed.

[0063] FIG. 10 is a call flow diagram illustrating a baseline solution for BC-to-UC service continuity when a UE is moving out of an eMBMS coverage area providing a group communication. In step 1, the group communication (GC) call is ongoing. The UE is being served by eNB1 of an MBSFN area supporting an eMBMS service broadcasting the group communication. The UE receives the group communication service data/media from the content provider, e.g., the GCSE-AS, via an eMBMS bearer service.

[0064] In step 2, for make-before-break switching procedures, the UE detects that the UE is about to move out of the coverage area of the MBSFN area supporting the eMBMS service of the group communication. For example, the UE may detect that the eMBMS coverage is weak based on a measured signal strength that is marginal or below an acceptable threshold. The UE may detect such movement through one or more of the following implementation-specific methods. The UE may detect that the strength of the MBSFN signals being received from eNB1 participating in the SAI carrying the group communication has fallen below a threshold. For example, the UE can determine MBSFN RSRP/RSRQ/SINR thresholds based on an MCS configuration indicated in the MCCH. The UE may also detect such movement when the UE detects that the packet data loss rate associated with signals received from the eNB1 is increased or exceeds a certain loss rate.

[0065] In step 3, upon detecting weak eMBMS coverage when the UE is in an idle state, the UE enters the connected state by performing RRC connection procedures with the current serving eNB (e.g., eNB1). In step 4, the UE indicates to the GCSE-AS that the UE has moved out of the eMBMS coverage area. Such an indication may be provided through application signaling.

[0066] In step 5, the GSCE-AS sends an ACK to the UE through application signaling. In step 6, the UE receives the GC service data/media from the GCSE-AS via a unicast bearer through eNB1.

[0067] In step 7, a handoff of the UE from eNB1 to eNB2 occurs. eNB2 is not associated with the MBSFN area supporting an eMBMS service broadcasting the group communication. In step 8, the UE receives the GC service data/media from GCSE-AS via a unicast bearer through eNB2. In step 9, the UE stops receiving the MTCH associated with the eMBMS service, but continues receiving SIBs.

[0068] To further improve the service continuity performance of the baseline solution of FIG. 10, some optimizations can be performed. In one optimization, additional criteria for use by the UE in detecting weak eMBMS coverage and determining to switch to unicast are provided by the network to the UE. In another optimization, the decision to switch the UE from broadcast to unicast is performed by an eNB.

[0069] UE Assistance Optimization:

[0070] In this optimization, the network may send one or more of the following threshold parameters to the UE as assistance information for making a switching decision. These thresholds are used in addition to the thresholds used in step 2 of the baseline approach. In one implementation, the UE makes a preliminary decision based on the thresholds of step 2 and one or more confirming decisions based on the assistance information.

[0071] Proposal 1: MCE/eNB may send a MBSFN RSRP/RSRQ/SINR/BLER threshold to UE for switching preparation:

[0072] In one configuration, the assistance information may include one or more of a first MBSFN RSRP/RSRQ threshold, a first MBSFN SINR threshold and a first MBSFN BLER threshold or modulation coding scheme (MCS) that are used by the UE to prepare for switching from broadcast reception mode to unicast reception mode of the group communication. When any of the MBSFN RSRP/RSRQ/SINR measurements fall below the respective associated first threshold, or when the MBSFN BLER measurement exceeds the respective associated first threshold, the UE enters RRC CONNECTED state (as show in step 3 of FIG. 10) when the UE is in an RRC IDLE state.

[0073] Proposal 2: MCE/eNB sends MBSFN RSRP/RSRQ/SINR/BLER threshold to the UE to initiate BC-UC switching.

[0074] In this optimization, the assistance information may further include one or more of a second MBSFN RSRP/RSRQ threshold, a second MBSFN SINR threshold and a second MBSFN BLER threshold that are used by the UE to initiate BC-to-UC switching. These second thresholds may be used after the UE has entered a RRC CONNECTED state based on the first thresholds. The second MBSFN RSRP/RSRQ threshold and a second MBSFN SINR threshold may be less than their respective first thresholds, while the second MBSFN BLER threshold may be greater than the respective first threshold.

[0075] When any of the MBSFN RSRP/RSRQ measurements or MBSFN SINR measurements falls below the respective second threshold, or the MBSFN BLER measurement exceeds the second threshold , the UE sends an indication to the anchor node, e.g. GCSE AS (as show in step 4 of figure 1) requesting media delivery over unicast.

[0076] As noted above, the second MBSFN RSRP/RSRQ/SINR threshold is normally lower than the first threshold and the second MBSFN BLER threshold is normally higher than the first threshold. These differences between first and second thresholds may provide some protection time for the UE to perform switching while avoiding ping-ponging between UC and BC reception modes. The first and second thresholds can be per MBSFN area, per cell or per PMCH based. The per PMCH thresholds are similar to the current MCS configuration and may be per PMCH based.

[0077] The MCE can determine the first and second MBSFN RSRP/RSRQ/SINR/BLER thresholds and send them to all eNBs in an MBSFN area. The eNBs in turn, send the thresholds to the UE. The thresholds can be sent on the MCCH, as part of the information of a SIB, or via RRC dedicated signaling. The eNB may change the threshold per that eNB's local coverage status. (Note: the UE or the network can have a mapping table of SNR and MCS if MCS is used to indicate threshold to the UE.)

[0078] BC-to-UC switching decision at eNB:

[0079] In the baseline solution, the switching decision is made by UE. The eNB may, however, have additional information that can improve the group communication switching decisions. For example, the eNB may have: a counting result, measurement reports of MBSFN and/or unicast signal strength, and MBSFN coverage area information. Accordingly, improvements presented below include UE group communication switching decisions that are either partially or fully made at the network level, for example, by the eNB.

[0080] Proposal 3: eNB may send indication/command for UE to switch from BC to UC.

[0081] FIG. 11 is a call flow diagram illustrating a make-before-break UE-assisted network based solution for maintaining service continuity when moving out of eMBMS coverage for a group communication. In a UE-assisted solution, the eNB informs the UE to initiate switching from BC-to-UC reception mode of the group communication.

[0082] In step 1 the group communication call is ongoing. The UE is being served by eNB1 of an MBSFN area supporting an eMBMS service broadcasting the group communication. The UE receives the group communication service data/media from the content provider, e.g., the GCSE-AS, via an eMBMS bearer service.

[0083] In step 2, for make-before-break switching procedures, the UE itself detects that the UE is about to move out of the MBSFN coverage area supporting the eMBMS broadcast service of the group communication. For example, the UE may detect that the eMBMS coverage is weak. The UE may detect that the UE is moving outside of the eMBMS coverage area of the group communication through one or more of the following implementation-specific methods. The UE may detect that the strength of the MBSFN signals being received have become weak and fallen below a threshold. For example, the UE can determine MBSFN RSRP/RSRQ/SINR thresholds based on the MCS configuration indicated in the corresponding MCCH to initiate switching procedures. The UE may also detect moving outside of the coverage area (or at the boundary of the coverage area) by detecting that the packet data loss rate associated with eMBMS group communication signals increases above a threshold.

[0084] In step 3, upon detecting weak eMBMS coverage when the UE is in idle state, the UE enters the connected state by performing RRC connection procedures with the serving eNB (e.g., eNB1).

[0085] In step 4, the UE may autonomously send a report which may include MBMS interest indication (MII), a counting response, an MBSFN or unicast measurement report. Alternatively, the UE may receive a report request from the serving eNB1 that triggers the UE to send a counting response, an MBSFN or unicast measurement report based on MII received from the UE. Alternatively, the network, e.g., eNB1, may trigger the UE to send MII, a counting response, an MBSFN or unicast measurement by sending a request once the eNB detects that the UE has entered the RRC CONNECTED state.

[0086] In step 5, the eNB determines that the UE should switch from broadcast to unicast based on the report sent by the UE. For example, based on the information transmitted by the UE, the eNB may detect that the UE is at the boundary of the MBSFN area supporting the eMBMS service broadcasting the group communication. In step 6, the eNB indicates to the UE to use the unicast channel for the group communication service.

[0087] In step 7, the UE indicates to the GCSE-AS that it has moved out of the eMBMS coverage area of the group communication. Such indication may be provided through application signaling.

[0088] In step 8, the GSCE-AS sends an ACK to the UE through application signaling. In step 9, the UE receives the GC service data/media from the GCSE-AS via the unicast bearer through eNB1.

[0089] In step 10, a handoff of the UE is handoff from eNB1 to eNB2 occurs. The eNB2 is not an eNB of the MBSFN area supporting the group communication over an eMBMS broadcast service. In step 11, the UE receives the GC service data/media from GCSE-AS via the unicast bearer through eNB2. In step 12, the UE stops receiving the MTCH associated with the group communication carried via eMBMS and continues receiving SIBs.

[0090] FIG. 12 is a call flow diagram illustrating a make-before-break, full network based solution for maintaining service continuity when moving outside the coverage area of a group communication carried over eMBMS.

[0091] In step 1 the group communication call over eMBMS is ongoing. The UE is being served by eNB1 of an MBSFN area supporting an eMBMS service broadcasting the group communication. The UE receives the group communication service data/media from the content provider, e.g., the GCSE-AS, via an eMBMS bearer service.

[0092] In step 2, the eNB triggers UEs to enter the connected state. This may be based on, for example, one or more of the following methods: the eNB at the boundary of the MBSFN area sends SIB to indicate to the UEs to enter the connected state; the eNB at the boundary of the MBSFN area sends counting request or measurement request over MCCH; the eNB sends paging message to the UEs to indicate that the UE located in Cell ID x should enter connected state. The eNB sends a paging message to specific UEs based on UE's history and/or UE's location if known.

[0093] In step 3, upon detecting weak eMBMS coverage when the UE is in idle state, the UE enters the connected state by performing RRC connection procedures with the serving eNB, e.g., eNB1.

[0094] In step 4, the UE may autonomously send a report which may include MII, a counting response, an MBSFN or unicast measurement report. Alternatively, the UE may receive a report request from the serving eNB1 that triggers the UE to send a counting response, an MBSFN or unicast measurement report based on MII received from the UE. Alternatively, the network, e.g., eNB1, may trigger the UE to send MII, counting response, MBSFN or unicast measurement by sending a request once the eNB detects that the UE has entered the RRC CONNECTED state.

[0095] In step 5, the eNB determines that the UE should switch from broadcast to unicast reception mode of the group communication based on the report sent by the UE. For example, based on the information transmitted by the UE, the eNB may detect that the UE is at the boundary of the MBSFN area supporting the eMBMS service broadcasting the group communication. In step 6, the eNB indicates to the UE to use the unicast channel for the group communication service.

[0096] In step 7, the UE indicates to the GCSE-AS that it has moved outside the eMBMS coverage area broadcasting the group communication. Such indication may be provided through application signaling.

[0097] In step 8, the GSCE-AS sends an ACK to the UE through application signaling. In step 9, the UE receives the GC service data/media from the GCSE-AS via the unicast bearer through eNB1.

[0098] In step 10, a handoff of the UE from eNB1 to eNB2 occurs. The eNB2 may not be an eNB of an MBSFN area supporting an eMBMS broadcast service broadcasting the group communication. In step 11, the UE receives the GC service data/media from GCSE-AS via the unicast bearer through eNB2. In step 12, the UE stops receiving the corresponding MTCH associated with the eMBMS service broadcasting the group communication and continues receiving SIBs.

[0099] Proposal 4: Existing BM-SC based BC to UC fallback mechanism can be reused for group communication.

[00100] BC to UC switching with anchor at BM-SC

[00101] In the above solutions, the user plane switching anchor may be at the GCSE AS. Alternatively, the BM-SC may be the switching anchor to simplify the GCSE AS. When BC-to-UC switching of a group communication with a UE is needed, the UE sends a request to the BM-SC to receive media from the BM-SC via unicast bearer. The switching decision procedure can be the same as either of above solutions.

[00102] FIG. 13 is a call flow diagram illustrating a make-before-break solution for maintaining service continuity when moving outside the eMBMS coverage area of a group communication when the anchor is at the BM-SC.

[00103] In step 1 the group communication call via an eMBMS service is ongoing. The UE is being served by eNB1 of an MBSFN area supporting the eMBMS service broadcasting the group communication. The UE receives the group communication service data/media from the content provider, e.g., the GCSE-AS, via an eMBMS bearer service.

[00104] In step 2, UE or eNB decides to switch from BC to UC reception mode of the group communication. The switching decision procedure may be made in accordance with any of the above described solutions. For example, the decision may be entirely UE based, as described with respect to FIG. 10 and possibly with one or more of the assistance information also described. The decision may be network based with assistance from a UE, as described with respect to FIG. 11, or fully network based as described with respect to FIG. 12.

[00105] In step 3, instead of sending an indication to the GCSE AS as shown in FIGs 10-12, the UE connects to the URL associated with the TMGI of the eMBMS service broadcasting the group communication. The URL may be derived during eMBMS registration to the BM-SC. The UE may activate dedicated EPS bearer to carry the media. In step 4, the BM-SC acknowledges the request.

[00106] In step 5, the media is sent from the BM-SC to the UE over unicast. In step 6, a handover of the UE to eNB2 occurs. In step 7, the unicast media delivery continues via eNB2.

[00107] Proposal 5: UE may be enhanced to support M1 interface protocol to receive media from MBMS-GW directly.

[00108] BC-to-UC switching with anchor at MBMS-GW

[00109] In this solution, the UE is enhanced to support the M1 interface including GTP and SYNC protocols. When BC-to-UC switching is needed, the UE activates a dedicated EPS bearer for media transmission, if needed, and sends IPv4 IGMP Join or IPv6 MLD message to the MBMS-GW. Then, the MBMS-GW sends the media packets to the UE following the M1 protocol.

[00110] The multicast IP address of the TMGI on the MBMS-GW is sent to the UE in e.g. MCCH. Some security mechanism is provided for the MBMS-GW to safely receive IP multicast request from UE.

[00111] BC-to-BC

[00112] BC-to-BC across different MBSFN areas

[00113] When the UE moves from one MBSFN area to another MBSFN area with the same service supported, the UE may switch to the UC before moving to another MBSFN area using same procedures as specified above. Then the UE can switch back to BC when the UE fully enters the other MBSFN area. This procedure allows seamless transition from one MBSFN area to another.

[00114] Neighbor cell doesn’t support MBMS services of UE’s interest

[00115] Proposal 6: Add a new parameter TMGI (or TMGI list) to MII.

[00116] Proposal 7: In the area with the special cases as showed in FIG. 9A and FIG. 9B, the MCE/eNB shall send a MBSFN RSRP/RSRQ/SINR/BLER threshold for UE to enter RRC CONNECTED mode timely so that eNB can handover UE to the cell with UE desired TMGI.

[00117] SIB15 only provides frequency level information for UE. When same frequency is used for different purpose as shown in FIGs. 9A and 9B, the SIB15 cannot help. Accordingly, a UE in idle mode may reselect to a cell which doesn't have its desired TMGI. However, the eNB knows the services of each neighbor cell. So, for the two special cases of scenario 2, when the UE detects MBSFN RSRP/RSRQ/SINR is below the threshold received from eNB/MCE, the UE should enter RRC CONNECTED mode and send MII with TMGI to the eNB for the eNB to handover the UE to the correct cell when necessary.

[00118] FIG. 14 is a flow chart 1400 of a method of wireless communication. The method may be performed by a UE. At step 1402, the UE detects insufficient eMBMS coverage at the UE, where the UE is receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service. At step 1404, the UE receives at least one MBSFN threshold from the network. AT step 1406, the UE receives at least one MBSFN measurement from the network. Finally, at step 1106, the UE determines whether to switch from broadcast to unicast for continued receipt based on the at least one MBSFN threshold and the at least one MBSFN measurement.

[00119] FIG. 15 is a conceptual data flow diagram 1500 illustrating the data flow between different modules/means/components in an exemplary apparatus 1502. The apparatus may be a UE. The apparatus 1502 includes a receiving module 1504, an eMBMS coverage detection module 1506, an MBSFN threshold module 1508, and an MBSFN measurement module 1510, a BC-to-UC switch determination module 1512 and a transmission module 1514.

[00120] The receiving module 1504 receives signals from a network element 1550, e.g., base station, of a network within an MFSFN area supporting an eMBMS broadcast service that is broadcasting content of interest to the UE. The signals may correspond to, or provide information related to, one or more of eMBMS broadcast content, MBSFN thresholds, MBSFN measurements. The receiving module 1504 provides the eMBMS content signals to the eMBMS coverage detection module 1506, the MBSFN threshold signals to the MBSFN threshold module 1508, and the MBSFN measurement signals to the MBSFN measurement module 1510.

[00121] The eMBMS coverage detection module 1504 detects insufficient eMBMS coverage at the UE, based on the received eMBMS broadcast content. The MBSFN

threshold module 1508 processes the received threshold signals to provide thresholds to the BC-to-UC switch determination module 1512. Likewise, the MBSFN measurement module 1510 processes the MBSFN measurement signals to provide measurements to the BC-to-UC switch determination module 1512. The BC-to-UC switch determination module 1512 determines whether to switch from broadcast to unicast for continued receipt based on the at least one MBSFN threshold and the at least one MBSFN measurement. The transmission module 1514 outputs a signal to the network element 1550 indicating a switch from broadcast to uncast.

[00122] The apparatus may include additional modules that perform each of the steps of the algorithm in the aforementioned flow charts of FIG. 14. As such, each step in the aforementioned flow charts of FIG. 14 may be performed by a module and the apparatus may include one or more of those modules. The modules may be one or more hardware components specifically configured to carry out the stated processes/algorithm, implemented by a processor configured to perform the stated processes/algorithm, stored within a computer-readable medium for implementation by a processor, or some combination thereof.

[00123] FIG. 16 is a diagram 1300 illustrating an example of a hardware implementation for an apparatus 1502' employing a processing system 1614. The processing system 1614 may be implemented with a bus architecture, represented generally by the bus 1624. The bus 1624 may include any number of interconnecting buses and bridges depending on the specific application of the processing system 1614 and the overall design constraints. The bus 1624 links together various circuits including one or more processors and/or hardware modules, represented by the processor 1604, the modules 1504, 1506, 1508, 1510, 1512, 1514 and the computer-readable medium / memory 1606. The bus 1624 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.

[00124] The processing system 1614 may be coupled to a transceiver 1610. The transceiver 1610 is coupled to one or more antennas 1620. The transceiver 1610 provides a means for communicating with various other apparatus over a transmission medium. The transceiver 1610 receives a signal from the one or more antennas 1620, extracts information from the received signal, and provides the

extracted information to the processing system 1614, specifically the receiving module 1514. In addition, the transceiver 1610 receives information from the processing system 1614, specifically the transmission module 1514, and based on the received information, generates a signal to be applied to the one or more antennas 1620. The processing system 1614 includes a processor 1604 coupled to a computer-readable medium / memory 1606. The processor 1604 is responsible for general processing, including the execution of software stored on the computer-readable medium / memory 1606. The software, when executed by the processor 1604, causes the processing system 1614 to perform the various functions described *supra* for any particular apparatus. The computer-readable medium / memory 1606 may also be used for storing data that is manipulated by the processor 1604 when executing software. The processing system further includes at least one of the modules 1204, 1206, 1208, 1510, 1512, and 1514. The modules may be software modules running in the processor 1604, resident/stored in the computer readable medium / memory 1606, one or more hardware modules coupled to the processor 1604, or some combination thereof. The processing system 1614 may be a component of the UE 650 and may include the memory 660 and/or at least one of the TX processor 668, the RX processor 656, and the controller/processor 659.

[00125] In one configuration, the apparatus 1502/1502' for wireless communication includes means for detecting insufficient eMBMS coverage at the UE, the UE receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service; means for receiving at least one MBSFN threshold from the network; means for receiving at least one MBSFN measurement from the network; and means for determining whether to switch from broadcast to unicast for continued receipt based on the at least one MBSFN threshold and the at least one MBSFN measurement.

[00126] The aforementioned means may be one or more of the aforementioned modules of the apparatus 1502 and/or the processing system 1614 of the apparatus 1502' configured to perform the functions recited by the aforementioned means. As described *supra*, the processing system 1614 may include the TX Processor 668, the RX Processor 656, and the controller/processor 659. As such, in one configuration, the aforementioned means may be the TX Processor 668, the RX Processor 656, and

the controller/processor 659 configured to perform the functions recited by the aforementioned means.

[00127] It is understood that the specific order or hierarchy of steps in the processes / flow charts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes / flow charts may be rearranged. Further, some steps may be combined or omitted. 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.

[00128] 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 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.” The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects.” Unless specifically stated otherwise, the term “some” refers to one or more. Combinations such as “at least one of A, B, or C,” “at least one of A, B, and C,” and “A, B, C, or any combination thereof” include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “at least one of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or 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 as a means plus function unless the element is expressly recited using the phrase “means for.”

WHAT IS CLAIMED IS:

CLAIMS

1. A method of maintaining continuity of evolved multimedia broadcast multicast service (eMBMS) broadcast service at a user equipment (UE), said method comprising:

detecting insufficient eMBMS coverage at the UE, the UE receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service;

receiving at least one MBSFN threshold from the network;

receiving at least one MBSFN measurement from the network; and

determining whether to switch from broadcast to unicast for continued reception of the eMBMS broadcast content based on the at least one MBSFN threshold and the at least one MBSFN measurement.

2. The method of claim 1, wherein:

the at least one MBSFN threshold comprises one or more of a MBSFN RSRP/RSRQ threshold, a MBSFN SINR threshold and a MBSFN BLER threshold; and

the at least one MBSFN measurement comprises one or more of a MBSFN RSRP/RSRQ measurement, a MBSFN SINR measurement and a MBSFN BLER measurement.

3. The method of claim 1, wherein the at least one MBSFN threshold comprises a switching-preparation threshold and determining whether to switch from broadcast to unicast comprises switching to an RRC CONNECTED state when the at least on MBSFN measurement satisfies the MBSFN threshold and the UE is in an RRC IDLE state.

4. The method of claim 3, wherein the at least one MBSFN threshold further comprises a switching-initiation threshold and determining whether to switch from broadcast to unicast comprises requesting from a network element of the network, content delivery over a unicast channel.

5. The method of claim 4, wherein the network element comprises an application server and requesting comprises sending an indication to the application server.

6. The method of claim 4, wherein the network element comprises a BM-SC and requesting comprises connecting to the URL of the TMGI.

7. The method of claim 4, wherein the network element comprises a MBMS-GW and requesting comprises sending an IP multicast joining message to the MBMS-GW.

8. The method of claim 7, further comprising activating a dedicated EPS bearer for transmission of the eMBMS broadcast service content if UE doesn't have suitable EPS bearer for this purpose.

9. The method of claim 7, further comprising the UE receiving the MBMS-GW multicast address and related GTP parameters of the TMGI from the network.

10. The method of claim 7, further comprising implementing a necessary security mechanism for MBMS-GW to accept the IP multicast join message from UE.

11. The method of claim 1, further comprising:

switching from broadcast to unicast;

detecting sufficient eMBMS coverage at the UE, from a network within another MFSFN area supporting the eMBMS broadcast service; and

switching from unicast to broadcast for continued receipt of the content

12. The method of claim 1, wherein the at least one UE determined or network provided MBSFN threshold comprises a switching-preparation threshold and determining whether to switch from broadcast to unicast comprises:

switching to an RRC CONNECTED state when the at least on MBSFN measurement satisfies the MBSFN threshold and the UE is in an RRC IDLE state; and

sending a MBMS interest indication (MII) with the TMGI and/or SAI list corresponding to the eMBMS service of interest.

13. A user equipment (UE) for maintaining continuity of evolved multimedia broadcast multicast service (eMBMS) broadcast service at the user equipment (UE), said UE comprising:

means for detecting insufficient eMBMS coverage at the UE, the UE receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service;

means for receiving at least one MBSFN threshold from the network;

means for receiving at least one MBSFN measurement from the network; and

means for determining whether to switch from broadcast to unicast for continued reception of the eMBMS broadcast content based on the at least one MBSFN threshold and the at least one MBSFN measurement.

14. A user equipment (UE) for maintaining continuity of evolved multimedia broadcast multicast service (eMBMS) broadcast service at the user equipment (UE), said UE comprising:

a memory; and

a processor coupled to the memory and configured to:

detect insufficient eMBMS coverage at the UE, the UE receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service;

receive at least one MBSFN threshold from the network;

receive at least one MBSFN measurement from the network; and

determine whether to switch from broadcast to unicast for continued reception of the eMBMS broadcast content based on the at least one MBSFN threshold and the at least one MBSFN measurement.

15. A method of maintaining continuity of evolved multimedia broadcast multicast service (eMBMS) broadcast service at a user equipment (UE), said method comprising:

receiving at a base station of a network within an MFSFN area supporting the eMBMS broadcast service, at least one parameter from the UE, while the UE is in a connected state;

determining whether the UE should switch from broadcast to unicast for continued reception of eMBMS broadcast service content, based on the at least one parameter;

indicating to the UE to switch to unicast reception mode to continue receiving the content; and transmitting the content over a unicast channel through the base station.

16. The method of claim 15, further comprising:

prior to receiving the at least one parameter, triggering the UE to enter the connected state.

17. An apparatus for maintaining continuity of evolved multimedia broadcast multicast service (eMBMS) broadcast service at a user equipment (UE), said apparatus comprising:

means for receiving at a base station of a network within an MFSFN area supporting the eMBMS broadcast service, at least one parameter from the UE, while the UE is in a connected state;

means for determining whether the UE should switch from broadcast to unicast for continued reception of eMBMS broadcast service content, based on the at least one parameter;

means for indicating to the UE to switch to unicast reception mode to continue receiving the content; and

means for transmitting the content over a unicast channel through the base station.

18. An apparatus for maintaining continuity of evolved multimedia broadcast multicast service (eMBMS) broadcast service at a user equipment (UE), said apparatus comprising:

a memory; and

a processor coupled to the memory and configured to:

receive at a base station of a network within an MFSFN area supporting the eMBMS broadcast service, at least one parameter from the UE, while the UE is in a connected state;

determine whether the UE should switch from broadcast to unicast for continued reception of eMBMS broadcast service content, based on the at least one parameter;

indicate to the UE to switch to unicast reception mode to continue receiving the content; and transmit the content over a unicast channel through the base station.

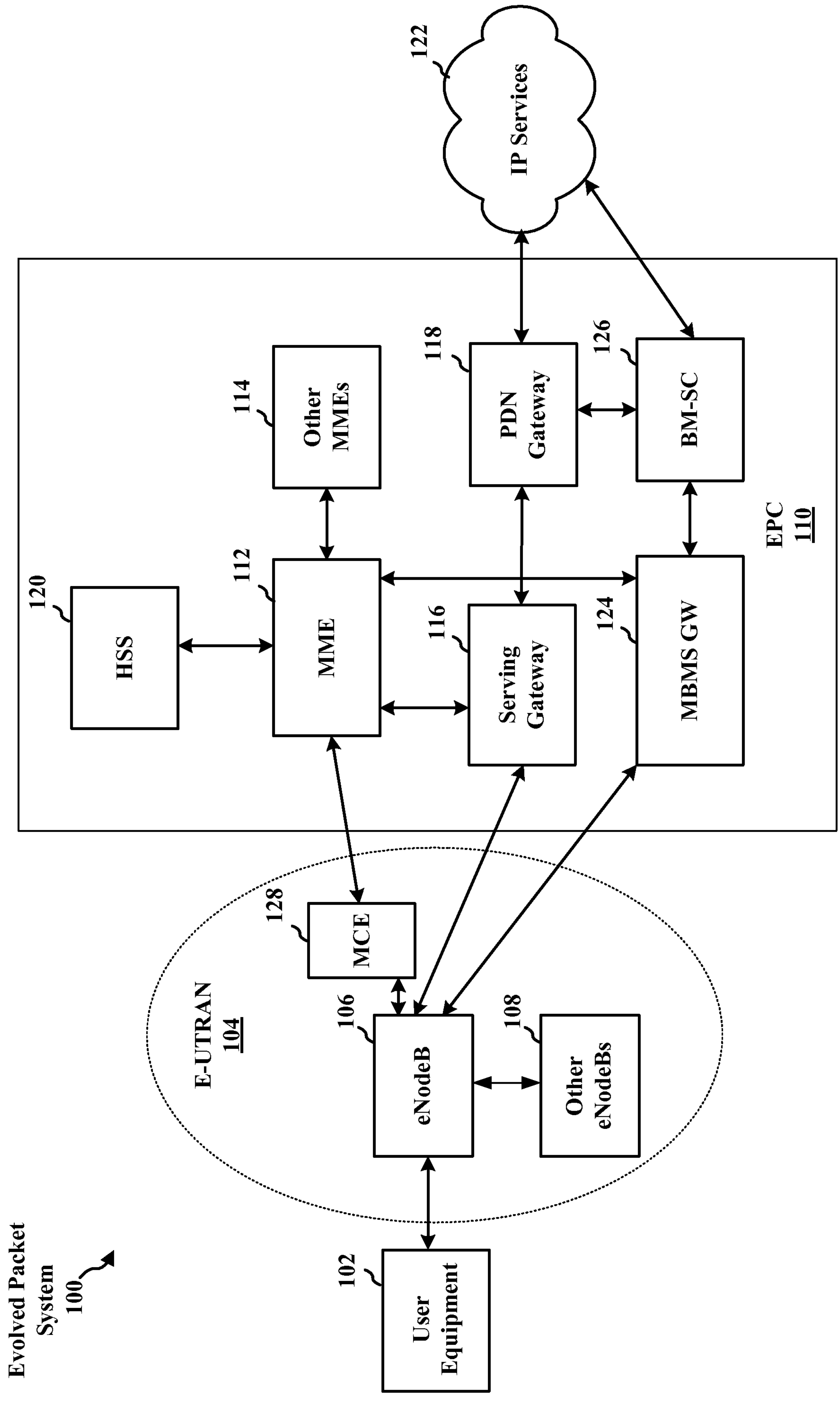
Evolved Packet System
100
User Equipment
102
E-UTRAN
104
eNodeB
106
Other eNodeBs
108
MCE
128
EPC
110
HSS
120
MME
112
Other MMEs
114
Serving Gateway
116
PDN Gateway
118
MBMS GW
124
BM-SC
126
IP Services
122

FIG. 1

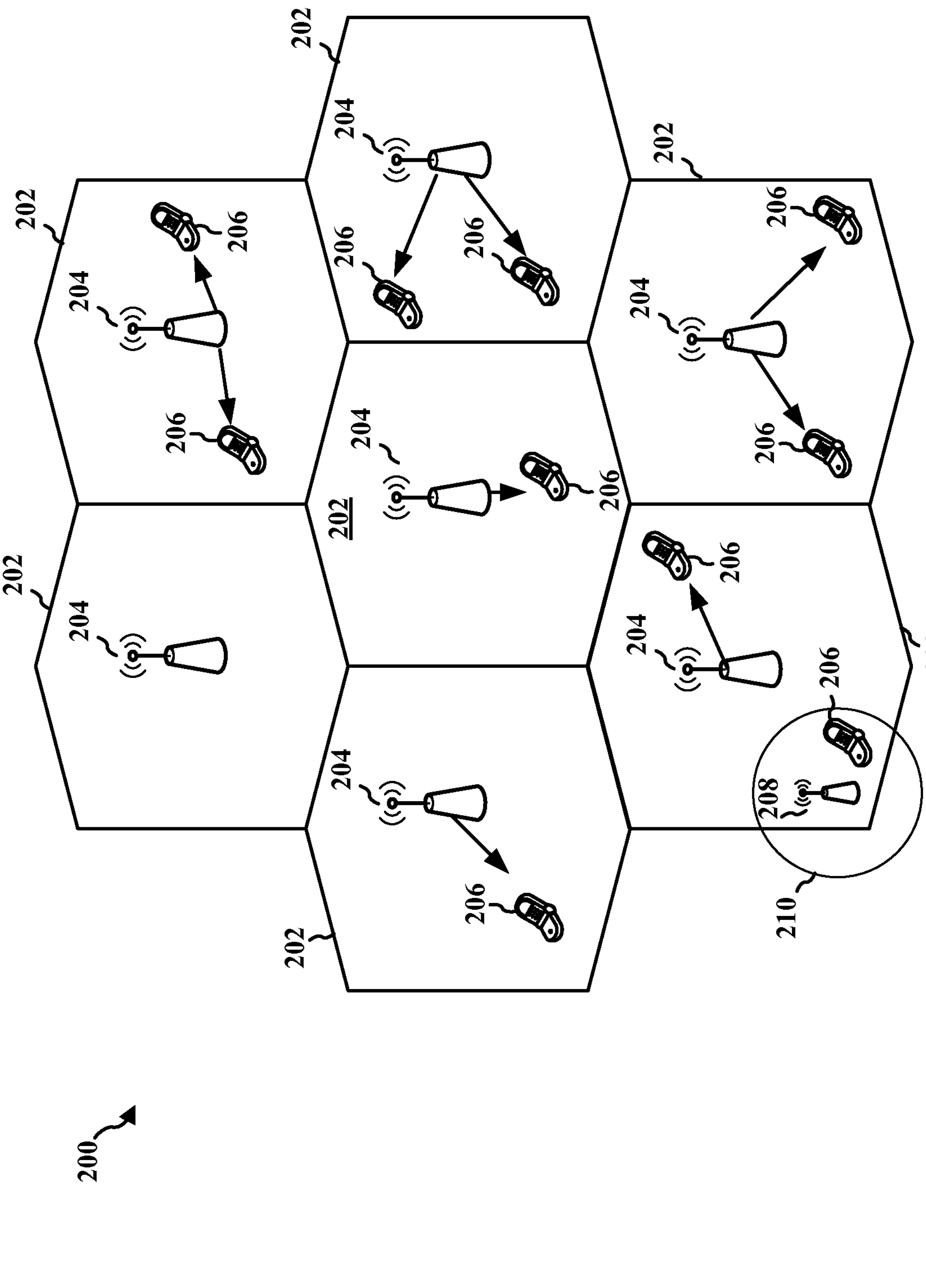

FIG. 2

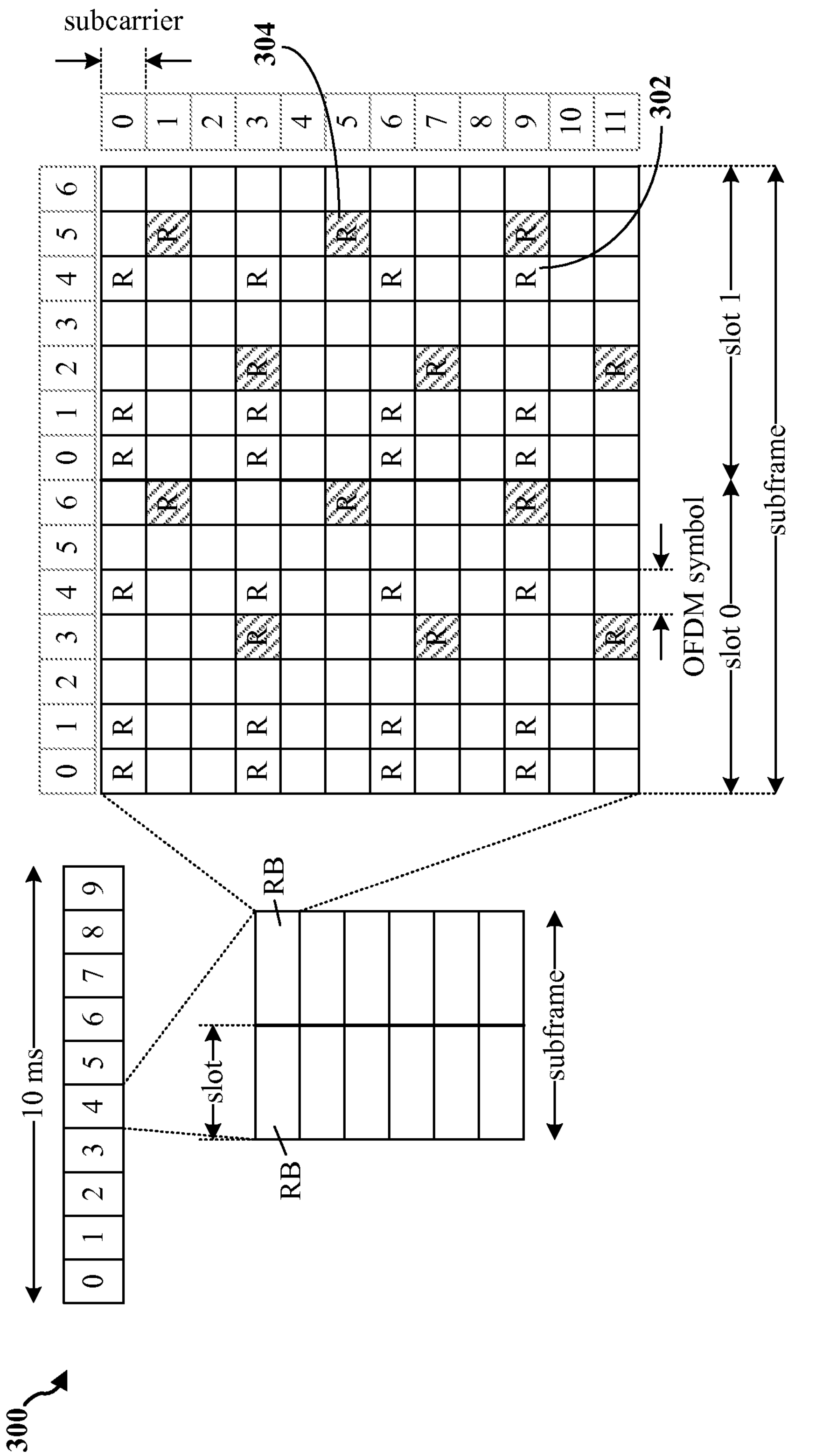
300
10 ms
0 1 2 3 4 5 6 7 8 9
RB
slot
subframe
subcarrier
304
302
OFDM symbol
slot 0
slot 1
subframe

FIG. 3

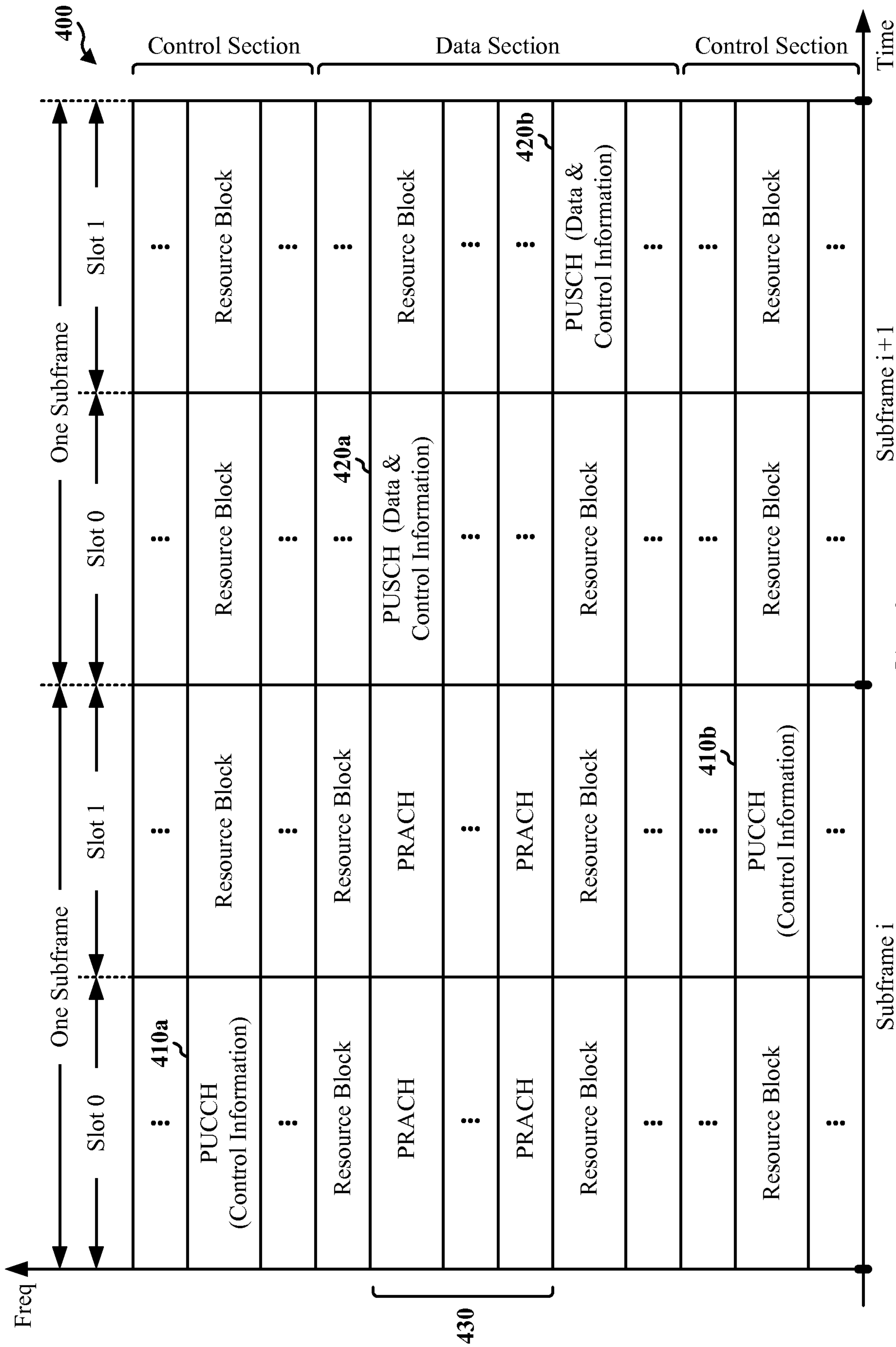
400
Control Section
Data Section
Control Section
Time
Freq
One Subframe
One Subframe
Slot 0
Slot 1
Slot 0
Slot 1
Resource Block
PUCCH (Control Information)
410a
410b
PRACH
PUSCH (Data & Control Information)
420a
420b
Subframe i
Subframe i + 1
430

FIG. 4

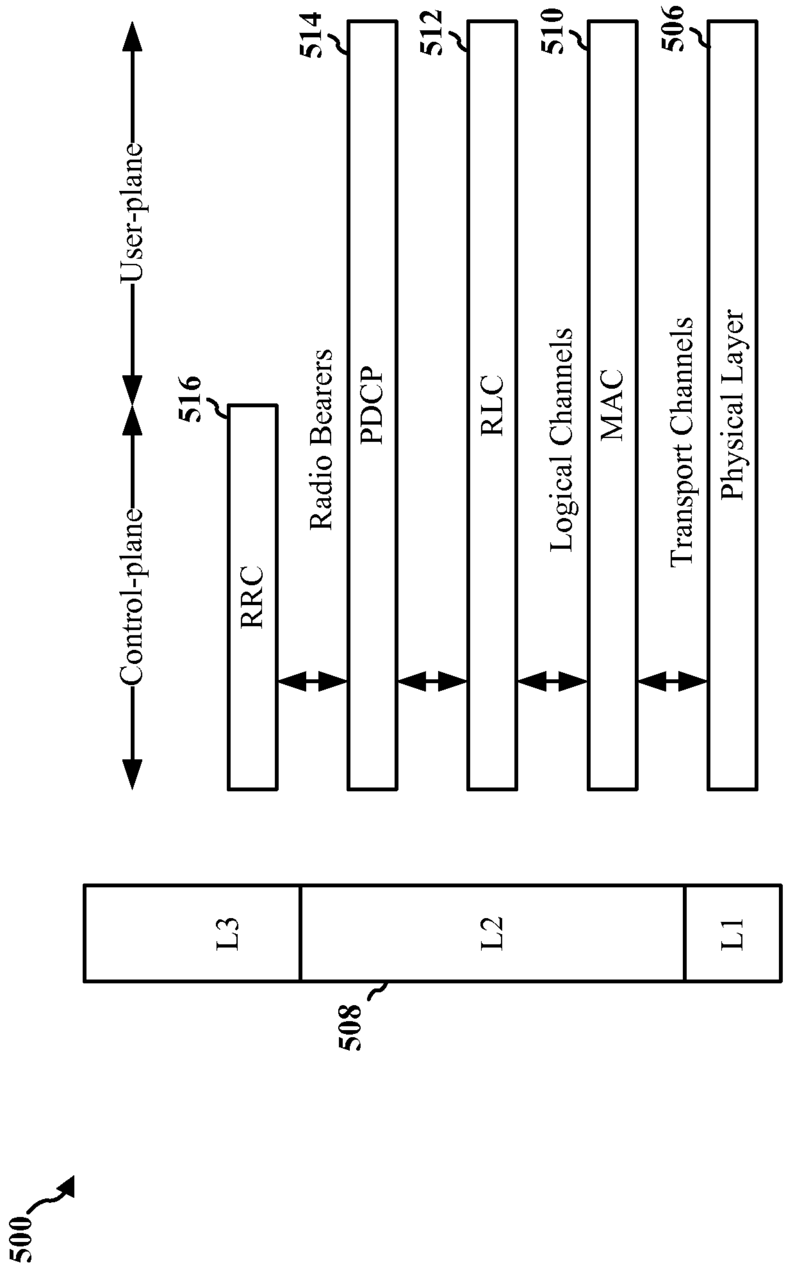
500
Control-plane
User-plane
516
RRC
Radio Bearers
514
PDCP
512
RLC
Logical Channels
510
MAC
Transport Channels
506
Physical Layer
L3
L2
L1
508

FIG. 5

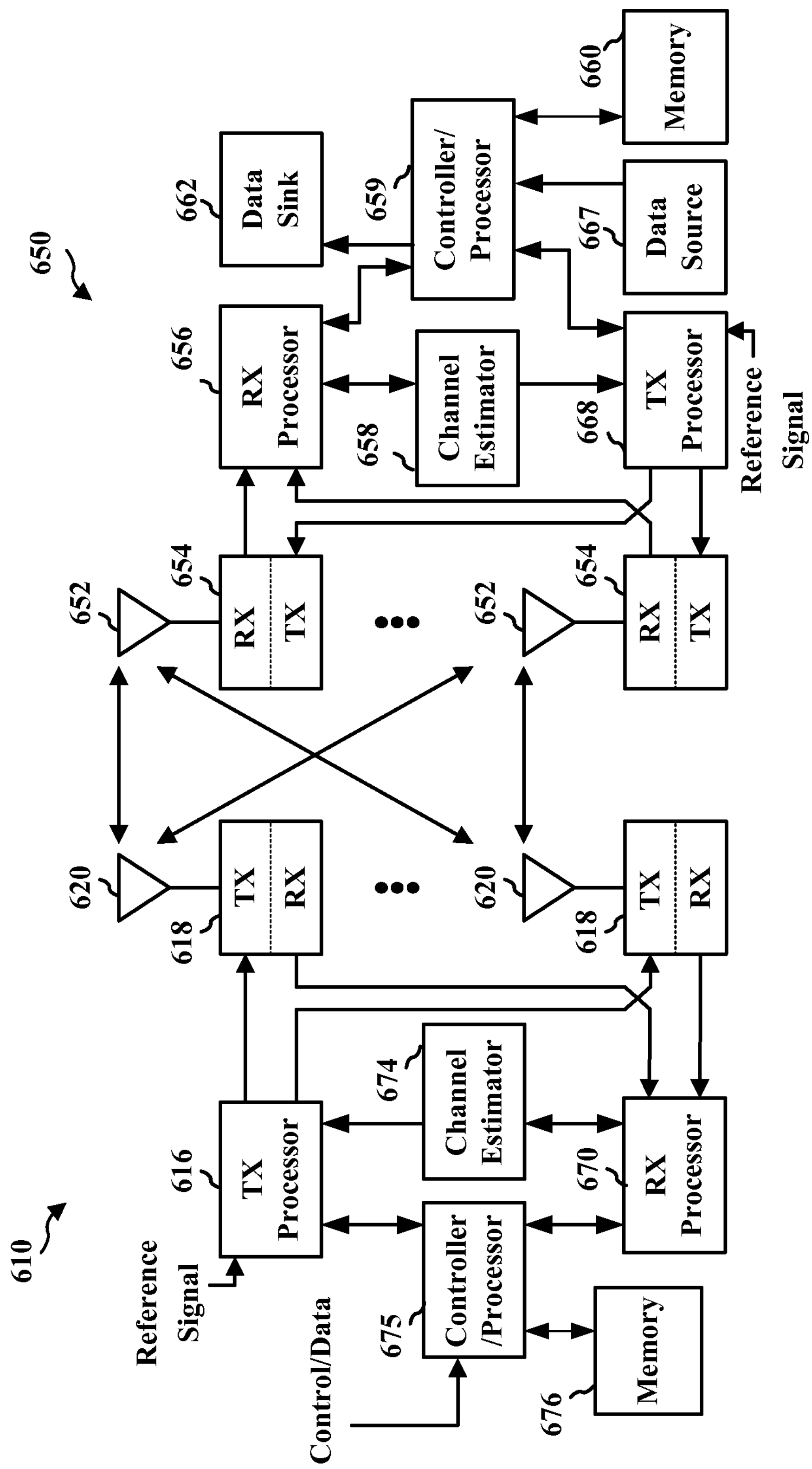
650
662
Data Sink
659
Controller/ Processor
660
Memory
667
Data Source
656
RX Processor
658
Channel Estimator
668
TX Processor
Reference Signal
652
654
RX
TX
652
654
RX
TX
620
618
TX
RX
620
618
TX
RX
610
616
TX Processor
674
Channel Estimator
670
RX Processor
Reference Signal
675
Controller /Processor
Control/Data
676
Memory

FIG. 6

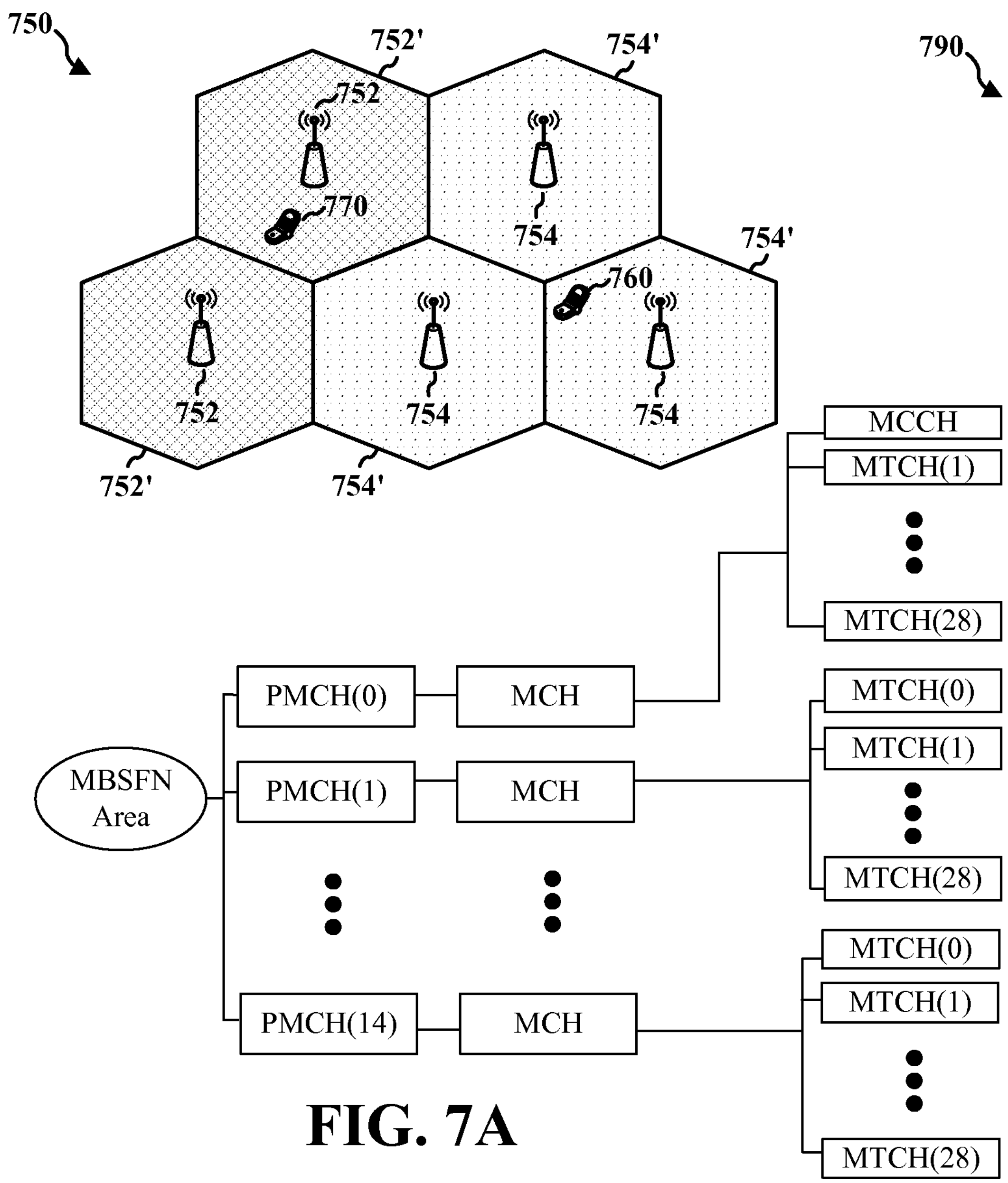
750
752'
752
770
754'
754
754'
760
754
752
754
752'
754'
MBSFN Area
PMCH(0)
PMCH(1)
PMCH(14)
MCH
MCH
MCH
MCCH
MTCH(1)
MTCH(28)
MTCH(0)
MTCH(1)
MTCH(28)
MTCH(0)
MTCH(1)
MTCH(28)

FIG. 7A

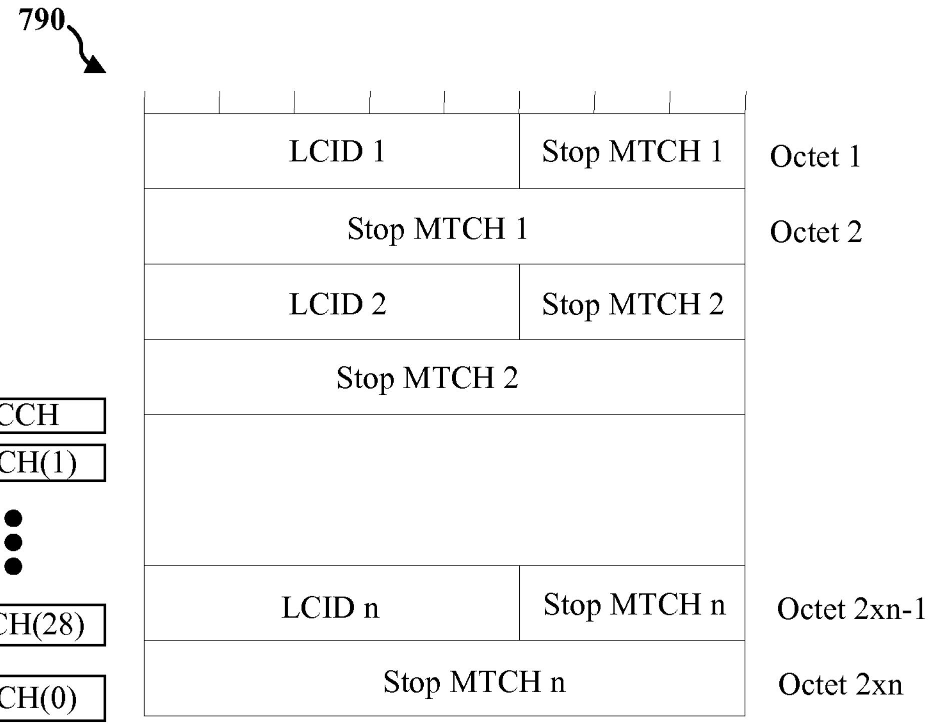
790
LCID 1
Stop MTCH 1
Octet 1
Stop MTCH 1
Octet 2
LCID 2
Stop MTCH 2
Stop MTCH 2
LCID n
Stop MTCH n
Octet 2xn-1
Stop MTCH n
Octet 2xn

FIG. 7B

800

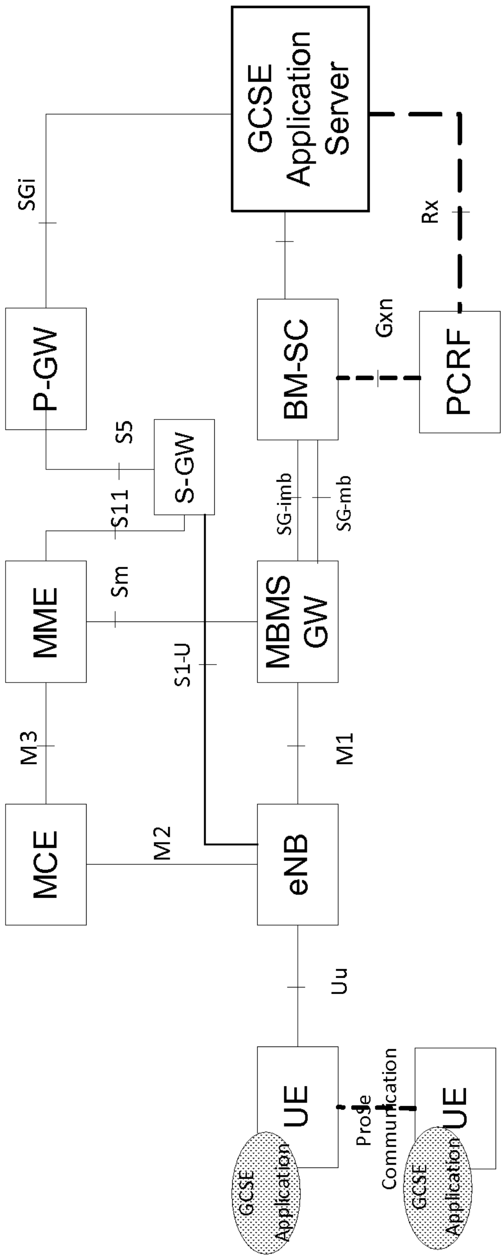
GCSE Application Server
SGi
P-GW
S5
S-GW
S11
MME
Sm
MBMS GW
BM-SC
SG-imb
SG-mb
Gxn
PCRF
Rx
M3
M1
S1-U
MCE
M2
eNB
Uu
UE
UE
Prose Communication
GCSE Application
GCSE Application

FIG. 8

900

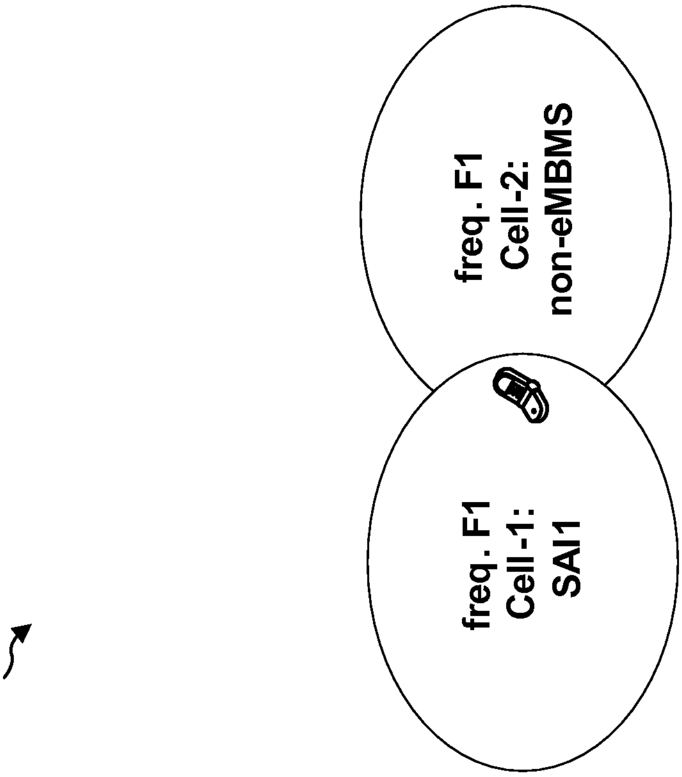

FIG. 9A

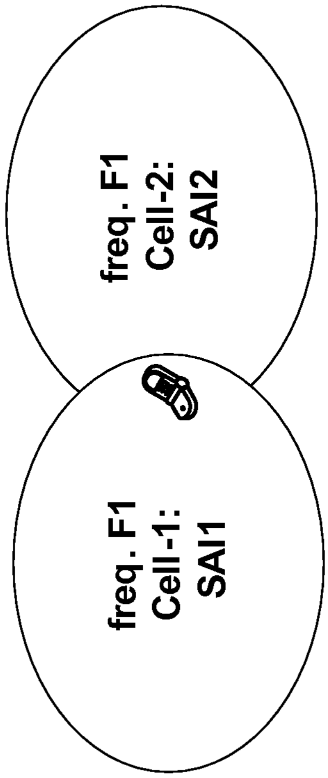

FIG. 9B

1000

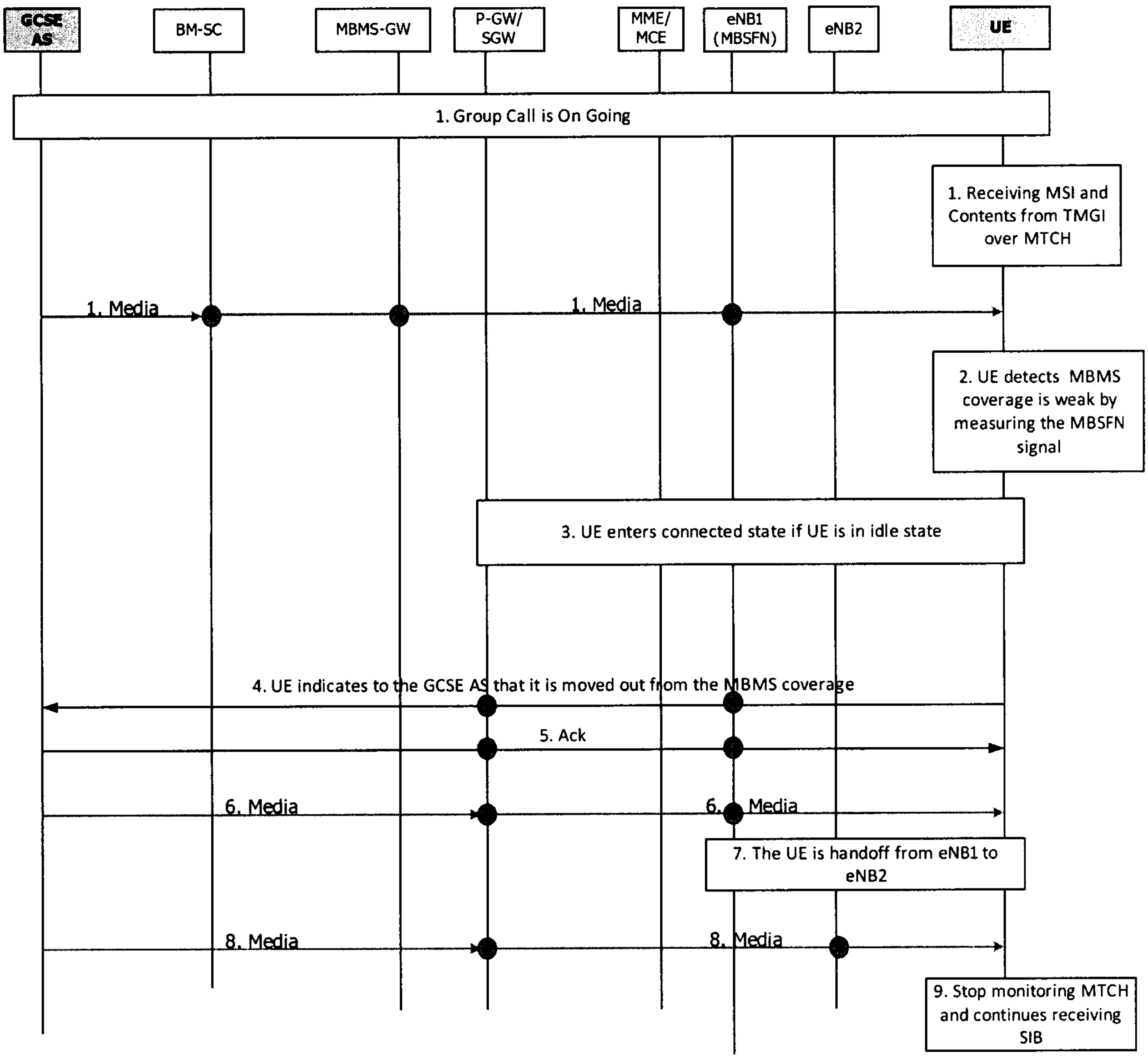
GCSE AS
BM-SC
MBMS-GW
P-GW/ SGW
MME/ MCE
eNB1 (MBSFN)
eNB2
UE
1. Group Call is On Going
1. Receiving MSI and Contents from TMGI over MTCH
1. Media
1. Media
2. UE detects MBMS coverage is weak by measuring the MBSFN signal
3. UE enters connected state if UE is in idle state
4. UE indicates to the GCSE AS that it is moved out from the MBMS coverage
5. Ack
6. Media
6. Media
7. The UE is handoff from eNB1 to eNB2
8. Media
8. Media
9. Stop monitoring MTCH and continues receiving SIB

FIG. 10

1100

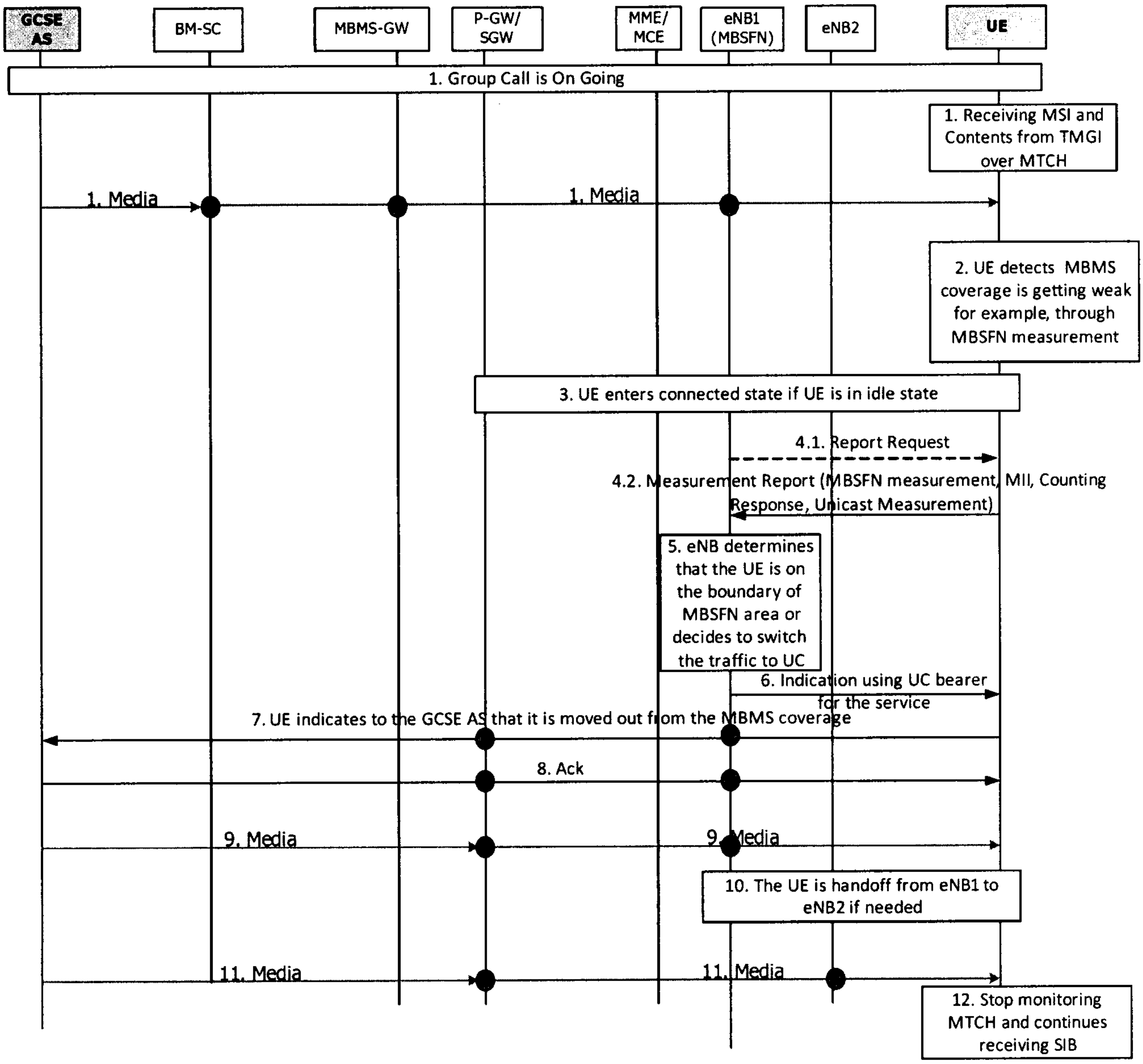
GCSE AS
BM-SC
MBMS-GW
P-GW/ SGW
MME/ MCE
eNB1 (MBSFN)
eNB2
UE
1. Group Call is On Going
1. Receiving MSI and Contents from TMGI over MTCH
1. Media
1. Media
2. UE detects MBMS coverage is getting weak for example, through MBSFN measurement
3. UE enters connected state if UE is in idle state
4.1. Report Request
4.2. Measurement Report (MBSFN measurement, MII, Counting Response, Unicast Measurement)
5. eNB determines that the UE is on the boundary of MBSFN area or decides to switch the traffic to UC
6. Indication using UC bearer for the service
7. UE indicates to the GCSE AS that it is moved out from the MBMS coverage
8. Ack
9. Media
9. Media
10. The UE is handoff from eNB1 to eNB2 if needed
11. Media
11. Media
12. Stop monitoring MTCH and continues receiving SIB

FIG. 11

1200

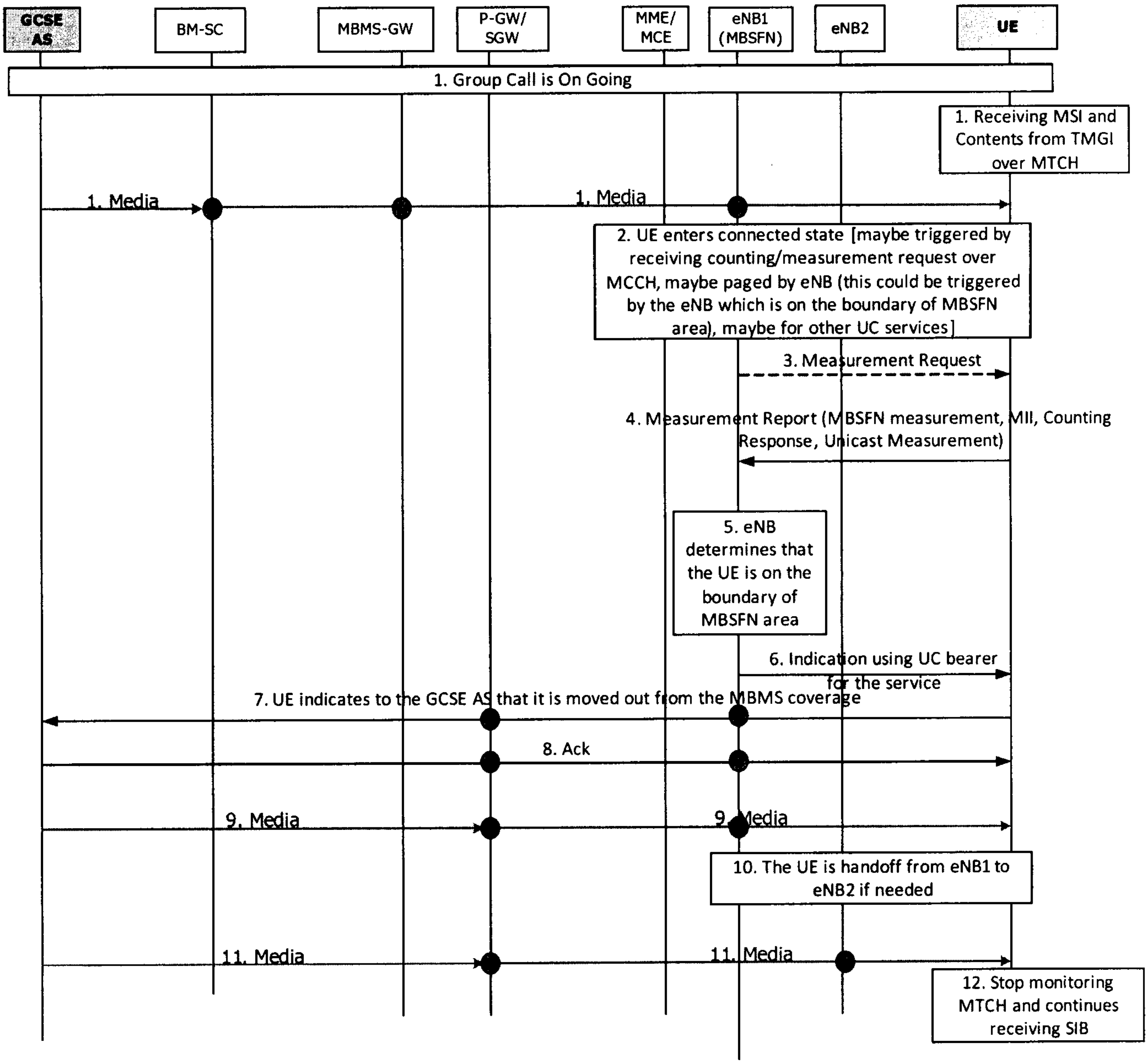
GCSE AS
BM-SC
MBMS-GW
P-GW/ SGW
MME/ MCE
eNB1 (MBSFN)
eNB2
UE
1. Group Call is On Going
1. Receiving MSI and Contents from TMGI over MTCH
1. Media
1. Media
2. UE enters connected state [maybe triggered by receiving counting/measurement request over MCCH, maybe paged by eNB (this could be triggered by the eNB which is on the boundary of MBSFN area), maybe for other UC services]
3. Measurement Request
4. Measurement Report (MBSFN measurement, MII, Counting Response, Unicast Measurement)
5. eNB determines that the UE is on the boundary of MBSFN area
6. Indication using UC bearer for the service
7. UE indicates to the GCSE AS that it is moved out from the MBMS coverage
8. Ack
9. Media
9. Media
10. The UE is handoff from eNB1 to eNB2 if needed
11. Media
11. Media
12. Stop monitoring MTCH and continues receiving SIB

FIG. 12

1300

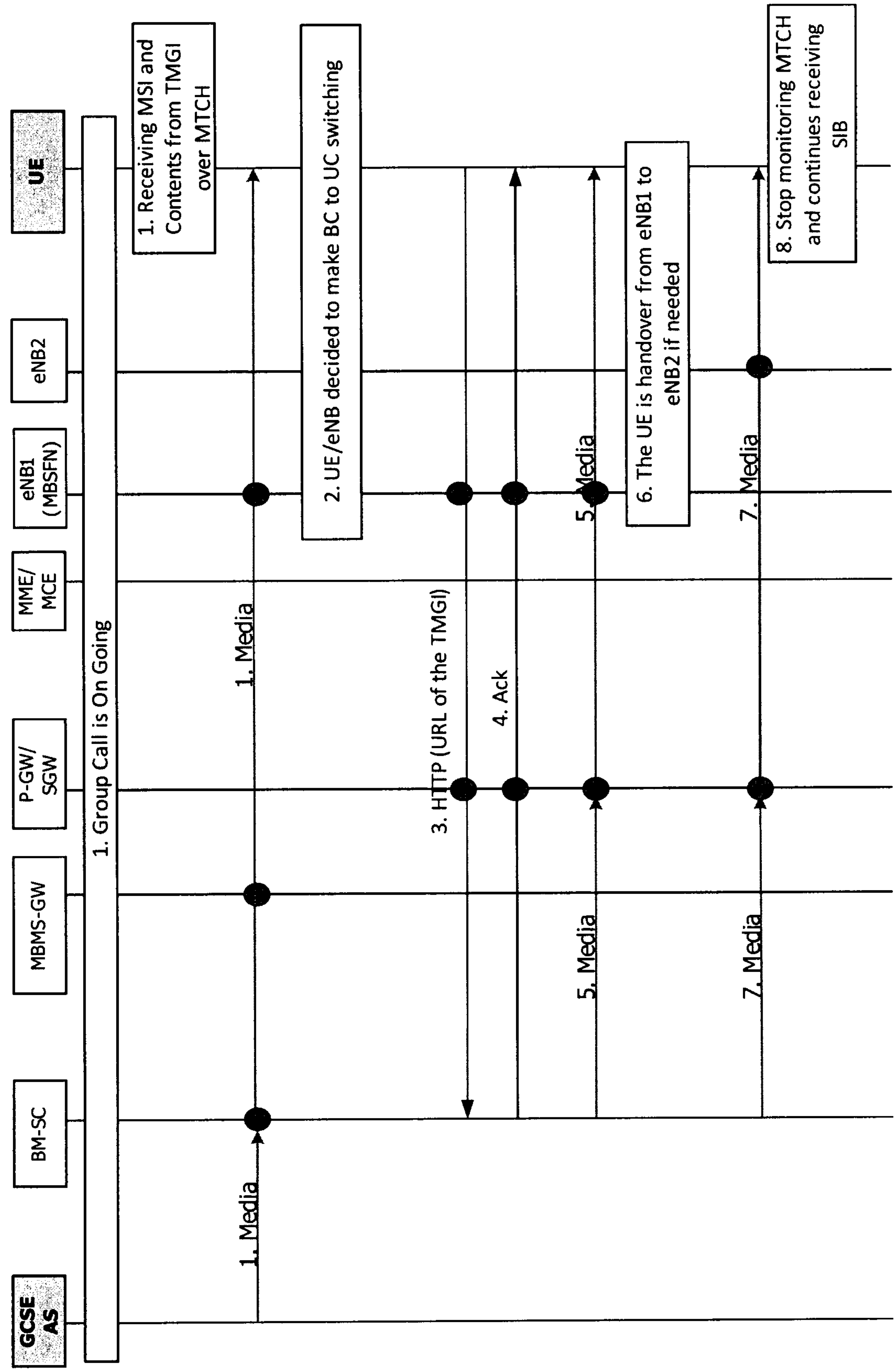
GCSE AS
BM-SC
MBMS-GW
P-GW/SGW
MME/MCE
eNB1 (MBSFN)
eNB2
UE
1. Group Call is On Going
1. Receiving MSI and Contents from TMGI over MTCH
1. Media
1. Media
2. UE/eNB decided to make BC to UC switching
3. HTTP (URL of the TMGI)
4. Ack
5. Media
5. Media
6. The UE is handover from eNB1 to eNB2 if needed
7. Media
7. Media
8. Stop monitoring MTCH and continues receiving SIB

FIG. 13

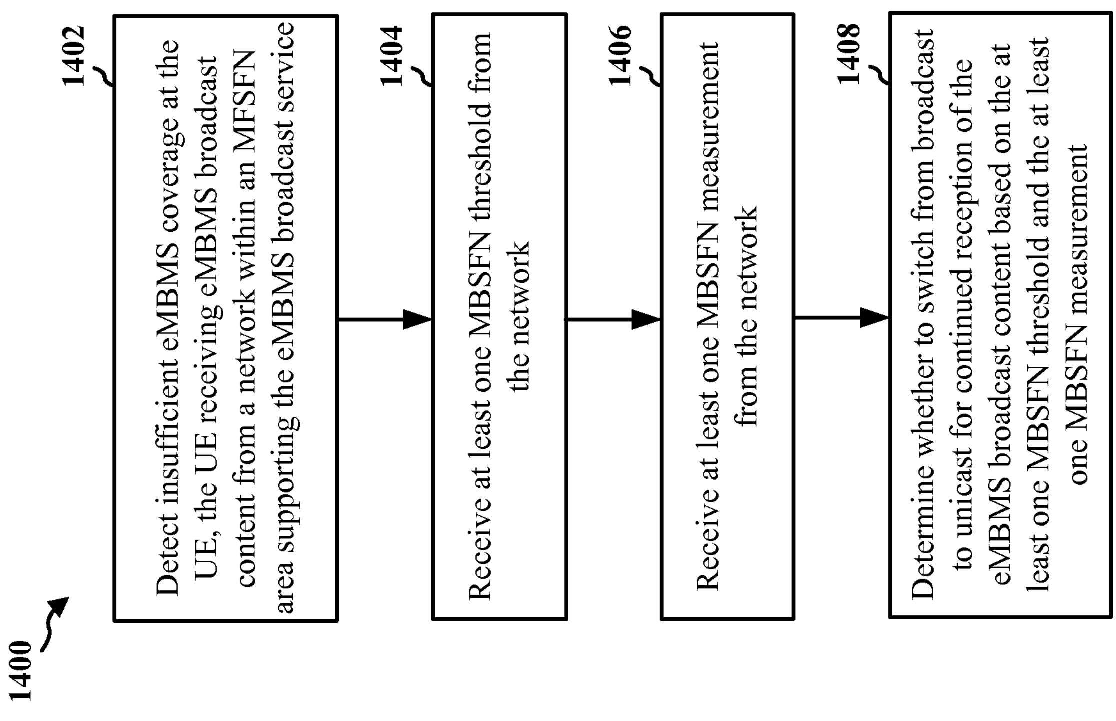
1400
1402
Detect insufficient eMBMS coverage at the UE, the UE receiving eMBMS broadcast content from a network within an MFSFN area supporting the eMBMS broadcast service
1404
Receive at least one MBSFN threshold from the network
1406
Receive at least one MBSFN measurement from the network
1408
Determine whether to switch from broadcast to unicast for continued reception of the eMBMS broadcast content based on the at least one MBSFN threshold and the at least one MBSFN measurement

FIG. 14

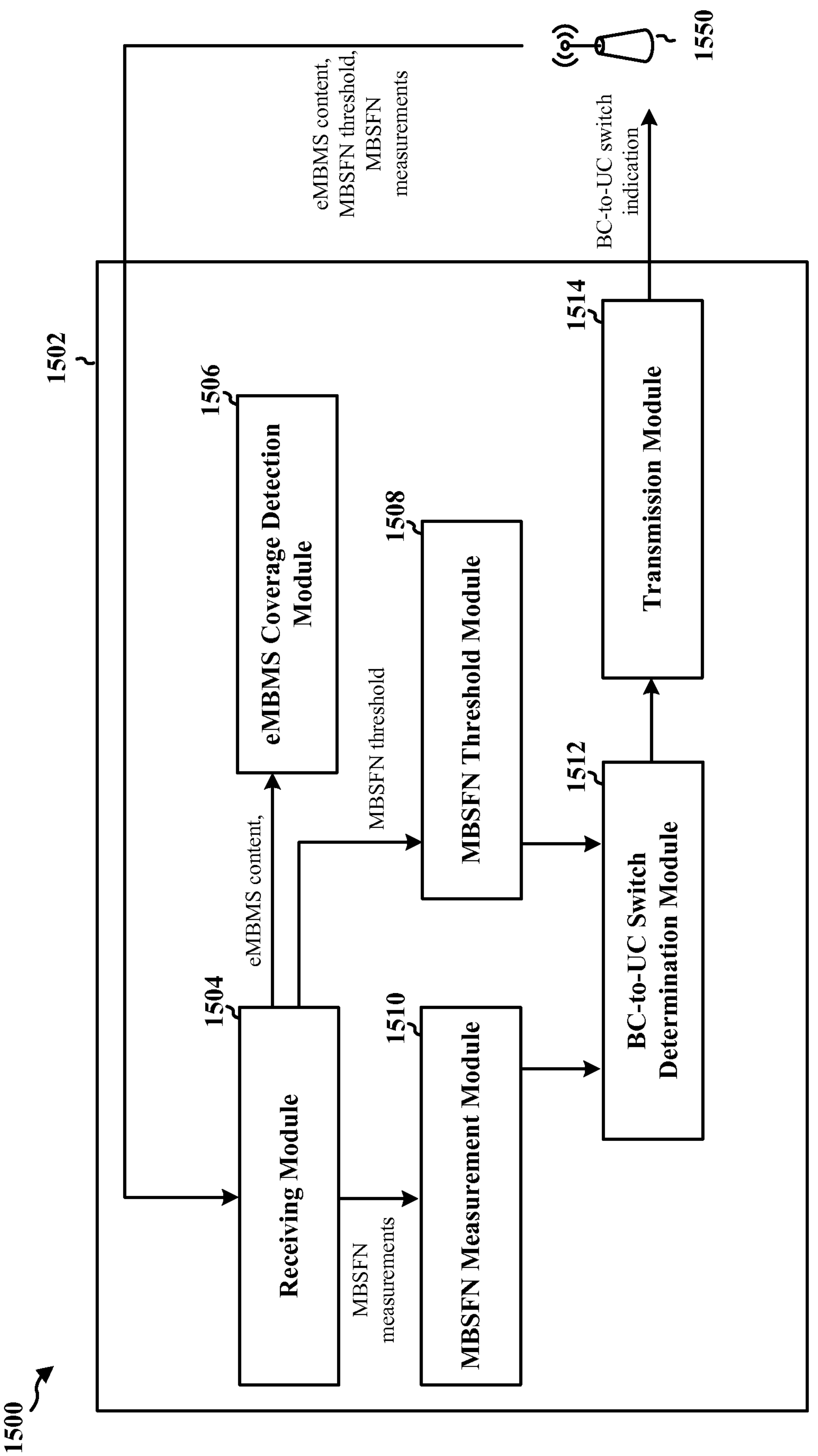
1500
1502
1504
Receiving Module
1506
eMBMS Coverage Detection Module
1508
MBSFN Threshold Module
1510
MBSFN Measurement Module
1512
BC-to-UC Switch Determination Module
1514
Transmission Module
1550
eMBMS content, MBSFN threshold, MBSFN measurements
eMBMS content,
MBSFN threshold
MBSFN measurements
BC-to-UC switch indication

FIG. 15

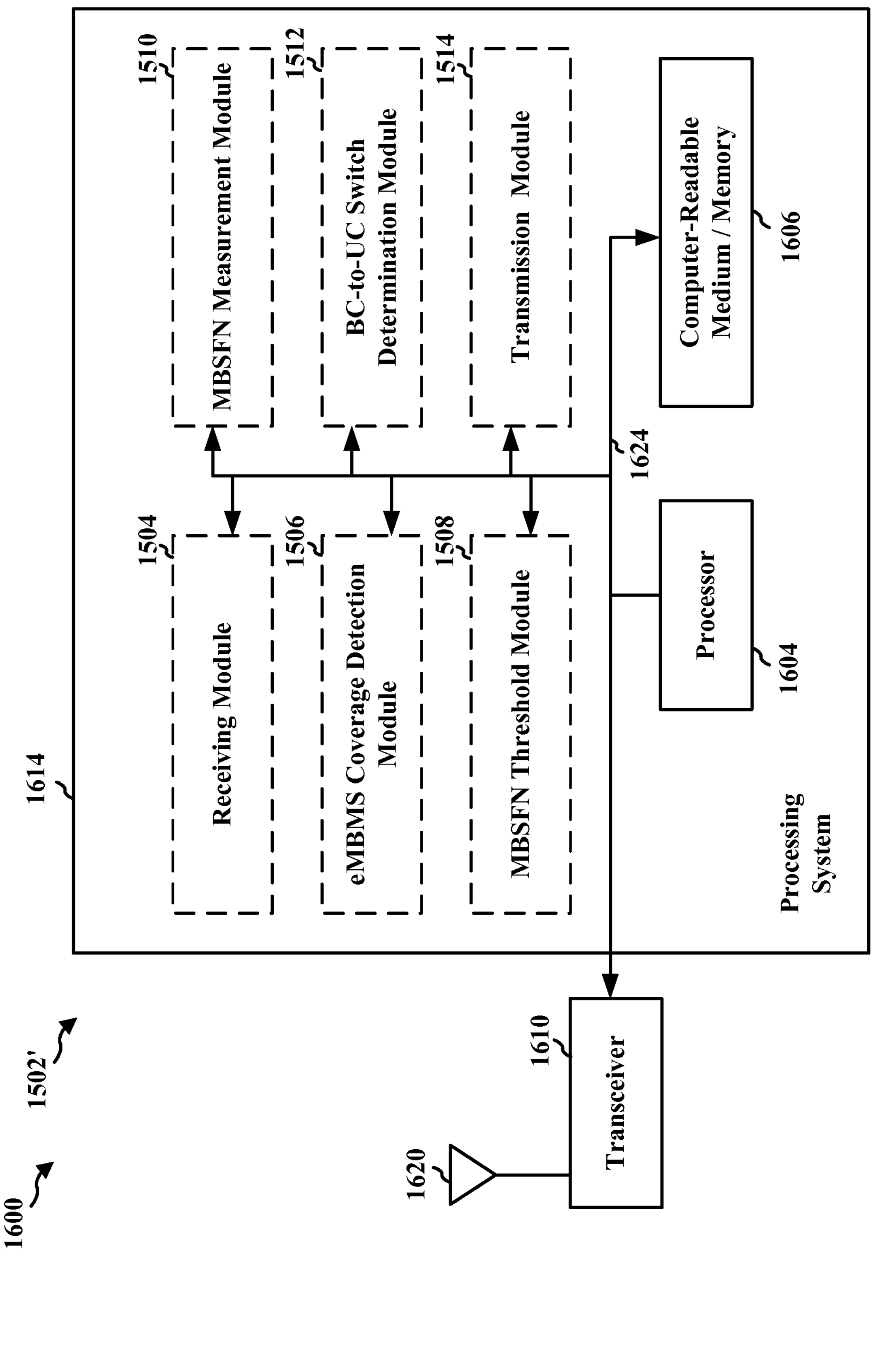
1600
1502'
1614
Receiving Module
1504
eMBMS Coverage Detection Module
1506
MBSFN Threshold Module
1508
MBSFN Measurement Module
1510
BC-to-UC Switch Determination Module
1512
Transmission Module
1514
1624
Processor
1604
Computer-Readable Medium / Memory
1606
Processing System
Transceiver
1610
1620

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/086216

A. CLASSIFICATION OF SUBJECT MATTER

H04W 28/16 (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; H04L

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)

CNABS, CNTXT, CNKI, VEN, 3GPP FTP, IEEE: MBMS, broadcast, multicast, unicast, point to multipoint, point to point, switch+, convert+, chang+, transform+, threshold?, measurement?, coverage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1650989 A1 (CIT-ALCATEL) 26 April 2006 (2006-04-26) description, paragraphs [0027]-[0030]	1-18
A	WO 2008134554 A2 (INTERDIGITAL TECHNOLOGY CORPORATION) 06 November 2008 (2008-11-06) the whole document	1-18
A	WO 2008046347 A1 (HUAWEI TECHNOLOGIES CO LTD) 24 April 2008 (2008-04-24) the whole document	1-18
A	CN 101237668 A (ZTE CORPORATION) 06 August 2008 (2008-08-06) the whole document	1-18

☐ 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
28 July 2014	**11 August 2014**

Name and mailing address of the ISA/	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA(ISA/CN) **6,Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China**	**LV,Sihua**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62089473**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/086216

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
EP	1650989	A1	26 April 2006	CN	1764293	A	26 April 2006
				DE	602004004148	D1	15 February 2007
				CN	100345454	C	24 October 2007
				AT	350866	T	15 January 2007
				EP	1650989	B1	03 January 2007
				US	2006087994	A1	27 April 2006
				DE	602004004148	T2	11 October 2007
				JP	2006135956	A	25 May 2006
WO	2008134554	A2	06 November 2008	EP	2143242	A2	13 January 2010
				CA	2685340	A1	06 November 2008
				IL	201781	D0	16 June 2010
				AU	2008245594	A1	06 November 2008
				US	2012195221	A1	02 August 2012
				KR	20100017470	A	16 February 2010
				WO	2008134554	A3	12 February 2009
				MX	2009011602	A	14 January 2010
				KR	20130054433	A	24 May 2013
				CN	103052159	A	17 April 2013
				CN	103220785	A	24 July 2013
				AR	066329	A1	12 August 2009
				TW	200847815	A	01 December 2008
				US	2008267109	A1	30 October 2008
				CN	101669336	A	10 March 2010
				KR	20100002294	A	06 January 2010
				CN	101669336	B	08 May 2013
				JP	2010525763	A	22 July 2010
				KR	20140037285	A	26 March 2014
				RU	2009143863	A	10 June 2011
				US	8175069	B2	08 May 2012
				JP	5466146	B2	09 April 2014
				JP	2014096845	A	22 May 2014
WO	2008046347	A1	24 April 2008	CN	101163324	A	16 April 2008
CN	101237668	A	06 August 2008		Non	e	