TITLE

HANDOVER OF USER EQUIPMENT WITH MULTIMEDIA BROADCAST MULTICAST SERVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/423,644, filed November 17, 2016 which is hereby incorporated by reference in its entirety.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0002] Examples of several of the various embodiments of the present invention are described herein with reference to the drawings.

[0003] FIG. 1 is a diagram depicting example sets of OFDM subcarriers as per an aspect of an embodiment of the present disclosure.

[0004] FIG. 2 is a diagram depicting an example transmission time and reception time for two carriers in a carrier group as per an aspect of an embodiment of the present disclosure.

[0005] FIG. 3 is a diagram depicting OFDM radio resources as per an aspect of an embodiment of the present disclosure.

[0006] FIG. 4 is a block diagram of a base station and a wireless device as per an aspect of an embodiment of the present disclosure.

[0007] FIG. 5A, FIG. 5B, FIG. 5C and FIG. 5D are example diagrams for uplink and downlink signal transmission as per an aspect of an embodiment of the present disclosure.

[0008] FIG. 6 is an example diagram for a protocol structure with CA and DC as per an aspect of an embodiment of the present disclosure.

[0009] FIG. 7 is an example diagram for a protocol structure with CA and DC as per an aspect of an embodiment of the present disclosure.

[0010] FIG. 8 shows example TAG configurations as per an aspect of an embodiment of the present disclosure.

[0011] FIG. 9 is an example message flow in a random access process in a secondary TAG as per an aspect of an embodiment of the present disclosure.

[0012] FIG. 10 is an example handover flow in a wireless network as per an aspect of an embodiment of the present disclosure.

[0013] FIG. 11 is an example handover flow in a wireless network as per an aspect of an embodiment of the present disclosure.

[0014] FIG. 12 is an example handover flow in a wireless network as per an aspect of an embodiment of the present disclosure.

[0015] FIG. 13 is an example dual connectivity flow in a wireless network as per an aspect of an embodiment of the present disclosure.

[0016] FIG. 14 is an example flow diagram as per an aspect of an embodiment of the present disclosure.

[0017] FIG. 15 is an example flow diagram as per an aspect of an embodiment of the present disclosure.

[0018] FIG. 16 is an example flow diagram as per an aspect of an embodiment of the present disclosure.

[0019] FIG. 17 is an example flow diagram as per an aspect of an embodiment of the present disclosure.

[0020] FIG. 18 is an example flow diagram as per an aspect of an embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0021] Example embodiments of the present invention enable operation of carrier aggregation. Embodiments of the technology disclosed herein may be employed in the technical field of multicarrier communication systems. More particularly, the embodiments of the technology disclosed herein may relate to signal timing in a multicarrier communication systems.

[0022] The following Acronyms are used throughout the present disclosure:

ASIC	application-specific integrated circuit
BPSK	binary phase shift keying
CA	carrier aggregation
CSI	channel state information
CDMA	code division multiple access
CSS	common search space
CPLD	complex programmable logic devices
CC	component carrier
DL	downlink
DCI	downlink control information
DC	dual connectivity
EPC	evolved packet core
E-UTRAN	evolved-universal terrestrial radio access network
FPGA	field programmable gate arrays
FDD	frequency division multiplexing

HDL	hardware description languages
HARQ	hybrid automatic repeat request
IE	information element
LTE	long term evolution
MCG	master cell group
MeNB	master evolved node B
MIB	master information block
MAC	media access control
MAC	media access control
MME	mobility management entity
NAS	non-access stratum
OFDM	orthogonal frequency division multiplexing
PDCP	packet data convergence protocol
PDU	packet data unit
PHY	physical
PDCCH	physical downlink control channel
PHICH	physical HARQ indicator channel
PUCCH	physical uplink control channel
PUSCH	physical uplink shared channel
PCell	primary cell
PCell	primary cell
PCC	primary component carrier
PSCell	primary secondary cell
pTAG	primary timing advance group
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RBG	Resource Block Groups
RLC	radio link control
RRC	radio resource control
RA	random access
RB	resource blocks
SCC	secondary component carrier
SCell	secondary cell
Scell	secondary cells
SCG	secondary cell group

SeNB	secondary evolved node B
sTAGs	secondary timing advance group
SDU	service data unit
S-GW	serving gateway
SRB	signaling radio bearer
SC-OFDM	single carrier-OFDM
SFN	system frame number
SIB	system information block
TAI	tracking area identifier
TAT	time alignment timer
TDD	time division duplexing
TDMA	time division multiple access
TA	timing advance
TAG	timing advance group
TB	transport block
UL	uplink
UE	user equipment
VHDL	VHSIC hardware description language

[0023] Example embodiments of the invention may be implemented using various physical layer modulation and transmission mechanisms. Example transmission mechanisms may include, but are not limited to: CDMA, OFDM, TDMA, Wavelet technologies, and/or the like. Hybrid transmission mechanisms such as TDMA/CDMA, and OFDM/CDMA may also be employed. Various modulation schemes may be applied for signal transmission in the physical layer. Examples of modulation schemes include, but are not limited to: phase, amplitude, code, a combination of these, and/or the like. An example radio transmission method may implement QAM using BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, and/or the like. Physical radio transmission may be enhanced by dynamically or semi-dynamically changing the modulation and coding scheme depending on transmission requirements and radio conditions.

[0024] FIG. 1 is a diagram depicting example sets of OFDM subcarriers as per an aspect of an embodiment of the present invention. As illustrated in this example, arrow(s) in the diagram may depict a subcarrier in a multicarrier OFDM system. The OFDM system may use technology such as OFDM technology, DFTS-OFDM, SC-OFDM technology, or the like. For example, arrow 101 shows a subcarrier transmitting information symbols. FIG. 1 is for illustration purposes, and a typical multicarrier OFDM system may include more subcarriers

in a carrier. For example, the number of subcarriers in a carrier may be in the range of 10 to 10,000 subcarriers. FIG. 1 shows two guard bands 106 and 107 in a transmission band. As illustrated in FIG. 1, guard band 106 is between subcarriers 103 and subcarriers 104. The example set of subcarriers A 102 includes subcarriers 103 and subcarriers 104. FIG. 1 also illustrates an example set of subcarriers B 105. As illustrated, there is no guard band between any two subcarriers in the example set of subcarriers B 105. Carriers in a multicarrier OFDM communication system may be contiguous carriers, non-contiguous carriers, or a combination of both contiguous and non-contiguous carriers.

[0025] FIG. 2 is a diagram depicting an example transmission time and reception time for two carriers as per an aspect of an embodiment of the present invention. A multicarrier OFDM communication system may include one or more carriers, for example, ranging from 1 to 10 carriers. Carrier A 204 and carrier B 205 may have the same or different timing structures. Although FIG. 2 shows two synchronized carriers, carrier A 204 and carrier B 205 may or may not be synchronized with each other. Different radio frame structures may be supported for FDD and TDD duplex mechanisms. FIG. 2 shows an example FDD frame timing. Downlink and uplink transmissions may be organized into radio frames 201. In this example, radio frame duration is 10 msec. Other frame durations, for example, in the range of 1 to 100 msec may also be supported. In this example, each 10 ms radio frame 201 may be divided into ten equally sized subframes 202. Other subframe durations such as including 0.5 msec, 1 msec, 2 msec, and 5 msec may also be supported. Subframe(s) may consist of two or more slots (*e.g.* slots 206 and 207). For the example of FDD, 10 subframes may be available for downlink transmission and 10 subframes may be available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions may be separated in the frequency domain. Slot(s) may include a plurality of OFDM symbols 203. The number of OFDM symbols 203 in a slot 206 may depend on the cyclic prefix length and subcarrier spacing.

[0026] FIG. 3 is a diagram depicting OFDM radio resources as per an aspect of an embodiment of the present invention. The resource grid structure in time 304 and frequency 305 is illustrated in FIG. 3. The quantity of downlink subcarriers or RBs (in this example 6 to100 RBs) may depend, at least in part, on the downlink transmission bandwidth 306 configured in the cell. The smallest radio resource unit may be called a resource element (*e.g.* 301). Resource elements may be grouped into resource blocks (*e.g.* 302). Resource blocks may be grouped into larger radio resources called Resource Block Groups (RBG) (*e.g.* 303). The transmitted signal in slot 206 may be described by one or several resource grids of a plurality of subcarriers and a plurality of OFDM symbols. Resource blocks may be used to describe the mapping of certain physical channels to resource elements. Other pre-defined

groupings of physical resource elements may be implemented in the system depending on the radio technology. For example, 24 subcarriers may be grouped as a radio block for a duration of 5 msec. In an illustrative example, a resource block may correspond to one slot in the time domain and 180 kHz in the frequency domain (for 15 KHz subcarrier bandwidth and 12 subcarriers).

[0027] FIG. 5A, FIG. 5B, FIG. 5C and FIG. 5D are example diagrams for uplink and downlink signal transmission as per an aspect of an embodiment of the present invention. FIG. 5A shows an example uplink physical channel. The baseband signal representing the physical uplink shared channel may perform the following processes. These functions are illustrated as examples and it is anticipated that other mechanisms may be implemented in various embodiments. The functions may comprise scrambling, modulation of scrambled bits to generate complex-valued symbols, mapping of the complex-valued modulation symbols onto one or several transmission layers, transform precoding to generate complex-valued symbols, precoding of the complex-valued symbols, mapping of precoded complex-valued symbols to resource elements, generation of complex-valued time-domain DFTS-OFDM/SC-FDMA signal for each antenna port, and/or the like.

[0028] Example modulation and up-conversion to the carrier frequency of the complex-valued DFTS-OFDM/SC-FDMA baseband signal for each antenna port and/or the complex-valued PRACH baseband signal is shown in FIG. 5B. Filtering may be employed prior to transmission.

[0029] An example structure for Downlink Transmissions is shown in FIG. 5C. The baseband signal representing a downlink physical channel may perform the following processes. These functions are illustrated as examples and it is anticipated that other mechanisms may be implemented in various embodiments. The functions include scrambling of coded bits in each of the codewords to be transmitted on a physical channel; modulation of scrambled bits to generate complex-valued modulation symbols; mapping of the complex-valued modulation symbols onto one or several transmission layers; precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports; mapping of complex-valued modulation symbols for each antenna port to resource elements; generation of complex-valued time-domain OFDM signal for each antenna port, and/or the like.

[0030] Example modulation and up-conversion to the carrier frequency of the complex-valued OFDM baseband signal for each antenna port is shown in FIG. 5D. Filtering may be employed prior to transmission.

[0031] FIG. 4 is an example block diagram of a base station 401 and a wireless device 406, as per an aspect of an embodiment of the present invention. A communication network 400 may include at least one base station 401 and at least one wireless device 406. The base station 401 may include at least one communication interface 402, at least one processor 403, and at least one set of program code instructions 405 stored in non-transitory memory 404 and executable by the at least one processor 403. The wireless device 406 may include at least one communication interface 407, at least one processor 408, and at least one set of program code instructions 410 stored in non-transitory memory 409 and executable by the at least one processor 408. Communication interface 402 in base station 401 may be configured to engage in communication with communication interface 407 in wireless device 406 via a communication path that includes at least one wireless link 411. Wireless link 411 may be a bi-directional link. Communication interface 407 in wireless device 406 may also be configured to engage in a communication with communication interface 402 in base station 401. Base station 401 and wireless device 406 may be configured to send and receive data over wireless link 411 using multiple frequency carriers. According to some of the various aspects of embodiments, transceiver(s) may be employed. A transceiver is a device that includes both a transmitter and receiver. Transceivers may be employed in devices such as wireless devices, base stations, relay nodes, and/or the like. Example embodiments for radio technology implemented in communication interface 402, 407 and wireless link 411 are illustrated are FIG. 1, FIG. 2, FIG. 3, FIG. 5, and associated text.

[0032] An interface may be a hardware interface, a firmware interface, a software interface, and/or a combination thereof. The hardware interface may include connectors, wires, electronic devices such as drivers, amplifiers, and/or the like. A software interface may include code stored in a memory device to implement protocol(s), protocol layers, communication drivers, device drivers, combinations thereof, and/or the like. A firmware interface may include a combination of embedded hardware and code stored in and/or in communication with a memory device to implement connections, electronic device operations, protocol(s), protocol layers, communication drivers, device drivers, hardware operations, combinations thereof, and/or the like.

[0033] The term configured may relate to the capacity of a device whether the device is in an operational or non-operational state. Configured may also refer to specific settings in a device that effect the operational characteristics of the device whether the device is in an operational or non-operational state. In other words, the hardware, software, firmware, registers, memory values, and/or the like may be “configured” within a device, whether the device is in an operational or nonoperational state, to provide the device with specific

characteristics. Terms such as “a control message to cause in a device” may mean that a control message has parameters that may be used to configure specific characteristics in the device, whether the device is in an operational or non-operational state.

[0034] According to some of the various aspects of embodiments, an LTE network may include a multitude of base stations, providing a user plane PDCP/RLC/MAC/PHYand control plane (RRC) protocol terminations towards the wireless device. The base station(s) may be interconnected with other base station(s) (*e.g.* employing an X2 interface). The base stations may also be connected employing, for example, an S1 interface to an EPC. For example, the base stations may be interconnected to the MME employing the S1-MME interface and to the S-G) employing the S1-U interface. The S1 interface may support a many-to-many relation between MMEs / Serving Gateways and base stations. A base station may include many sectors for example: 1, 2, 3, 4, or 6 sectors. A base station may include many cells, for example, ranging from 1 to 50 cells or more. A cell may be categorized, for example, as a primary cell or secondary cell. At RRC connection establishment/re-establishment/handover, one serving cell may provide the NAS (non-access stratum) mobility information (*e.g.* TAI), and at RRC connection re-establishment/handover, one serving cell may provide the security input. This cell may be referred to as the Primary Cell (PCell). In the downlink, the carrier corresponding to the PCell may be the Downlink Primary Component Carrier (DL PCC), while in the uplink, it may be the Uplink Primary Component Carrier (UL PCC). Depending on wireless device capabilities, Secondary Cells (SCells) may be configured to form together with the PCell a set of serving cells. In the downlink, the carrier corresponding to an SCell may be a Downlink Secondary Component Carrier (DL SCC), while in the uplink, it may be an Uplink Secondary Component Carrier (UL SCC). An SCell may or may not have an uplink carrier.

[0035] A cell, comprising a downlink carrier and optionally an uplink carrier, may be assigned a physical cell ID and a cell index. A carrier (downlink or uplink) may belong to only one cell. The cell ID or Cell index may also identify the downlink carrier or uplink carrier of the cell (depending on the context it is used). In the specification, cell ID may be equally referred to a carrier ID, and cell index may be referred to carrier index. In implementation, the physical cell ID or cell index may be assigned to a cell. A cell ID may be determined using a synchronization signal transmitted on a downlink carrier. A cell index may be determined using RRC messages. For example, when the specification refers to a first physical cell ID for a first downlink carrier, the specification may mean the first physical cell ID is for a cell comprising the first downlink carrier. The same concept may apply to, for

example, carrier activation. When the specification indicates that a first carrier is activated, the specification may equally mean that the cell comprising the first carrier is activated.

[0036] Embodiments may be configured to operate as needed. The disclosed mechanism may be performed when certain criteria are met, for example, in a wireless device, a base station, a radio environment, a network, a combination of the above, and/or the like. Example criteria may be based, at least in part, on for example, traffic load, initial system set up, packet sizes, traffic characteristics, a combination of the above, and/or the like. When the one or more criteria are met, various example embodiments may be applied. Therefore, it may be possible to implement example embodiments that selectively implement disclosed protocols.

[0037] A base station may communicate with a mix of wireless devices. Wireless devices may support multiple technologies, and/or multiple releases of the same technology. Wireless devices may have some specific capability(ies) depending on its wireless device category and/or capability(ies). A base station may comprise multiple sectors. When this disclosure refers to a base station communicating with a plurality of wireless devices, this disclosure may refer to a subset of the total wireless devices in a coverage area. This disclosure may refer to, for example, a plurality of wireless devices of a given LTE release with a given capability and in a given sector of the base station. The plurality of wireless devices in this disclosure may refer to a selected plurality of wireless devices, and/or a subset of total wireless devices in a coverage area which perform according to disclosed methods, and/or the like. There may be a plurality of wireless devices in a coverage area that may not comply with the disclosed methods, for example, because those wireless devices perform based on older releases of LTE technology.

[0038] FIG. 6 and FIG. 7 are example diagrams for protocol structure with CA and DC as per an aspect of an embodiment of the present invention. E-UTRAN may support Dual Connectivity (DC) operation whereby a multiple RX/TX UE in RRC_CONNECTED may be configured to utilize radio resources provided by two schedulers located in two eNBs connected via a non-ideal backhaul over the X2 interface. eNBs involved in DC for a certain UE may assume two different roles: an eNB may either act as an MeNB or as an SeNB. In DC a UE may be connected to one MeNB and one SeNB. Mechanisms implemented in DC may be extended to cover more than two eNBs. FIG. 7 illustrates one example structure for the UE side MAC entities when a Master Cell Group (MCG) and a Secondary Cell Group (SCG) are configured, and it may not restrict implementation. Media Broadcast Multicast Service (MBMS) reception is not shown in this figure for simplicity.

[0039] In DC, the radio protocol architecture that a particular bearer uses may depend on how the bearer is setup. Three alternatives may exist, an MCG bearer, an SCG bearer and a

split bearer as shown in FIG. 6. RRC may be located in MeNB and SRBs may be configured as a MCG bearer type and may use the radio resources of the MeNB. DC may also be described as having at least one bearer configured to use radio resources provided by the SeNB. DC may or may not be configured/implemented in example embodiments of the invention.

[0040] In the case of DC, the UE may be configured with two MAC entities: one MAC entity for MeNB, and one MAC entity for SeNB. In DC, the configured set of serving cells for a UE may comprise of two subsets: the Master Cell Group (MCG) containing the serving cells of the MeNB, and the Secondary Cell Group (SCG) containing the serving cells of the SeNB. For a SCG, one or more of the following may be applied: at least one cell in the SCG has a configured UL CC and one of them, named PSCell (or PCell of SCG, or sometimes called PCell), is configured with PUCCH resources; when the SCG is configured, there may be at least one SCG bearer or one Split bearer; upon detection of a physical layer problem or a random access problem on a PSCell, or the maximum number of RLC retransmissions has been reached associated with the SCG, or upon detection of an access problem on a PSCell during a SCG addition or a SCG change: a RRC connection re-establishment procedure may not be triggered, UL transmissions towards cells of the SCG are stopped, a MeNB may be informed by the UE of a SCG failure type, for split bearer, the DL data transfer over the MeNB is maintained; the RLC AM bearer may be configured for the split bearer; like PCell, PSCell may not be de-activated; PSCell may be changed with a SCG change (*e.g.* with security key change and a RACH procedure); and/or neither a direct bearer type change between a Split bearer and a SCG bearer nor simultaneous configuration of a SCG and a Split bearer are supported.

[0041] With respect to the interaction between a MeNB and a SeNB, one or more of the following principles may be applied: the MeNB may maintain the RRM measurement configuration of the UE and may, (e.g, based on received measurement reports or traffic conditions or bearer types), decide to ask a SeNB to provide additional resources (serving cells) for a UE; upon receiving a request from the MeNB, a SeNB may create a container that may result in the configuration of additional serving cells for the UE (or decide that it has no resource available to do so); for UE capability coordination, the MeNB may provide (part of) the AS configuration and the UE capabilities to the SeNB; the MeNB and the SeNB may exchange information about a UE configuration by employing of RRC containers (inter-node messages) carried in X2 messages; the SeNB may initiate a reconfiguration of its existing serving cells (*e.g.*, PUCCH towards the SeNB); the SeNB may decide which cell is the PSCell within the SCG; the MeNB may not change the content of the RRC configuration provided by

the SeNB; in the case of a SCG addition and a SCG SCell addition, the MeNB may provide the latest measurement results for the SCG cell(s); both a MeNB and a SeNB may know the SFN and subframe offset of each other by OAM, (*e.g.*, for the purpose of DRX alignment and identification of a measurement gap). In an example, when adding a new SCG SCell, dedicated RRC signalling may be used for sending required system information of the cell as for CA, except for the SFN acquired from a MIB of the PSCell of a SCG.

[0042] In an example, serving cells may be grouped in a TA group (TAG). Serving cells in one TAG may use the same timing reference. For a given TAG, user equipment (UE) may use at least one downlink carrier as a timing reference. For a given TAG, a UE may synchronize uplink subframe and frame transmission timing of uplink carriers belonging to the same TAG. In an example, serving cells having an uplink to which the same TA applies may correspond to serving cells hosted by the same receiver. A UE supporting multiple TAs may support two or more TA groups. One TA group may contain the PCell and may be called a primary TAG (pTAG). In a multiple TAG configuration, at least one TA group may not contain the PCell and may be called a secondary TAG (sTAG). In an example, carriers within the same TA group may use the same TA value and/or the same timing reference. When DC is configured, cells belonging to a cell group (MCG or SCG) may be grouped into multiple TAGs including a pTAG and one or more sTAGs.

[0043] FIG. 8 shows example TAG configurations as per an aspect of an embodiment of the present invention. In Example 1, pTAG comprises PCell, and an sTAG comprises SCell1. In Example 2, a pTAG comprises a PCell and SCell1, and an sTAG comprises SCell2 and SCell3. In Example 3, pTAG comprises PCell and SCell1, and an sTAG1 includes SCell2 and SCell3, and sTAG2 comprises SCell4. Up to four TAGs may be supported in a cell group (MCG or SCG) and other example TAG configurations may also be provided. In various examples in this disclosure, example mechanisms are described for a pTAG and an sTAG. Some of the example mechanisms may be applied to configurations with multiple sTAGs.

[0044] In an example, an eNB may initiate an RA procedure via a PDCCH order for an activated SCell. This PDCCH order may be sent on a scheduling cell of this SCell. When cross carrier scheduling is configured for a cell, the scheduling cell may be different than the cell that is employed for preamble transmission, and the PDCCH order may include an SCell index. At least a non-contention based RA procedure may be supported for SCell(s) assigned to sTAG(s).

[0045] FIG. 9 is an example message flow in a random access process in a secondary TAG as per an aspect of an embodiment of the present invention. An eNB transmits an activation

command 600 to activate an SCell. A preamble 602 (Msg1) may be sent by a UE in response to a PDCCH order 601 on an SCell belonging to an sTAG. In an example embodiment, preamble transmission for SCells may be controlled by the network using PDCCH format 1A. Msg2 message 603 (RAR: random access response) in response to the preamble transmission on the SCell may be addressed to RA-RNTI in a PCell common search space (CSS). Uplink packets 604 may be transmitted on the SCell in which the preamble was transmitted.

[0046] According to some of the various aspects of embodiments, initial timing alignment may be achieved through a random access procedure. This may involve a UE transmitting a random access preamble and an eNB responding with an initial TA command NTA (amount of timing advance) within a random access response window. The start of the random access preamble may be aligned with the start of a corresponding uplink subframe at the UE assuming NTA=0. The eNB may estimate the uplink timing from the random access preamble transmitted by the UE. The TA command may be derived by the eNB based on the estimation of the difference between the desired UL timing and the actual UL timing. The UE may determine the initial uplink transmission timing relative to the corresponding downlink of the sTAG on which the preamble is transmitted.

[0047] The mapping of a serving cell to a TAG may be configured by a serving eNB with RRC signaling. The mechanism for TAG configuration and reconfiguration may be based on RRC signaling. According to some of the various aspects of embodiments, when an eNB performs an SCell addition configuration, the related TAG configuration may be configured for the SCell. In an example embodiment, an eNB may modify the TAG configuration of an SCell by removing (releasing) the SCell and adding(configuring) a new SCell (with the same physical cell ID and frequency) with an updated TAG ID. The new SCell with the updated TAG ID may initially be inactive subsequent to being assigned the updated TAG ID. The eNB may activate the updated new SCell and start scheduling packets on the activated SCell. In an example implementation, it may not be possible to change the TAG associated with an SCell, but rather, the SCell may need to be removed and a new SCell may need to be added with another TAG. For example, if there is a need to move an SCell from an sTAG to a pTAG, at least one RRC message, for example, at least one RRC reconfiguration message, may be send to the UE to reconfigure TAG configurations by releasing the SCell and then configuring the SCell as a part of the pTAG (when an SCell is added/configured without a TAG index, the SCell may be explicitly assigned to the pTAG). The PCell may not change its TA group and may be a member of the pTAG.

[0048] The purpose of an RRC connection reconfiguration procedure may be to modify an RRC connection, (*e.g.* to establish, modify and/or release RBs, to perform handover, to setup,

modify, and/or release measurements, to add, modify, and/or release SCells). If the received RRC Connection Reconfiguration message includes the sCellToReleaseList, the UE may perform an SCell release. If the received RRC Connection Reconfiguration message includes the sCellToAddModList, the UE may perform SCell additions or modification.

[0049] In LTE Release-10 and Release-11 CA, a PUCCH is only transmitted on the PCell (PSCell) to an eNB. In LTE-Release 12 and earlier, a UE may transmit PUCCH information on one cell (PCell or PSCell) to a given eNB.

[0050] As the number of CA capable UEs and also the number of aggregated carriers increase, the number of PUCCHs and also the PUCCH payload size may increase. Accommodating the PUCCH transmissions on the PCell may lead to a high PUCCH load on the PCell. A PUCCH on an SCell may be introduced to offload the PUCCH resource from the PCell. More than one PUCCH may be configured for example, a PUCCH on a PCell and another PUCCH on an SCell. In the example embodiments, one, two or more cells may be configured with PUCCH resources for transmitting CSI/ACK/NACK to a base station. Cells may be grouped into multiple PUCCH groups, and one or more cell within a group may be configured with a PUCCH. In an example configuration, one SCell may belong to one PUCCH group. SCells with a configured PUCCH transmitted to a base station may be called a PUCCH SCell, and a cell group with a common PUCCH resource transmitted to the same base station may be called a PUCCH group.

[0051] In an example embodiment, a MAC entity may have a configurable timer timeAlignmentTimer per TAG. The timeAlignmentTimer may be used to control how long the MAC entity considers the Serving Cells belonging to the associated TAG to be uplink time aligned. The MAC entity may, when a Timing Advance Command MAC control element is received, apply the Timing Advance Command for the indicated TAG; start or restart the timeAlignmentTimer associated with the indicated TAG. The MAC entity may, when a Timing Advance Command is received in a Random Access Response message for a serving cell belonging to a TAG and/orif the Random Access Preamble was not selected by the MAC entity, apply the Timing Advance Command for this TAG and start or restart the timeAlignmentTimer associated with this TAG. Otherwise, if the timeAlignmentTimer associated with this TAG is not running, the Timing Advance Command for this TAG may be applied and the timeAlignmentTimer associated with this TAG started. When the contention resolution is considered not successful, a timeAlignmentTimer associated with this TAG may be stopped. Otherwise, the MAC entity may ignore the received Timing Advance Command.

[0052] In example embodiments, a timer is running once it is started, until it is stopped or until it expires; otherwise it may not be running. A timer can be started if it is not running or restarted if it is running. For example, a timer may be started or restarted from its initial value.

[0053] Example embodiments of the invention may enable operation of multi-carrier communications. Other example embodiments may comprise a non-transitory tangible computer readable media comprising instructions executable by one or more processors to cause operation of multi-carrier communications. Yet other example embodiments may comprise an article of manufacture that comprises a non-transitory tangible computer readable machine-accessible medium having instructions encoded thereon for enabling programmable hardware to cause a device (*e.g.* wireless communicator, UE, base station, etc.) to enable operation of multi-carrier communications. The device may include processors, memory, interfaces, and/or the like. Other example embodiments may comprise communication networks comprising devices such as base stations, wireless devices (or user equipment: UE), servers, switches, antennas, and/or the like.

[0054] The amount of data traffic carried over cellular networks is expected to increase for many years to come. The number of users/devices is increasing and each user/device accesses an increasing number and variety of services, e.g. video delivery, large files, images. This requires not only high capacity in the network, but also provisioning very high data rates to meet customers' expectations on interactivity and responsiveness. More spectrum is therefore needed for cellular operators to meet the increasing demand. Considering user expectations of high data rates along with seamless mobility, it is beneficial that more spectrum be made available for deploying macro cells as well as small cells for cellular systems.

[0055] Striving to meet the market demands, there has been increasing interest from operators in deploying some complementary access utilizing unlicensed spectrum to meet the traffic growth. This is exemplified by the large number of operator-deployed Wi-Fi networks and the 3GPP standardization of LTE/WLAN interworking solutions. This interest indicates that unlicensed spectrum, when present, can be an effective complement to licensed spectrum for cellular operators to help addressing the traffic explosion in some scenarios, such as hotspot areas. LAA offers an alternative for operators to make use of unlicensed spectrum while managing one radio network, thus offering new possibilities for optimizing the network's efficiency.

[0056] In an example embodiment, Listen-before-talk (clear channel assessment) may be implemented for transmission in an LAA cell. In a listen-before-talk (LBT) procedure, equipment may apply a clear channel assessment (CCA) check before using the channel. For example, the CCA utilizes at least energy detection to determine the presence or absence of

other signals on a channel in order to determine if a channel is occupied or clear, respectively. For example, European and Japanese regulations mandate the usage of LBT in the unlicensed bands. Apart from regulatory requirements, carrier sensing via LBT may be one way for fair sharing of the unlicensed spectrum.

[0057] In an example embodiment, discontinuous transmission on an unlicensed carrier with limited maximum transmission duration may be enabled. Some of these functions may be supported by one or more signals to be transmitted from the beginning of a discontinuous LAA downlink transmission. Channel reservation may be enabled by the transmission of signals, by an LAA node, after gaining channel access via a successful LBT operation, so that other nodes that receive the transmitted signal with energy above a certain threshold sense the channel to be occupied. Functions that may need to be supported by one or more signals for LAA operation with discontinuous downlink transmission may include one or more of the following: detection of the LAA downlink transmission (including cell identification) by UEs; time & frequency synchronization of UEs.

[0058] In an example embodiment, DL LAA design may employ subframe boundary alignment according to LTE-A carrier aggregation timing relationships across serving cells aggregated by CA. This may not imply that the eNB transmissions can start only at the subframe boundary. LAA may support transmitting PDSCH when not all OFDM symbols are available for transmission in a subframe according to LBT. Delivery of necessary control information for the PDSCH may also be supported.

[0059] LBT procedure may be employed for fair and friendly coexistence of LAA with other operators and technologies operating in unlicensed spectrum. LBT procedures on a node attempting to transmit on a carrier in unlicensed spectrum require the node to perform a clear channel assessment to determine if the channel is free for use. An LBT procedure may involve at least energy detection to determine if the channel is being used. For example, regulatory requirements in some regions, e.g., in Europe, specify an energy detection threshold such that if a node receives energy greater than this threshold, the node assumes that the channel is not free. While nodes may follow such regulatory requirements, a node may optionally use a lower threshold for energy detection than that specified by regulatory requirements. In an example, LAA may employ a mechanism to adaptively change the energy detection threshold, e.g., LAA may employ a mechanism to adaptively lower the energy detection threshold from an upper bound. Adaptation mechanism may not preclude static or semi-static setting of the threshold. In an example Category 4 LBT mechanism or other type of LBT mechanisms may be implemented.

[0060] Various example LBT mechanisms may be implemented. In an example, for some signals, in some implementation scenarios, in some situations, and/or in some frequencies no LBT procedure may performed by the transmitting entity. In an example, Category 2 (e.g. LBT without random back-off) may be implemented. The duration of time that the channel is sensed to be idle before the transmitting entity transmits may be deterministic. In an example, Category 3 (e.g. LBT with random back-off with a contention window of fixed size) may be implemented. The LBT procedure may have the following procedure as one of its components. The transmitting entity may draw a random number N within a contention window. The size of the contention window may be specified by the minimum and maximum value of N. The size of the contention window may be fixed. The random number N may be employed in the LBT procedure to determine the duration of time that the channel is sensed to be idle before the transmitting entity transmits on the channel. In an example, Category 4 (e.g. LBT with random back-off with a contention window of variable size) may be implemented. The transmitting entity may draw a random number N within a contention window. The size of contention window may be specified by the minimum and maximum value of N. The transmitting entity may vary the size of the contention window when drawing the random number N. The random number N is used in the LBT procedure to determine the duration of time that the channel is sensed to be idle before the transmitting entity transmits on the channel.

[0061] LAA may employ uplink LBT at the UE. The UL LBT scheme may be different from the DL LBT scheme (e.g. by using different LBT mechanisms or parameters) for example, since the LAA UL is based on scheduled access which affects a UE's channel contention opportunities. Other considerations motivating a different UL LBT scheme include, but are not limited to, multiplexing of multiple UEs in a single subframe.

[0062] In an example, a DL transmission burst may be a continuous transmission from a DL transmitting node with no transmission immediately before or after from the same node on the same CC. An UL transmission burst from a UE perspective may be a continuous transmission from a UE with no transmission immediately before or after from the same UE on the same CC. In an example, UL transmission burst is defined from a UE perspective. In an example, an UL transmission burst may be defined from an eNB perspective. In an example, in case of an eNB operating DL+UL LAA over the same unlicensed carrier, DL transmission burst(s) and UL transmission burst(s) on LAA may be scheduled in a TDM manner over the same unlicensed carrier. For example, an instant in time may be part of a DL transmission burst or an UL transmission burst.

[0063] In an example embodiment, a handover source base station (or a dual connectivity master base station) may provide, to a handover target base station (or a dual connectivity secondary base station), MBMS information of MBMS services for the wireless device. The MBMS information may comprise at least one of a temporary mobile group identity (TMGI), an MBMS service session identifier, an MBMS service identifier, and/or the like. The MBMS service may comprise a vehicle-to-everything (V2X) service for a V2X type UE. By receiving the MBMS information, the handover target base station (or the dual connectivity secondary base station) may be able to configure one or more MBMS parameters to provide the MBMS services for the wireless device before completing a handover procedure (or a dual connectivity addition/modification procedure), and/or may be able to provide the MBMS services to the wireless device with a reduced (or no) service interruption time. In an example, by configuring MBMS parameters before completing a handover procedure (or a dual connectivity procedure), a base station may provide, to a wireless device (e.g. V2X type UE), a reliable MBMS service (e.g. V2X service) when the wireless device moves fast from one base station to another base station.

[0064] In an example, control information relevant for UEs supporting MBMS may be separated as much as possible from unicast control information. Most of the MBMS control information may be provided on a logical channel specific for MBMS common control information: the MCCH. E-UTRA may employ one MCCH logical channel per MBSFN area. In case that network configures multiple MBSFN areas, the UE may acquire the MBMS control information from the MCCHs that may be configured to identify if services it is interested to receive are ongoing. In an example, an action applicable when the UE is unable to simultaneously receive MBMS and/or unicast services may be up to UE implementation. In an example, an MBMS capable UE may be required to support reception of a single MBMS service at a time, and/or reception of more than one MBMS service (also possibly on more than one MBSFN area) in parallel may be left for UE implementation. The MCCH may carry an MBSFNAreaConfiguration message, which may indicate MBMS sessions that may be ongoing as well as (corresponding) radio resource configuration. MCCH may carry an MBMSCountingRequest message, when E-UTRAN wishes to count the number of UEs in RRC_CONNECTED that may be receiving or interested to receive one or more specific MBMS services.

[0065] A limited amount of MBMS control information may be provided on the BCCH. This primarily may concern the information needed to acquire the MCCH(s). This information may be carried by means of a single MBMS specific SystemInformationBlock: SystemInformationBlockType13. An MBSFN area may be identified by the mbsfn-AreaId in

SystemInformationBlockType13. At mobility, the UE may consider that the MBSFN area may be continuous when the source cell and the target cell broadcast the same value in the mbsfn-AreaId.

[0066] MCCH information may be transmitted periodically, using a configurable repetition period. Scheduling information may be not provided for MCCH i.e. both the time domain scheduling as well as the lower layer configuration are semi-statically configured, as defined within SystemInformationBlockType13.

[0067] For MBMS user data, which may be carried by MTCH logical channel, E-UTRAN may periodically provide MCH scheduling information (MSI) at lower layers (MAC). This MCH information may concern time domain scheduling i.e. frequency domain scheduling and lower layer configuration may be semi-statically configured. The periodicity of the MSI may be configurable and defined by the MCH scheduling period.

[0068] Change of MCCH information may occur at specific radio frames, i.e. a concept of a modification period may be used. Within a modification period, the same MCCH information may be transmitted a number of times, as defined by its scheduling (which is based on a repetition period). Modification period boundaries may be defined by SFN values for which SFN mod m= 0, where m may be the number of radio frames comprising a modification period. The modification period may be configured by means of SystemInformationBlockType13.

[0069] When the network changes (some of) the MCCH information, it may notify UEs about the change during a first modification period. In a next modification period, a network may transmit updated MCCH information. Upon receiving a change notification, a UE interested to receive MBMS services may acquire new MCCH information from the start of a next modification period. The UE may apply previously acquired MCCH information until the UE acquires the new MCCH information.

[0070] In an example, indication of an MBMS specific RNTI, the M-RNTI, on PDCCH may be used to inform UEs in RRC_IDLE and UEs in RRC_CONNECTED about an MCCH information change. When receiving an MCCH information change notification, a UE may know that the MCCH information will change at the next modification period boundary. A notification on PDCCH may indicate which of MCCHs will change, which may be done by means of an 8-bit bitmap. Within this bitmap, the bit at the position indicated by the field notificationIndicator may be used to indicate changes for that MBSFN area: if the bit is set to "1", the corresponding MCCH may change. An MCCH information change notification may be used to inform the UE about a change of MCCH information upon session start or about the start of MBMS counting.

[0071] MCCH information change notifications on PDCCH may be transmitted periodically and/or may be carried on MBSFN subframes only. These MCCH information change notification occasions may be common for all MCCHs that may be configured, and/or configurable by parameters included in SystemInformationBlockType13: a repetition coefficient, a radio frame offset and a subframe index. These common notification occasions may be based on MCCH with the shortest modification period.

[0072] In an example, E-UTRAN may modify MBMS configuration information provided on MCCH as updating the MBMS configuration information carried on BCCH i.e. at a coinciding BCCH and MCCH modification period. Upon detecting that a new MCCH is configured on BCCH, a UE interested to receive one or more MBMS services may acquire the MCCH, unless it knows that the services it may be interested in are not provided by the corresponding MBSFN area.

[0073] A UE that may be receiving an MBMS service via MRB may acquire MCCH information from a start of each modification period. A UE interested to receive MBMS from a carrier on which dl-Bandwidth included in MasterInformationBlock may be set to n6 may acquire the MCCH information at least once every MCCH modification period. A UE that is not receiving an MBMS service via MRB, as well as UEs that are receiving an MBMS service via MRB but potentially interested to receive other services not started yet in another MBSFN area from a carrier on which dl-Bandwidth included in MasterInformationBlock may be other than n6, may verify that stored MCCH information remains valid by attempting to find MCCH information change notification at least notificationRepetitionCoeff times during the modification period of the applicable MCCH(s), if no MCCH information change notification is received.

[0074] In case that a UE is aware which MCCH(s) E-UTRAN may use for service(s) it may be interested to receive, the UE may need to monitor change notifications for a subset of the MCCHs that may be configured, referred to as the 'applicable MCCH(s)'.

[0075] A UE may apply MCCH information acquisition procedure to acquire MBMS control information that may be broadcasted by E-UTRAN. A procedure may apply to MBMS capable UEs that may be in RRC_IDLE or in RRC_CONNECTED.

[0076] A UE interested to receive MBMS services may apply the MCCH information acquisition procedure upon entering a corresponding MBSFN area (e.g. upon power on, following UE mobility) and/or upon receiving a notification that MCCH information has changed. A UE that may be receiving an MBMS service may apply a MCCH information acquisition procedure to acquire MCCH, that may correspond with a service that may be being received, at a start of modification period.

[0077] Unless explicitly stated otherwise in a procedural specification, an MCCH information acquisition procedure may overwrite stored MCCH information, i.e. delta configuration may be not applicable for MCCH information and/or the UE discontinues using a field if it is absent in MCCH information.

[0078] An MBMS capable UE may: if the procedure is triggered by an MCCH information change notification: may start acquiring MBSFNAreaConfiguration message and/or MBMSCountingRequest message if present, from the beginning of a modification period following the one in which the change notification may be received. A UE may continue using previously received MCCH information until new MCCH information has been acquired. If a UE enters an MBSFN area: may acquire an MBSFNAreaConfiguration message and/or an MBMSCountingRequest message if present, at the next repetition period. If a UE is receiving an MBMS service: may start acquiring an MBSFNAreaConfiguration message and/or an MBMSCountingRequest message if present, that both concern the MBSFN area of the service that may be being received, from the beginning of modification period.

[0079] In an example, No UE requirements related to the contents of this MBSFNAreaConfiguration may apply other than those specified elsewhere e.g. within procedures using concerned system information, corresponding field descriptions. Upon receiving MBMSCountingRequest message, the UE may perform an MBMS Counting procedure.

[0080] In an example, an MBMS PTM radio bearer configuration procedure may be used by the UE to configure RLC, MAC and/or the physical layer upon starting and/or stopping to receive an MRB. The procedure may apply to UEs interested to receive one or more MBMS services.

[0081] In case the UE is unable to receive an MBMS service due to capability limitations, upper layers may take appropriate action e.g. terminate a lower priority unicast service.

[0082] In an example, a UE may apply an MRB establishment procedure to start receiving a session of a service it may have an interest in. The procedure may be initiated e.g. upon start of the MBMS session, upon (re-)entry of the corresponding MBSFN service area, upon becoming interested in the MBMS service, upon removal of UE capability limitations inhibiting reception of the concerned service.

[0083] A UE may apply an MRB release procedure to stop receiving a session. The procedure may be initiated e.g. upon stop of the MBMS session, upon leaving the corresponding MBSFN service area, upon losing interest in the MBMS service, when capability limitations may start inhibiting reception of the concerned service.

[0084] In an example, upon MRB establishment, the UE may: establish an RLC entity in accordance with the configuration; configure an MTCH logical channel in accordance with a received locgicalChannelIdentity, applicable for an MRB, as included in an MBSFNAreaConfiguration message; configure a physical layer in accordance with a pmch-Config, applicable for an MRB, as included in an MBSFNAreaConfiguration message; and/or inform upper layers about an establishment of an MRB by indicating a corresponding tmgi and/or sessionId;

[0085] In an example, upon MRB release, a UE may: release an RLC entity as well as a related MAC and/or physical layer configuration; and/or inform upper layers about a release of an MRB by indicating corresponding tmgi and/or sessionId.

[0086] In an example, an MBMS Counting procedure may be used by an E-UTRAN to count the number of RRC_CONNECTED mode UEs which may be receiving via an MRB or interested to receive via an MRB specified MBMS services. A UE may determine interest in an MBMS service, that may be identified by the TMGI, by interaction with upper layers. An E-UTRAN may initiate a procedure by sending an MBMSCountingRequest message.

[0087] In an example, upon receiving an MBMSCountingRequest message, a UE in RRC_CONNECTED mode may: if a SystemInformationBlockType1, that provided scheduling information for the systemInformationBlockType13 that included configuration of an MCCH via which an MBMSCountingRequest message was received, contained an identity of a Registered PLMN. If a UE is receiving via an MRB or interested to receive via an MRB at least one of services in a received countingRequestList: if more than one entry is included in mbsfn-AreaInfoList received in SystemInformationBlockType13 that may be included configuration of an MCCH via which an MBMSCountingRequest message was received: include an mbsfn-AreaIndex in an MBMSCountingResponse message and/or set it to an index of entry in an mbsfn-AreaInfoList within a received SystemInformationBlockType13 that may correspond with an MBSFN area used to transfer a received MBMSCountingRequest message. For an MBMS service included in a received countingRequestList: if a UE is receiving via an MRB or interested to receive via an MRB this MBMS service: may include an entry in a countingResponseList within an MBMSCountingResponse message with countingResponseService set it to an index of entry in a countingRequestList within a received MBMSCountingRequest that may correspond with an MBMS service the UE is receiving or interested to receive; may submit an MBMSCountingResponse message to lower layers for transmission upon which the procedure ends.

[0088] UEs that are receiving an MBMS User Service by means of a Unicast Bearer Service (i.e. via a DRB), but are interested to receive a concerned MBMS User Service via an MBMS

Bearer Service (i.e. via an MRB), respond to the counting request. If ciphering is used at upper layers, a UE may not respond to the counting request if it can not decipher the MBMS service for which counting is performed.

[0089] A UE may treat an MBMSCountingRequest messages received in a modification period independently. In an case E-UTRAN may repeat an MBMSCountingRequest (i.e. including the same services) in a subsequent modification period, a UE may respond again. A UE may provide a one MBMSCountingResponse message to multiple transmission attempts of an MBMSCountingRequest messages in a given modification period.

[0090] A purpose of this procedure may be to inform E-UTRAN that a UE is receiving or is interested to receive MBMS service(s) via an MRB or SC-MRB, and if so, to inform E-UTRAN about a priority of MBMS versus unicast reception.

[0091] An MBMS or SC-PTM capable UE in RRC_CONNECTED may initiate a procedure in several cases including upon successful connection establishment, upon entering or leaving the service area, upon session start or stop, upon change of interest, upon change of priority between MBMS reception and unicast reception or upon change to a PCell broadcasting SystemInformationBlockType15.

[0092] Upon initiating the procedure, a UE may: if SystemInformationBlockType15 is broadcast by a PCell: ensure having a valid version of SystemInformationBlockType15 for a PCell; if the UE did not transmit an MBMSInterestIndication message since last entering RRC_CONNECTED state; or if since the last time the UE transmitted an MBMSInterestIndication message, a UE connected to a PCell not broadcasting SystemInformationBlockType15: if a set of MBMS frequencies of interest may not be empty: may initiate transmission of an MBMSInterestIndication message; else: if a set of MBMS frequencies of interest may have changed since a last transmission of an MBMSInterestIndication message; or if a prioritisation of reception of indicated MBMS frequencies compared to reception of the established unicast bearers has changed since a last transmission of an MBMSInterestIndication message: may initiate transmission of an MBMSInterestIndication message; else if SystemInformationBlockType20 is broadcast by the PCell: if since the last time a UE transmitted an MBMSInterestIndication message, the UE connected to a PCell not broadcasting SystemInformationBlockType20; or if a set of MBMS services of interest may be different from mbms-Services included in a last transmission of an MBMSInterestIndication message; may initiate a transmission of an MBMSInterestIndication message.

[0093] A UE may send an MBMSInterestIndication even when it is able to receive the MBMS services it is interested in i.e. to avoid that a network allocates a configuration inhibiting MBMS reception.

[0094] In an example, a UE may: consider a frequency to be part of the MBMS frequencies of interest if following conditions are met: at least one MBMS session a UE is receiving or interested to receive via an MRB or SC-MRB is ongoing or about to start; and/or for at least one of these MBMS sessions SystemInformationBlockType15 acquired from a PCell may include for a concerned frequency one or more MBMS SAIs as indicated in a USD for this session; and/or a UE is capable of simultaneously receiving MRBs and/or is capable of simultaneously receiving SC-MRBs on a set of MBMS frequencies of interest, regardless of whether a serving cell is configured on each of these frequencies or not; and/or a supportedBandCombination a UE included in UE-EUTRA-Capability may contain at least one band combination including a set of MBMS frequencies of interest.

[0095] A UE may determine whether a session is ongoing from a start and stop time indicated a the User Service Description (USD). A UE may consider a frequency to be part of MBMS frequencies of interest even though E-UTRAN may (temporarily) not employ an MRB or SC-MRB for a concerned session. I.e. a UE may not verify if a session is indicated on (SC-)MCCH. A UE may consider frequencies of interest independently of any synchronization state. Indicating a frequency may imply that a UE supports SystemInformationBlockType13 or SystemInformationBlockType20 acquisition for a concerned frequency i.e. the indication may be independent of whether a serving cell is configured on that frequency. When evaluating which frequencuy it can receive simultaneously, a UE may not take into account serving frequencies that may be currently configured i.e. it may consider MBMS frequencies it is interested to receive. A set of MBMS frequencies of interest may include at most one frequency for a given physical frequency. A UE may consider a physical frequency to be part of MBMS frequencies of interest if it may support at least one of the bands indicated for this physical frequency in SystemInformationBlockType1 (for serving frequency) or SystemInformationBlockType15 (for neighbouring frequencies). In this case, E-UTRAN may assume the UE supports MBMS reception on any of the bands supported by the UE (i.e. according to supportedBandCombination).

[0096] A UE may: consider a MBMS service to be part of MBMS services of interest if following conditions are met: the UE is SC-PTM capable; and the UE is receiving or interested to receive this service via an SC-MRB; and one session of this service is ongoing or about to start; and one or more MBMS SAIs in the USD for this service is included in

SystemInformationBlockType15 acquired from a PCell for a frequency belonging to a set of MBMS frequencies of interest.

[0097] A UE may set the contents of the MBMSInterestIndication message as follows: if a set of MBMS frequencies of interest is not empty: include mbms-FreqList and/or set it to include MBMS frequencies of interest sorted by decreasing order of interest, using EARFCN corresponding with freqBandIndicator included in SystemInformationBlockType1 (for serving frequency), if applicable, and EARFCN(s) as included in SystemInformationBlockType15 (for neighbouring frequencies); include mbms-Priority if a UE prioritises reception of all indicated MBMS frequencies above reception of any of unicast bearers; if SystemInformationBlockType20 is broadcast by a PCell: include mbms-Services and/or set it to indicate a set of MBMS services of interest.

[0098] An EARFCN included in mbms-FreqList may be used to indicate a physical frequency a UE is interested to receive i.e. a UE may not support a band corresponding to an included EARFCN (but it may support at least one of bands indicated in system information for a concerned physical frequency). If a UE prioritises MBMS reception and unicast data may not be supported because of congestion on the MBMS carrier(s), E-UTRAN may initiate release of unicast bearers. It may be up to E-UTRAN implementation whether all bearers or only GBR bearers are released. E-UTRAN may not initiate re-establishment of the released unicast bearers upon alleviation of congestion. A UE may submit an MBMSInterestIndication message to lower layers for transmission.

[0099] In an example, SC-PTM control information may be provided on a specific logical channel: an SC-MCCH. An SC-MCCH may carry an SCPTMConfiguration message which may indicate MBMS sessions that may be ongoing as well as (corresponding) information on when each session may be scheduled, i.e. scheduling period, scheduling window, and/or start offset. An SCPTMConfiguration message may provide information about neighbour cells transmitting MBMS sessions which may be ongoing on the current cell. A limited amount of SC-PTM control information may be provided on a BCCH. This may concern information needed to acquire an SC-MCCH.

[00100] In an example, SC-MCCH information (i.e. information transmitted in messages sent over SC-MCCH) may be transmitted periodically, using a configurable repetition period. SC-MCCH transmissions (and the associated radio resources and MCS) may be indicated on PDCCH.

[00101] Change of SC-MCCH information may occur at specific radio frames, i.e. a concept of a modification period may be used. Within a modification period, a same SC-MCCH information may be transmitted a number of times, as defined by its scheduling (which may

be based on a repetition period). Modification period boundaries may be defined by SFN values for which SFN mod m= 0, where m may be a number of radio frames comprising a modification period. A modification period may be configured by means of SystemInformationBlockType20.

[00102] When a network changes (some of) SC-MCCH information, it may notify UEs about a change in a first subframe which may be used for SC-MCCH transmission in a repetition period. LSB bit in 8-bit bitmap when set to '1' may indicate a change in SC-MCCH. Upon receiving a change notification, a UE interested to receive MBMS services transmitted using SC-PTM may acquire new SC-MCCH information starting from a same subframe. A UE may apply previously acquired SC-MCCH information until the UE acquires new SC-MCCH information.

[00103] In an example, a SC-PTM capable UE receiving or interested to receive MBMS service(s) via SC-MRB may apply SC-PTM procedures and/or a MBMS interest indication procedure.

[00104] In an example, a UE may apply an SC-MCCH information acquisition procedure to acquire SC-PTM control information that may be broadcast by E-UTRAN. The procedure may apply to SC-PTM capable UEs that are in RRC_IDLE or in RRC_CONNECTED.

[00105] A UE interested to receive MBMS services via SC-MRB may apply the SC-MCCH information acquisition procedure upon entering the cell broadcasting SystemInformationBlockType20 (e.g. upon power on, following UE mobility) and upon receiving a notification that SC-MCCH information may have changed. A UE that is receiving an MBMS service via SC-MRB may apply an SC-MCCH information acquisition procedure to acquire SC-MCCH information that may correspond with a service that may be being received, at the start of a modification period.

[00106] An SC-MCCH information acquisition procedure may overwrite stored SC-MCCH information, i.e. delta configuration may not be applicable for SC-MCCH information and a UE may discontinue using a field if it is absent in SC-MCCH information.

[00107] A SC-PTM capable UE may: if a procedure is triggered by an SC-MCCH information change notification: start acquiring an SCPTMConfiguration message from a subframe where a change notification may be received; if a UE enters a cell broadcasting SystemInformationBlockType20: may acquire an SCPTMConfiguration message at a next repetition period; if the UE is receiving an MBMS service via an SC-MRB: may start acquiring an SCPTMConfiguration message from a beginning of modification period. A UE may continue using a previously received SC-MCCH information until new SC-MCCH information has been acquired. No UE requirements related to contents of this

SCPTMConfiguration may apply other than those specified elsewhere e.g. within procedures using concerned system information, corresponding field descriptions.

[00108] An SC-PTM radio bearer configuration procedure may be used by a UE to configure RLC, MAC, and/or a physical layer upon starting and/or stopping to receive an SC-MRB transmitted on SC-MTCH. The procedure may apply to SC-PTM capable UEs that may be in RRC_CONNECTED or in RRC_IDLE and may be interested to receive one or more MBMS services via SC-MRB.

[00109] In case a UE is unable to receive an MBMS service via an SC-MRB due to capability limitations, upper layers may take appropriate action e.g. terminate a lower priority unicast service.

[00110] A UE may apply an SC-MRB establishment procedure to start receiving a session of a MBMS service it may have an interest in. The procedure may be initiated e.g. upon start of an MBMS session, upon entering a cell providing via SC-MRB a MBMS service in which a UE may have interest, upon becoming interested in an MBMS service, upon removal of UE capability limitations inhibiting reception of a concerned service.

[00111] A UE may apply an SC-MRB release procedure to stop receiving a session. The procedure may be initiated e.g. upon stop of an MBMS session, upon leaving a cell where a SC-MRB is established, upon losing interest in an MBMS service, when capability limitations start inhibiting reception of a concerned service.

[00112] Upon SC-MRB establishment, a UE may: establish an RLC entity in accordance with configuration; configure a SC-MTCH logical channel applicable for an SC-MRB and/or instruct MAC to receive DL-SCH on a cell where an SCPTMConfiguration message was received for an MBMS service for which an SC-MRB may be established and/or using g-RNTI and/or sc-mtch-SchedulingInfo (if included) in this message for this MBMS service: configure a physical layer in accordance with an sc-mtch-InfoList, applicable for an SC-MRB, as included in an SCPTMConfiguration message; and/or inform upper layers about an establishment of an SC-MRB by indicating a corresponding tmgi and/or sessionId;

[00113] Upon SC-MRB release, a UE may: release an RLC entity as well as a related MAC and/or physical layer configuration; and/or inform upper layers about a release of an SC-MRB by indicating a corresponding tmgi and/or sessionId.

[00114] An MBMSCountingRequest message may be used by E-UTRAN to count UEs that are receiving or interested to receive specific MBMS services. An MBMSCountingResponse message may be used by a UE to respond to an MBMSCountingRequest message. An MBMSInterestIndication message may be used to inform E-UTRAN that a UE is

receiving/interested to receive or no longer receiving/interested to receive MBMS via an MRB or SC-MRB.

[00115] An mbms-FreqList may be a list of MBMS frequencies on which a UE is receiving or interested to receive MBMS via an MRB or SC-MRB. An mbms-Priority may indicate whether a UE prioritises MBMS reception above unicast reception. A field may be present (i.e. value true), if a UE prioritises reception of listed MBMS frequencies above reception of unicast bearers. Otherwise the field may be absent.

[00116] An MBSFNAreaConfiguration message may contain MBMS control information applicable for an MBSFN area. For MBSFN area included in SystemInformationBlockType13 E-UTRAN may configure an MCCH (i.e. the MCCH identifies the MBSFN area) and/or signals the MBSFNAreaConfiguration message. An SCPTMConfiguration message may contain control information applicable for MBMS services transmitted via SC-MRB. An sc-mtch-InfoList may provide configuration of SC-MTCH in a current cell. An scptm-NeighbourCellList may be a list of neighbour cells providing MBMS services via SC-MRB. When absent, a UE may assume that MBMS services listed in the SCPTMConfiguration message may not be provided via SC-MRB in any neighbour cell. An IE MBMS-NotificationConfig may specify MBMS notification related configuration parameters, that may be applicable for MBSFN areas. An IE MBMS-ServiceList may provide a list of MBMS services which a UE is receiving or interested to receive. An IE MBSFN-AreaInfoList may contain information required to acquire MBMS control information associated with one or more MBSFN areas. An IE MBSFN-SubframeConfig may define subframes that may be reserved for MBSFN in downlink. An IE PMCH-InfoList may specify configuration of PMCHs of an MBSFN area, while IE PMCH-InfoListExt may include additional PMCHs, i.e. extend PMCH list using general principles. Information provided for an individual PMCH may include configuration parameters of sessions that are carried by a concerned PMCH. For PMCH that E-UTRAN may include in PMCH-InfoList, a list of ongoing sessions may have at least one entry. An IE SC-MTCH-InfoList may provide a list of ongoing MBMS sessions transmitted via SC-MRB and for MBMS session, an associated G-RNTI and scheduling information.

[00117] In an example, an mbmsSessionInfo may indicate an ongoing MBMS session in a SC-MTCH. A g-RNTI may be used to scramble scheduling and transmission of a SC-MTCH. An IE SCPTM-NeighbourCellList may indicate a list of neighbour cells where ongoing MBMS sessions provided via SC-MRB in current cells may be also provided. A sessionId may indicate an optional MBMS Session Identity, which together with TMGI may identify a transmission or a possible retransmission of a specific MBMS session. The field may be

included when upper layers have assigned a session identity i.e. one may be available for an MBMS session in E-UTRAN. A serviceId may identify an identity of an MBMS service within a PLMN. The field may contain octet 3- 5 of an IE Temporary Mobile Group Identity (TMGI). A first octet may contain a third octet of the TMGI, a second octet may contain a fourth octet of the TMGI and so on.

[00118] An issue with respect to exchanging an MBMS (and/or V2X) service information between eNBs is how a list of MBMS (and/or V2X) services that a UE may be receiving and/or interested in may be transferred to a target eNB for reliable continuation of MBMS (and/or V2X) services during a handover and/or an SeNB addition/modification procedure. In an example embodiments, an eNB may receive, from a UE, an MBMS (and/or V2X) interest service list, a list of MBMS (and/or V2X) interest services that the UE may be receiving and/or interested in. An MBMS (and/or V2X) interest service list may comprise MBMS frequency, MBMS (and/or V2X) priority, TMGI, MBMS session ID, G-RNTI, and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service. In an example, an eNB may transfer an MBMS (and/or V2X) interest service list received from a UE to a target eNB during a handover and/or an SeNB addition/modification procedure for the UE.

[00119] In the current LTE technology, TMGI information of one or more MBMS services of the wireless device are not exchanged between the serving and target base stations. For SC-PTM, during a handover and/or an SeNB addition/modification, a target eNB and/or a target SeNB may not recognize which MBMS (and/or V2X) service a UE is interested in with only MBMS (and/or V2X) frequency information. To recognize a list of MBMS (and/or V2X) services that a UE may be receiving and/or interested in, a target eNB and/or a target SeNB may receive, from a source eNB, and utilize MBMS frequency, MBMS (and/or V2X) priority, TMGI, MBMS session ID, G-RNTI, and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service for a handover UE.

[00120] In an example, a UE with MBMS (and/or V2X) services and/or initiating MBMS (and/or V2X) services may handover from one cell to another cell. A UE with MBMS (and/or V2X) services may continue MBMS (and/or V2X) services after completing a handover procedure. A UE initiating MBMS (and/or V2X) services may start MBMS (and/or V2X) services after completing a handover procedure. In the legacy network, MBMS (and/or V2X) services for a UE may be interrupted and/or delayed during a handover procedure of the UE. The current X2 protocol, S1 protocol, and/or handover mechanisms/signaling may require enhancements to reduce a time duration that MBMS (and/or V2X) services may be interrupted and/or delayed for because of a UE handover. The current X2 protocol, S1

protocol, and/or handover mechanisms/signaling may require enhancements to improve handover procedures for a UE with MBMS (and/or V2X) services.

[00121] In an example, a UE with MBMS (and/or V2X) services and/or initiating MBMS (and/or V2X) services may add and/or modify cells of an SeNB. A UE with MBMS (and/or V2X) services may continue MBMS (and/or V2X) services after completing an SeNB addition/modification procedure. A UE initiating MBMS (and/or V2X) services may start MBMS (and/or V2X) services after completing an SeNB addition/modification procedure. In the legacy network, MBMS (and/or V2X) services for a UE may be interrupted and/or delayed during an SeNB addition/modification procedure of the UE. A UE may have to send another MBMSInterestIndication in order to communicates its interest. This may introduce additional delay and/or dis-continuity in receiving MBMS services from a target/secondary eNB. The current X2 protocol, S1 protocol, and/or SeNB addition/modification mechanisms/signaling may require enhancements to reduce a time duration that MBMS (and/or V2X) services may be interrupted and/or delayed for because of an SeNB addition/modification of a UE. The current X2 protocol, S1 protocol, and/or SeNB addition/modification mechanisms/signaling may require enhancements to improve SeNB addition/modification procedures for a UE with MBMS (and/or V2X) services.

[00122] - Handover

[00123] Example embodiments may improve the handover procedures for a UE with MBMS (and/or V2X) services. Example embodiments may provide enhancements to current handover mechanism and increase MBMS (and/or V2X) service reliability and continuity. In an example embodiment, a UE with MBMS (and/or V2X) services may continue the MBMS (and/or V2X) services that may be provided to the UE in a current cell after moving to another cell without interrupting the MBMS (and/or V2X) services for a long time duration. In an example embodiment, a UE may start MBMS (and/or V2X) services after moving to another cell without delaying the MBMS (and/or V2X) services for a long time duration. Example embodiments may enable a UE to continue its MBMS (and/or V2X) services without a long service interruption or initiate its MBMS (and/or V2X) services without a long service delay when it is moving in an area covered by multiple eNB. Example embodiments may enhance network performance by enabling a target eNB of a UE handover to get a list of MBMS (and/or V2X) services that the UE may be receiving and/or interested in prior to completing the handover. An example handover signaling is shown below.

[00124] In an example embodiment, in RRC_CONNECTED mode, the network may control UE mobility, for example, the network may decide when the UE connects to which E-UTRA cell(s) or inter-RAT cell. For network controlled mobility in RRC_CONNECTED, the PCell

may be changed using an RRC Connection Reconfiguration message including the mobilityControlInfo (handover). The SCell(s) may be changed using the RRC Connection Reconfiguration message either with or without the mobilityControlInfo. The network may trigger the handover procedure e.g. based on radio conditions, load, QoS, UE category, and/or the like. To facilitate this, the network may configure the UE to perform measurement reporting (possibly including the configuration of measurement gaps). The network may also initiate handover blindly, for example without having received measurement reports from the UE. Before sending the handover message to the UE, the source eNB may prepare one or more target cells. The source eNB may select the target PCell. The source eNB may also provide the target eNB with a list of best cells on each frequency for which measurement information is available, for example, in order of decreasing RSRP. The source eNB may also include available measurement information for the cells provided in the list. The target eNB may decide which SCells are configured for use after handover, which may include cells other than the ones indicated by the source eNB.

[00125] According to some of the various aspects of embodiments, the target eNB may generate a message used to configure the UE for the handover, for example, the message including the access stratum configuration to be used in the target cell(s). The source eNB may transparently (for example, does not alter values/content) forward the handover message/information received from the target eNB to the UE. When appropriate, the source eNB may initiate data forwarding for (a subset of) the dedicated radio bearers. After receiving the handover message, the UE may attempt to access the target PCell at the available RACH occasion according to a random access resource selection. When allocating a dedicated preamble for the random access in the target PCell, E-UTRA may ensure the preamble is available from the first RACH occasion the UE may use. Upon successful completion of the handover, the UE may send a message used to confirm the handover to the target eNB.

[00126] According to some of the various aspects of embodiments, if the target eNB does not support the release of RRC protocol which the source eNB used to configure the UE, the target eNB may be unable to comprehend the UE configuration provided by the source eNB. In this case, the target eNB may use the full configuration option to reconfigure the UE for handover and re-establishment. Full configuration option includes an initialization of the radio configuration, which makes the procedure independent of the configuration used in the source cell(s) with the exception that the security algorithms are continued for the RRC re-establishment.

[00127] According to some of the various aspects of embodiments, after the successful completion of handover, PDCP SDUs may be re-transmitted in the target cell(s). This may

apply for dedicated radio bearers using RLC-AM mode and/or for handovers not involving full configuration option. After the successful completion of handover not involving full configuration option, the SN (sequence number) and/or the HFN (hyper frame number) may be reset for some radio bearers. For the dedicated radio bearers using RLC-AM mode both SN and HFN may continue. For reconfigurations involving the full configuration option, the PDCP entities may be newly established (SN and HFN may not continue) for dedicated radio bearers irrespective of the RLC mode. UE behavior to be performed upon handover may be the same regardless of the handover procedures used within the network (e.g. whether the handover includes X2 or S1 signalling procedures).

[00128] In an example, the source eNB may, for some time, maintain a context to enable the UE to return in case of handover failure. After having detected handover failure, the UE may attempt to resume the RRC connection either in the source PCell or in another cell using the RRC re-establishment procedure. This connection resumption may succeed if the accessed cell is prepared. For example, when the access cell is a cell of the source eNB or of another eNB towards which handover preparation has been performed. The cell in which the re-establishment procedure succeeds becomes the PCell while SCells, if configured, may be released.

[00129] In an example, normal measurement and mobility procedures may be used to support handover to cells broadcasting a CSG (closed subscriber group) identity. In addition, E-UTRAN may configure the UE to report that it is entering or leaving the proximity of cell(s) included in its CSG whitelist. E-UTRAN may request the UE to provide additional information broadcast by the handover candidate cell e.g. cell global identity, CSG identity, CSG membership status. E-UTRAN may use the proximity report to configure measurements as well as to decide whether or not to request additional information broadcast by the handover candidate cell. The additional information may be used to verify whether or not the UE is authorised to access the target PCell and may also be needed to identify handover candidate cell. This may involve resolving PCI confusion, for example, when the physical layer identity that is included in the measurement report may not uniquely identify the cell.

[00130] In an example, the purpose of RRC connection reconfiguration procedure may be to modify an RRC connection, e.g. to establish, modify and/or release RBs, to perform handover, to setup, modify, and/or release measurements, to add, modify, and/or release SCells. As part of the procedure, NAS dedicated information may be transferred from E-UTRAN to the UE. If the received RRC Connection Reconfiguration message includes the sCellToReleaseList, UE performs SCell release. If the received RRC Connection

Reconfiguration message includes the sCellToAddModList, UE performs SCell additions or modification.

[00131] In an example, the UE context within the source eNB may contain information regarding roaming/handover restrictions which may be provided either at connection establishment or at the last TA (tracking area) update process. The source eNB may configure the UE measurement procedures employing at least one RRC connection reconfiguration message. The UE may be triggered to send at least one measurement report by the rules set by, for example, system information, RRC configuration, and/or the like. The source eNB may make a handover decision based on many parameters, for example, the measurement reports, RRM information, traffic and load, a combination of the above, and/or the like. The source eNB may initiate the handover procedure by sending a handover request message to one or more potential target eNBs. When the source eNB sends the handover request message, it may start a handover preparation timer. Upon reception of the handover request acknowledgement message the source eNB may stop the handover preparation timer.

[00132] In an example, in an X2 handover process, the source eNB may transmit a handover request message to one or more potential target eNB passing information to prepare the handover at the target side. The handover request message may comprise an MBMS (and/or V2X) interest service list, a list of MBMS (and/or V2X) services that a handover UE may be receiving and/or interested in. In an example, an RRC Context IE in the handover request message may contain an MBMS (and/or V2X) interest service list. In an example, an as-Context IE in an RRC Context IE in the handover request message may contain an MBMS (and/or V2X) interest service list. In another example, an MBMSInterestIndication-v1310 IE, which includes MBMS service lists, may be added in an as-Context IE in an RRC Context IE in the handover request message. In an example, an MBMS (and/or V2X) interest service list may comprise MBMS frequency, MBMS (and/or V2X) priority, TMGI, MBMS session ID, G-RNTI, and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service.

[00133] In an example, in an S1 handover process without MME relocation, the source eNB may transmit a handover required message to an MME for one or more potential target eNB, and the MME may transmit a handover request message to the potential target eNBs. The handover required message and/or the handover request message may pass information to prepare the handover at the target side. The handover required message and/or the handover request message may comprise an MBMS (and/or V2X) interest service list, a list of MBMS (and/or V2X) services that a handover UE may be receiving and/or interested in. In an example, a Source to Target Transparent Container IE in the handover required message and/or the handover request message may contain an MBMS (and/or V2X) interest service

list. In an example, an RRC Container IE in a Source to Target Transparent Container IE in the handover required message and/or the handover request message may contain an MBMS (and/or V2X) interest service list. In an example, an as-Context IE in an RRC Container IE in a Source to Target Transparent Container IE in the handover required message and/or the handover request message may contain an MBMS (and/or V2X) interest service list. In another example, an MBMSInterestIndication-v1310 IE, which includes MBMS service lists, may be added in an as-Context IE in an RRC Container IE in a Source to Target Transparent Container IE in the handover required message and/or the handover request message. In an example, an MBMS (and/or V2X) interest service list may comprise MBMS frequency, MBMS (and/or V2X) priority, TMGI, MBMS session ID, G-RNTI, and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service.

[00134] In an example, in an S1 handover process relocating an MME, the source eNB may transmit a handover required message to a source MME for one or more potential target eNB, the source MME may transmit a forward relocation request message to one or more potential target MMEs serving the potential target eNBs, and the potential target MMEs may transmit a handover request message to the potential target eNBs. The handover required message, the forward relocation request message, and/or the handover request message may pass information to prepare the handover at the target side. The handover required message, the forward relocation request message, and/or the handover request message may comprise an MBMS (and/or V2X) interest service list, a list of MBMS (and/or V2X) services that a handover UE may be receiving and/or interested in. In an example, a Source to Target Transparent Container IE in the handover required message and/or the handover request message may contain an MBMS (and/or V2X) interest service list. In an example, an E-UTRAN Transparent Container IE in the forward relocation request message may contain an MBMS (and/or V2X) interest service list.

[00135] During the handover preparation phase, the serving eNB may transmit an MBMS (and/or V2X) interest service list to one or more potential target eNBs. This information may be employed, at least in part, by the potential target eNB, for example, to configure the UE and/or schedule MBMS resources that may be employed after completing the handover.

[00136] In an example a target eNB may employ an MBMS (and/or V2X) interest service list in order to properly configure a UE. The target eNB may transmit one or more messages to the source eNB comprising one or more configuration parameters for the UE, e.g. scheduling information, G-RNTI, and one or more files of SIB20, and/or one or more fields of SC-PTMConfigurationMessage. The source eNB may forward one or more of the configuration parameters to the UE in a handover command message. In an example, a target

eNB may transmit one or more message to the UE comprising some of the one or more configuration parameters for the UE. A target eNB may configure a UE to provide MBMS (and/or V2X) services that the UE may be receiving and/or interested in.

[00137] In an example, a target eNB may schedule MBMS (and/or V2X) resources before or during a UE connecting to the target eNB. In an example, the target eNB may start transmission of the MBMS services for the UE. A target eNB may schedule MBMS (and/or V2X) resources to provide MBMS (and/or V2X) services that the UE may be receiving and/or interested in. The target eNB may schedule MBMS (and/or V2X) resources to provide to the wireless device at least one of the one or more MBMS services that the UE is interested in. In an example, the target eNB may transmit at least one of an SIB20 (e.g. updated SIB20) or an SCPTMconfiguration message (e.g. updated SCPTMconfiguration message) comprising one or more parameters for at least one of the one or more MBMS services for the UE. The target eNB may transmit traffic associated with at least one of the one or more MBMS services. The target eNB may update one of more traffic parameters of at least one of the one or more MBMS services. The target eNB may modify one or more MBMS bearers and/or MBMS configuration to include the UE in a multicast/broadcast service.

[00138] In an example, if a UE is receiving and/or interested in a certain MBMS (and/or V2X) service, a target eNB may increase the priority of the service when scheduling MBMS (and/or V2X) resources.

[00139] Handover admission control may be performed by the target eNB dependent on many factors, for example, QoS required for the UE bearers, UE capabilities, UE configuration, target eNB load, a combination of the above, and/or the like. The target eNB may configure the required resources according to the received information from the serving eNB and may reserve a C-RNTI and/or a RACH preamble. The access stratum configuration to be used in the target cell may be specified independently (for example as an establishment) or as a delta compared to the access stratum-configuration used in the source cell (for example as a reconfiguration).

[00140] In an example, the target eNB may prepare handover with L1/L2 and may send the handover request acknowledge message to the source eNB. In an X2 handover procedure, the handover request acknowledge message may include a transparent container to be sent to the UE as an RRC message to perform the handover. In an S1 handover procedure without MME relocation, the handover request acknowledge message from the target eNB to the MME and/or the handover command message from the MME to the source eNB may include a transparent container to be sent to the UE as an RRC message to perform the handover. In an S1 handover procedure relocating an MME, the handover request acknowledge message from

the target eNB to the target MME, the forward relocation response message from the target MME to the source MME, and/or the handover command message from the source MME to the source eNB may include a transparent container to be sent to the UE as an RRC message to perform the handover. The container may include a new C-RNTI, target eNB security algorithm identifiers for the selected security algorithms, a dedicated RACH preamble, access parameters, SIBs, and/or other configuration parameters. The target eNB may generate the RRC message to perform the handover, for example, RRC connection reconfiguration message including the mobility control information. The RRC message may be sent by the source eNB towards the UE.

[00141] The source eNB may perform the necessary integrity protection and ciphering of the message. The UE may receive the RRC connection reconfiguration message from the source eNB and may start performing the handover. The UE may not need to delay the handover execution for delivering the HARQ/ARQ responses to the source eNB.

[00142] After receiving the RRC connection reconfiguration message including the mobility control information, UE may perform synchronisation to the target eNB and accesses the target cell via RACH on the primary cell. The UE Random access procedure may employ a contention-free procedure if a dedicated RACH preamble was indicated in the mobility control information. The UE random access procedure may employ a contention-based procedure if no dedicated preamble was indicated. The UE may derive target eNB specific keys and may configure the selected security algorithms to be used in the target cell. The target eNB may respond with uplink allocation and timing advance.

[00143] After the UE has successfully accessed the target cell, the UE may send an RRC connection reconfiguration complete message (C-RNTI) to confirm the handover and to indicate that the handover procedure is completed for the UE. UE may transmit a MAC uplink Buffer Status Report (BSR) Control Element (CE) along with the uplink RRC Connection Reconfiguration Complete message or may transmit a MAC uplink BSR CE whenever possible to the target eNB. The target eNB verifies the C-RNTI sent in the RRC Connection Reconfiguration Complete message. The target eNB may now begin sending data to the UE and receiving data from the UE.

[00144] In an example, in a target cell, UE may receive mbms subframe configuration information, sc-mcch subframe configuration information, and/or sc-mtch subframe configuration information transmitted by the target eNB. Based on the subframe configuration information, UE may start receiving MBMS (and/or V2X) services that the UE may have been receiving and/or interested in before the handover.

[00145] Example procedures related to UEInterestIndication, SIB20, sc-mcch, sc-mtch, and receiving MBMS traffic (e.g. SC-PTM, MBSFN) are provided in the specification.

[00146] - Dual Connectivity

[00147] Example embodiments may improve the SeNB addition/modification procedures for a UE with MBMS (and/or V2X) services. Example embodiments may provide enhancements to current SeNB addition/modification mechanism and increase MBMS (and/or V2X) service reliability and continuity. In an example embodiment, a UE with MBMS (and/or V2X) services may continue the MBMS (and/or V2X) services that may be provided to the UE in a current cell after adding and/or modifying another cell without interrupting the MBMS (and/or V2X) services for a long time duration. In an example embodiment, a UE may start MBMS (and/or V2X) services after adding and/or modifying another cell without delaying the MBMS (and/or V2X) services for a long time duration. Example embodiments may enable a UE to continue its MBMS (and/or V2X) services without a long service interruption or initiate its MBMS (and/or V2X) services without a long service delay when it is adding and/or modifying cells in an area covered by multiple eNB. Example embodiments may enhance network performance by enabling a target SeNB for an SeNB addition and/or modification to get a list of MBMS (and/or V2X) services that the UE may be receiving and/or interested in prior to completing the SeNB addition/modification procedure. An example SeNB addition signaling is shown below.

[00148] - SeNB Addition

[00149] In an example embodiment, in RRC_CONNECTED mode, an SeNB addition procedure may be initiated by an MeNB and used to establish a UE context at an SeNB in order to provide radio resources from the SeNB to the UE. An SeNB addition procedure may be used to add at least a first cell (PSCell) of an SCG.

[00150] In an example, an MeNB may decide to request an SeNB to allocate radio resources for a specific E-RAB, and an MeNB may send an SeNB addition request message, which may indicate E-RAB characteristics (e.g. E-RAB parameters, TNL address information corresponding to bearer type, and other E-RAB related information). In addition, an MeNB may indicate, within SCG-ConfigInfo in an SeNB addition request message, an MCG configuration and an entire UE capabilities for UE capability coordination to be used as basis for the reconfiguration by an SeNB. An MeNB may provide the latest measurement results for the SCG cell(s) requested to be added. In an example, an SeNB addition request message may comprise an MBMS (and/or V2X) interest service list, a list of MBMS (and/or V2X) services that an SeNB addition UE may be receiving and/or interested in. In an example, an SCG-ConfigInfo IE in an SeNB addition request message may contain an MBMS (and/or

V2X) interest service list. In an example, an MBMSInterestIndication-v1310 IE, which includes MBMS service lists, may be added in an SCG-ConfigInfo IE in an SeNB addition request message. In an example, an MBMS (and/or V2X) interest service list may comprise MBMS frequency, MBMS (and/or V2X) priority, TMGI, MBMS session ID, G-RNTI, and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service. In an example, an MBMS (and/or V2X) interest service list may be employed, at least in part, by an SeNB, for example, to configure a UE and/or schedule MBMS resources that may be employed after completing an SeNB addition procedure.

[00151] In an example, after receiving an SeNB addition request message, an SeNB may make a decision on accepting or rejecting the SeNB addition request. For a split bearer option, an MeNB may decide to request resources from an SeNB of such an amount, that the QoS for a respective E-RAB may be guaranteed by the exact sum of resources provided by the MeNB and the SeNB together, or even more, and the decision may be reflected in an SeNB addition request by the E-RAB parameters signaled to the SeNB, which may differ from E-RAB parameters received from an MME over S1. For a specific E-RAB, an MeNB may request the direct establishment of an SCG bearer or a Split bearer (i.e. without first having to establish an MCG bearer).

[00152] In an example embodiment, if an RRM entity in an SeNB is able to admit the resource request included in an SeNB addition request, the SeNB may allocate respective radio resources and, dependent on an bearer option, respective transport network resources, and the SeNB may transmit an SeNB addition request acknowledge message to an MeNB. In an example, An SeNB may trigger Random Access so that synchronisation of an SeNB radio resource configuration can be performed. In an example, an SeNB may provide new radio resources of SCG for a UE in SCG-Config in an SeNB addition request acknowledge message to an MeNB. For SCG bearers, an SeNB may provide new radio resources of the SCG together with S1 DL TNL address information for the respective E-RAB and security algorithm. For split bearers, an SeNB may provide new radio resources of the SCG together with X2 DL TNL address information for the respective E-RAB and security algorithm. In case of split bearers, transmission of user plane data may take place after an SeNB addition request acknowledge. In case of SCG bearers, data forwarding and the SN Status Transfer may take place after an SeNB addition request acknowledge.

[00153] In an example a SeNB may employ an MBMS (and/or V2X) interest service list in order to properly configure a UE. The SeNB may transmit one or more messages to the MeNB comprising one or more configuration parameters for the UE, e.g. scheduling information, G-RNTI, and one or more files of SIB20, and/or one or more fields of SC-

PTMConfigurationMessage. The MeNB may forward one or more of the configuration parameters to the UE in at least one message (e.g. RRC message). In an example, a SeNB may transmit one or more message to the UE comprising some of the one or more configuration parameters for the UE. A SeNB may configure a UE to provide MBMS (and/or V2X) services that the UE may be receiving and/or interested in.

[00154] In an example, a SeNB may schedule MBMS (and/or V2X) resources before or during a UE connecting to the SeNB. In an example, the SeNB may start transmission of the MBMS services for the UE. A SeNB may schedule MBMS (and/or V2X) resources to provide MBMS (and/or V2X) services that the UE may be receiving and/or interested in. The SeNB may schedule MBMS (and/or V2X) resources to provide to the wireless device at least one of the one or more MBMS services that the UE is interested in. In an example, the SeNB may transmit at least one of an SIB20 (e.g. updated SIB20) or an SCPTMconfiguration message (e.g. updated SCPTMconfiguration message) comprising one or more parameters for at least one of the one or more MBMS services for the UE. The SeNB may transmit traffic associated with at least one of the one or more MBMS services. The SeNB may update one of more traffic parameters of at least one of the one or more MBMS services. The SeNB/MeNB may modify one or more MBMS bearers and/or MBMS configuration to include the UE in a multicast/broadcast service.

[00155] In an example, if a UE is receiving and/or interested in a certain MBMS (and/or V2X) service, a SeNB may increase the priority of the service when scheduling MBMS (and/or V2X) resources.

[00156] In an example, if an SeNB is not able to accept any of the bearers or a failure occurs during the SeNB addition preparation, the SeNB may send an SeNB addition request reject message with an appropriate cause value to an MeNB.

[00157] In an example, if an MeNB endorses a new radio resource configuration in an SeNB addition request acknowledge received from an SeNB, the MeNB may send an RRCConnectionReconfiguration message to a UE including a new radio resource configuration of SCG according to an SCG-Config included in an SeNB addition request acknowledge. In an example, receiving a new radio resource configuration from an MeNB, a UE may apply the new configuration and reply with an RRCConnectionReconfigurationComplete message. In case a UE is unable to comply with (part of) the configuration included in an RRCConnectionReconfiguration message, a UE may perform a reconfiguration failure procedure. In an example, if an MeNB receives an RRCConnectionReconfigurationComplete message from a UE, the MeNB may inform an

SeNB that the UE has completed the reconfiguration procedure successfully, for example, by sending an SeNB reconfiguration complete message to the SeNB.

[00158] In an example, after applying a new radio configuration for SCG included in an RRCConnectionReconfiguration message from an MeNB, a UE may perform synchronization towards a PSCell of an SeNB via a Random Access procedure. An order that a UE sends an RRCConnectionReconfigurationComplete message and performs the Random Access procedure towards an SCG may not be defined. A successful Random Access procedure towards the SCG may be not required for a successful completion of an RRC Connection Reconfiguration procedure. In case of SCG bearers, and dependent on bearer characteristics of a respective E-RAB, an MeNB may take actions to minimize service interruption due to activation of dual connectivity (e.g. data forwarding, SN status transfer). For SCG bearers, an update of the data traffic path towards the EPC may be performed. In an example, in an SeNB, a UE may start receiving MBMS (and/or V2X) services that the UE may have been receiving and/or interested in before the SeNB addition.

[00159] Example procedures related to UEInterestIndication, SIB20, sc-mcch, sc-mtch, and receiving MBMS traffic (e.g. SC-PTM, MBSFN) are provided in the specification.

[00160] - SeNB Modification

[00161] In an example embodiment, in RRC_CONNECTED mode, an SeNB modification procedure may be initiated by an MeNB and used to modify, establish, or release bearer contexts in order to transfer bearer contexts to and from an SeNB and/or to modify other properties of the UE context within a same SeNB. An SeNB modification procedure may not necessarily need to involve signaling towards a UE.

[00162] In an example, an MeNB may use an SeNB modification procedure to initiate configuration changes of an SCG within a same SeNB (e.g. the addition or release of SCG SCells; the addition, modification, or release of SCG bearer(s) and an SCG part of split bearer(s)) and/or to trigger PSCell change involving PSCell release. An SeNB may make a decision on accepting or rejecting an SeNB modification request. If an SeNB modification request concerns the release of SCG cells, of SCG bearer(s), or an SCG part of split bearer(s), an SeNB may accept the request.

[00163] In an example embodiment, an MeNB may send, to an SeNB, an SeNB modification request message, which may contain bearer context related information, other UE context related information, data forwarding address information, and/or an SCG-ConfigInfo that may contain an MCG configuration and/or entire UE capabilities for UE capability coordination to be used as basis for a reconfiguration by the SeNB. In case of SCG SCell addition request, an MeNB may provide the latest measurement results, received from

UE, for SCG cell(s) requested to be added and SCG serving cell(s) via an SeNB modification request message. In case of SCG Change, SCG Change Indication may be included in an SeNB modification request message. In an example, an MeNB may request establishment or release of an SCG bearer and/or a split bearer while not reconfiguring MCG bearers, which can be performed without SCG change.

[00164] In an example, an SeNB modification request message may comprise an MBMS (and/or V2X) interest service list, a list of MBMS (and/or V2X) services that an SeNB modification UE may be receiving and/or interested in. In an example, an SCG-ConfigInfo IE in an SeNB modification request message may contain an MBMS (and/or V2X) interest service list. In an example, an MBMSInterestIndication-v1310 IE, which includes MBMS service lists, may be added in an SCG-ConfigInfo IE in an SeNB modification request message. In an example, an MBMS (and/or V2X) interest service list may comprise MBMS frequency, MBMS (and/or V2X) priority, TMGI, MBMS session ID, G-RNTI, and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service. In an example, an MBMS (and/or V2X) interest service list may be employed, at least in part, by an SeNB, for example, to configure a UE and/or schedule MBMS resources that may be employed after completing an SeNB modification procedure.

[00165] In an example, an SeNB may respond with an SeNB modification request acknowledge message, which may contain radio configuration information within SCG-Config and/or data forwarding address information. In an SeNB modification request acknowledge, an SeNB may not initiate an SCG change (i.e. an SCG-Config message may indicate an SCG Change if an MeNB included an SCG Change Indication in an SeNB modification request message). In case of SCG Change, for E-RABs configured with the split bearer option for which no bearer type change may be performed, an SeNB may provide a new DL GTP TEID to an MeNB. In an example, an MeNB may continue sending DL PDCP PDUs to an SeNB with a previous DL GTP TEID until the MeNB may perform PDCP re-establishment or PDCP data recovery. An MeNB may use a new DL GTP TEID starting with a PDCP re-establishment or data recovery.

[00166] In an example a SeNB may employ an MBMS (and/or V2X) interest service list in order to properly configure a UE. The SeNB may transmit one or more messages to the MeNB comprising one or more configuration parameters for the UE, e.g. scheduling information, G-RNTI, and one or more files of SIB20, and/or one or more fields of SC-PTMConfigurationMessage. The MeNB may forward one or more of the configuration parameters to the UE in at least one message (e.g. RRC message). In an example, a SeNB may transmit one or more message to the UE comprising some of the one or more

configuration parameters for the UE. A SeNB may configure a UE to provide MBMS (and/or V2X) services that the UE may be receiving and/or interested in.

[00167] In an example, a SeNB may schedule MBMS (and/or V2X) resources before or during a UE connecting to the SeNB. In an example, the SeNB may start transmission of the MBMS services for the UE. A SeNB may schedule MBMS (and/or V2X) resources to provide MBMS (and/or V2X) services that the UE may be receiving and/or interested in. The SeNB may schedule MBMS (and/or V2X) resources to provide to the wireless device at least one of the one or more MBMS services that the UE is interested in. In an example, the SeNB may transmit at least one of an SIB20 (e.g. updated SIB20) or an SCPTMconfiguration message (e.g. updated SCPTMconfiguration message) comprising one or more parameters for at least one of the one or more MBMS services for the UE. The SeNB may transmit traffic associated with at least one of the one or more MBMS services. The SeNB may update one of more traffic parameters of at least one of the one or more MBMS services. The SeNB/MeNB may modify one or more MBMS bearers and/or MBMS configuration to include the UE in a multicast/broadcast service.

[00168] In an example, if a UE is receiving and/or interested in a certain MBMS (and/or V2X) service, a SeNB may increase the priority of the service when scheduling MBMS (and/or V2X) resources.

[00169] In an example, if an SeNB does not admit any modification requested by an MeNB, or a failure occurs during an MeNB initiated SeNB modification preparation, the SeNB may send an SeNB modification request reject message to the MeNB. An SeNB modification request reject message may contain an appropriate reject cause value. In an example, if an SeNB receives an SeNB modification request message containing an MeNB to SeNB Container IE that does not include required information, the SeNB may send an SeNB modification request reject message to an MeNB.

[00170] In an example, an MeNB may transfer, to a UE, an RRCConnectionReconfiguration. After receiving an RRCConnnectionReconfiguration, A UE may apply a new configuration and reply with RRCConnectionReconfigurationComplete. In case a UE is unable to comply with (part of) the configuration included in an RRCConnectionReconfiguration message, it performs the reconfiguration failure procedure.

[00171] In an example, upon successful completion of an RRC connection reconfiguration, an MeNB may indicate a success of an RRC connection reconfiguration procedure by transmitting an SeNB Reconfiguration Complete message to an SeNB. If instructed in an RRCConnectionReconfiguration, a UE may perform synchronisation towards a PSCell of an SeNB via a Random Access procedure. In an example, an order that a UE sends an

RRCConnectionReconfigurationComplete message and performs the Random Access procedure towards an SCG may not be defined. A successful Random Access procedure towards the SCG may be not required for a successful completion of an RRC Connection Reconfiguration procedure. Otherwise, a UE may perform UL transmission after having applied the new configuration. If applicable, data forwarding between MeNB and SeNB may take place. If applicable, a path update of data transmission towards a serving gateway may be performed.

[00172] In an example, in an SeNB, a UE may start receiving MBMS (and/or V2X) services that the UE may have been receiving and/or interested in before the SeNB addition. Example procedures related to UEInterestIndication, SIB20, sc-mcch, sc-mtch, and receiving MBMS traffic (e.g. SC-PTM, MBSFN) are provided in the specification.

[00173] Scheduling information for transmission and acquisition of SCPTMconfiguration message is transmitted in SIB20. The information may include periodicity, subframes, and/or other information. SIB20 may be broadcasted by a base station.

[00174] In an example, a first base station may receive, from a wireless device, at least one first message comprising one or more TMGIs of one or more MBMS services that the wireless device is interested to receive. The first base station may make a handover decision for the wireless device. In an example, the first base station may transmit, a second base station, a second message comprising the one or more TMGIs. The wireless device may receive, from the second base station, at least one of the one or more MBMS services.

[00175] In an example, a first base station may receive, from a wireless device, at least one first message comprising one or more TMGIs of one or more MBMS services that the wireless device is interested to receive. The first base station may make a decision for the wireless device. In an example, in response to the decision, the first base station may transmit, to a second base station, a second message comprising the one or more TMGIs. In an example, the decision may be at least one of a handover decision; a decision to initiate a dual connectivity connection with the second base station; and/or a decision to modify a dual connectivity connection with the second base station.

[00176] In an example, the second message and/or the first message may comprise at least one of: an MBMS frequency; an MBMS (and/or V2X) priority (information parameter); an MBMS session ID; G-RNTI; and/or Destination Layer-2 ID mapped to a MBMS (and/or V2X) service. In an example, the second base station may further schedule MBMS (and/or V2X) resources to provide to the wireless device at least one of the one or more MBMS services. In an example, the second base station may further configure the wireless device to receive at least one of the one or more MBMS services. In an example, the second base

station may further transmit at least one of an updated SIB20 or an updated SCPTMconfiguration message comprising one or more parameters for at least one of the one or more MBMS services. In an example, the second base station may increase a priority of at least one of the one or more MBMS services. In an example, the second base station may further transmit traffic associated with at least one of the one or more MBMS services. In an example, the second base station may further update one of more traffic parameters of at least one of the one or more MBMS services.

[00177] In an example, a first base station may receive, from a wireless device, at least one first message comprising one or more TMGIs of one or more MBMS services that the wireless device is interested to receive. The first base station may make a decision, for the wireless device, to initiate a dual connectivity connection with a second base station. The first base station may transmit, to a second base station in response to the decision, a second message comprising the one or more TMGIs.

[00178] In an example, a first base station may receive, from a wireless device, at least one first message comprising one or more TMGIs of one or more MBMS services that the wireless device is interested to receive. The first base station may make a decision, for the wireless device, to modify a dual connectivity connection with a second base station. The first base station may transmit, to a second base station in response to the decision, a second message comprising the one or more TMGIs.

[00179] According to various embodiments, a device (such as, for example, a wireless device, an off-network wireless device, a base station, and/or the like), may comprise, for example, one or more processors and memory. The memory may store instructions that, when executed by the one or more processors, cause the device to perform a series of actions. Embodiments of example actions are illustrated in the accompanying figures and specification. Features from various embodiments may be combined to create yet further embodiments.

[00180] FIG. 14 is an example flow diagram as per an aspect of an embodiment of the present disclosure. At 1410, a first base station may receive from a second base station, a handover request message for a wireless device. The handover request message may comprise: one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive; and at least one bearer identifier of at least one bearer for the wireless device. At 1420, the first base station may send to the second base station, a handover request acknowledge message in response to the handover request message. The handover request acknowledge message may indicate accepting at least one of the at least one bearer. At 1430,

the first base station may transmit transport blocks comprising: MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device; and data transport blocks of the at least one of the at least one bearer.

[00181] According to an embodiment, the second base station may receive from the wireless device, at least one radio resource control (RRC) message comprising the one or more TMGIs of the one or more MBMS services. According to an embodiment the handover request message may further comprise one or more MBMS parameters for at least one of the one or more MBMS services. The one or more MBMS parameters may comprise at least one of: an MBMS frequency; an MBMS session identifier; a group-radio network temporary identifier (G-RNTI); a destination layer-2 identifier; an MBMS service priority; or a V2X service priority. According to an embodiment, the second base station may transmit to the wireless device, a handover command message. The handover command message may comprise one or more MBMS configuration parameters for the at least one of the one or more MBMS services. The one or more MBMS configuration parameters may be received from the first base station via the handover request acknowledge message. According to an embodiment, the first base station may transmit at least one message of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message. The at least one message may comprise one or more parameters for at least one of the one or more MBMS services. According to an embodiment, the first base station may update one or more traffic parameters of at least one of the one or more MBMS services. According to an embodiment, the first base station may increase a priority of at least one of the one or more MBMS services.

[00182] FIG. 15 is an example flow diagram as per an aspect of an embodiment of the present disclosure. At 1510, a first base station may receive from a wireless device, at least one radio resource control (RRC) message. The at least one RRC message may comprise one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive. At 1520, the first base station may make a handover decision for the wireless device. At 1530, the first base station may send to a second base station in response to the handover decision, a handover request message for the wireless device, wherein the handover request message comprises the one or more TMGIs. At 1540, the first base station may receive from the second base station, a handover request acknowledge message in response to the handover request message. At 1550, the first base station may transmit MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device.

[00183] According to an embodiment, handover request message may further comprise one or more MBMS parameters for at least one of the one or more MBMS services. The one or more MBMS parameters may comprise at least one of: an MBMS frequency; an MBMS session identifier; a group-radio network temporary identifier (G-RNTI); a destination layer-2 identifier; an MBMS service priority; or a V2X service priority. According to an embodiment, the first base station may further transmit to the wireless device, a handover command message comprising one or more MBMS configuration parameters for the at least one of the one or more MBMS services. The one or more MBMS configuration parameters may be received from the second base station via the handover request acknowledge message. According to an embodiment, the second base station may transmit at least one message of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message. The at least one message may comprise one or more parameters for at least one of the one or more MBMS services. According to an embodiment, the second base station may further update one or more traffic parameters of at least one of the one or more MBMS services. According to an embodiment, the second base station may further increase a priority of at least one of the one or more MBMS services.

[00184] FIG. 16 is an example flow diagram as per an aspect of an embodiment of the present disclosure. At 1610, a first base station may receive from a second base station, a handover request message for a wireless device. The handover request message may comprise one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive. At 1620, the first base station may send to the second base station, a handover request acknowledge message in response to the handover request message. The handover request acknowledge message may indicate accepting at least one of the at least one bearer. At 1630, the first base station may transmit transport blocks comprising MBMS transport blocks to providing at least one of the one or more MBMS services to the wireless device.

[00185] FIG. 17 is an example flow diagram as per an aspect of an embodiment of the present disclosure. At 1710, a first base station may receive from a second base station, a secondary base station addition/modification request message for a wireless device. The handover request message may comprise: one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive; and at least one bearer identifier of at least one bearer for the wireless device. At 1720, the first base station may send to the second base station, a secondary base station addition/modification request acknowledge message in response to the secondary base station addition/modification request message. The secondary

base station addition/modification request acknowledge message may indicate acceptance of at least one of the at least one bearer. At 1730, the first base station may transmit transport blocks comprising: MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device; and data transport blocks of the at least one of the at least one bearer.

[00186] According to an embodiment, the second base station may further receive from the wireless device, at least one radio resource control (RRC) message comprising the one or more TMGIs of the one or more MBMS services. According to an embodiment, the secondary base station addition/modification request message may further comprise at least one of: an MBMS frequency; an MBMS session identifier; a group-radio network temporary identifier (G-RNTI) of an MBMS service or a vehicle-to-everything (V2X) service; a destination layer-2 identifier for an MBMS service or a V2X service; an MBMS service priority; or a V2X service priority. According to an embodiment, the second base station may transmit to the wireless device, an RRC connection reconfiguration message comprising one or more MBMS configuration parameters for the at least one of the one or more MBMS services. The one or more MBMS configuration parameters may be received from the first base station via the secondary base station addition/modification request acknowledge message. According to an embodiment, the first base station may further transmit at least one of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message comprising one or more parameters for at least one of the one or more MBMS services. According to an embodiment, the first base station may update one or more traffic parameters of at least one of the one or more MBMS services. According to an embodiment, the first base station may increase a priority of at least one of the one or more MBMS services.

[00187] FIG. 18 is an example flow diagram as per an aspect of an embodiment of the present disclosure. At 1810, a first base station may receive from a second base station, a request message for a wireless device. The request message may comprise: one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive; and at least one bearer identifier of at least one bearer for the wireless device. At 1820, the first base station may send to the second base station, a request acknowledge message in response to the request message. The request acknowledge message may indicate acceptance of at least one of the at least one bearer. At 1830, the first base station may transmit transport blocks comprising: MBMS transport blocks providing at least one of the one or more MBMS

services to the wireless device; and data transport blocks of the at least one of the at least one bearer.

[00188] According to an embodiment, the request message may comprise one of: a handover request message; a secondary base station addition request message; or a secondary base station modification request message. According to an embodiment, the second base station may receive from the wireless device, at least one radio resource control (RRC) message comprising the one or more TMGIs of the one or more MBMS services. According to an embodiment, the request message may further comprise at least one of: an MBMS frequency; an MBMS session identifier; a group-radio network temporary identifier (G-RNTI) of an MBMS service or a vehicle-to-everything (V2X) service; a destination layer-2 identifier for an MBMS service or a V2X service; an MBMS service priority; or a V2X service priority. According to an embodiment, the second base station may transmit to the wireless device, an RRC connection reconfiguration message comprising one or more MBMS configuration parameters for the at least one of the one or more MBMS services. The one or more MBMS configuration parameters may be received from the first base station via the request acknowledge message. According to an embodiment, the first base station may transmit at least one of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message comprising one or more parameters for at least one of the one or more MBMS services. According to an embodiment, the first base station may update, one or more traffic parameters of at least one of the one or more MBMS services. According to an embodiment, the first base station may increase a priority of at least one of the one or more MBMS services.

[00189] In this specification, “a” and “an” and similar phrases are to be interpreted as “at least one” and “one or more.” In this specification, the term “may” is to be interpreted as “may, for example.” In other words, the term “may” is indicative that the phrase following the term “may” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. If A and B are sets and every element of A is also an element of B, A is called a subset of B. In this specification, only non-empty sets and subsets are considered. For example, possible subsets of B = {cell1, cell2} are: {cell1}, {cell2}, and {cell1, cell2}. The phrase “based on” is indicative that the phrase following the term “based on” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase “in response to” is indicative that the phrase following the phrase “in response to” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments.

[00190] In this specification, various embodiments are disclosed. Limitations, features, and/or elements from the disclosed example embodiments may be combined to create further embodiments within the scope of the disclosure.

[00191] In this specification, parameters (Information elements: IEs) may comprise one or more objects, and each of those objects may comprise one or more other objects. For example, if parameter (IE) N comprises parameter (IE) M, and parameter (IE) M comprises parameter (IE) K, and parameter (IE) K comprises parameter (information element) J, then, for example, N comprises K, and N comprises J. In an example embodiment, when one or more messages comprise a plurality of parameters, it implies that a parameter in the plurality of parameters is in at least one of the one or more messages, but does not have to be in each of the one or more messages.

[00192] Furthermore, many features presented above are described as being optional through the use of "may" or the use of parentheses. For the sake of brevity and legibility, the present disclosure does not explicitly recite each and every permutation that may be obtained by choosing from the set of optional features. However, the present disclosure is to be interpreted as explicitly disclosing all such permutations. For example, a system described as having three optional features may be embodied in seven different ways, namely with just one of the three possible features, with any two of the three possible features or with all three of the three possible features.

[00193] Many of the elements described in the disclosed embodiments may be implemented as modules. A module is defined here as an isolatable element that performs a defined function and has a defined interface to other elements. The modules described in this disclosure may be implemented in hardware, software in combination with hardware, firmware, wetware (i.e. hardware with a biological element) or a combination thereof, all of which are behaviorally equivalent. For example, modules may be implemented as a software routine written in a computer language configured to be executed by a hardware machine (such as C, C++, Fortran, Java, Basic, Matlab or the like) or a modeling/simulation program such as Simulink, Stateflow, GNU Octave, or LabVIEWMathScript. Additionally, it may be possible to implement modules using physical hardware that incorporates discrete or programmable analog, digital and/or quantum hardware. Examples of programmable hardware comprise: computers, microcontrollers, microprocessors, application-specific integrated circuits (ASICs); field programmable gate arrays (FPGAs); and complex programmable logic devices (CPLDs). Computers, microcontrollers and microprocessors are programmed using languages such as assembly, C, C++ or the like. FPGAs, ASICs and CPLDs are often programmed using hardware description languages (HDL) such as VHSIC

hardware description language (VHDL) or Verilog that configure connections between internal hardware modules with lesser functionality on a programmable device. Finally, it needs to be emphasized that the above mentioned technologies are often used in combination to achieve the result of a functional module.

[00194] The disclosure of this patent document incorporates material which is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by anyone of the patent document or the patent disclosure, as it appears in the Patent and Trademark Office patent file or records, for the limited purposes required by law, but otherwise reserves all copyright rights whatsoever.

[00195] While various embodiments have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be apparent to persons skilled in the relevant art(s) that various changes in form and detail can be made therein without departing from the spirit and scope. In fact, after reading the above description, it will be apparent to one skilled in the relevant art(s) how to implement alternative embodiments. Thus, the present embodiments should not be limited by any of the above described exemplary embodiments. In particular, it should be noted that, for example purposes, the above explanation has focused on mission critical services such as mission critical push-to-talk services employing media types such as audio services, video services and media services. However, one skilled in the art will recognize that embodiments of the invention may also be implemented in a system comprising other types of services such as, for example, data services, augmented reality services, data fusion services, combinations thereof, and/or the like.

[00196] In addition, it should be understood that any figures which highlight the functionality and advantages, are presented for example purposes only. The disclosed architecture is sufficiently flexible and configurable, such that it may be utilized in ways other than that shown. For example, the actions listed in any flowchart may be re-ordered or only optionally used in some embodiments.

[00197] Further, the purpose of the Abstract of the Disclosure is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers and practitioners in the art who are not familiar with patent or legal terms or phraseology, to determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The Abstract of the Disclosure is not intended to be limiting as to the scope in any way.

[00198] Finally, it is the applicant's intent that only claims that include the express language "means for" or "step for" be interpreted under 35 U.S.C. 112. Claims that do not expressly include the phrase "means for" or "step for" are not to be interpreted under 35 U.S.C. 112.

Claims

1. A method comprising:

receiving, by the first base station from a second base station, a handover request message for a wireless device, wherein the handover request message comprises:

one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive; and

at least one bearer identifier of at least one bearer for the wireless device;

sending, by the first base station to the second base station, a handover request acknowledge message in response to the handover request message, wherein the handover request acknowledge message indicates accepting at least one of the at least one bearer; and

transmitting, by the first base station, transport blocks comprising:

MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device; and

data transport blocks of the at least one of the at least one bearer.

2. The method of claim 1, further comprising receiving, by the second base station from the wireless device, at least one radio resource control (RRC) message comprising the one or more TMGIs of the one or more MBMS services.

3. The method of claim 1, wherein the handover request message further comprises one or more MBMS parameters for at least one of the one or more MBMS services, the one or more MBMS parameters comprising at least one of:

an MBMS frequency;

an MBMS session identifier;

a group-radio network temporary identifier (G-RNTI);

a destination layer-2 identifier;

an MBMS service priority; or

a V2X service priority.

4. The method of claim 1, further comprising transmitting, by the second base station to the wireless device, a handover command message comprising one or more MBMS configuration parameters for the at least one of the one or more MBMS services, the one or

more MBMS configuration parameters received from the first base station via the handover request acknowledge message.

5. The method of claim 1, further comprising transmitting, by the first base station, at least one message of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message, the at least one message comprising one or more parameters for at least one of the one or more MBMS services.

6. The method of claim 1, further comprising updating, by the first base station, one or more traffic parameters of at least one of the one or more MBMS services.

7. The method of claim 1, further comprising increasing, by the first base station, a priority of at least one of the one or more MBMS services.

8. A base station comprising:

one or more processors;

memory storing instructions that, when executed by the one or more processors, cause the base station to:

receive, from a second base station, a handover request message for a wireless device, wherein the handover request message comprises:

one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive; and

at least one bearer identifier of at least one bearer for the wireless device;

send, to the second base station, a handover request acknowledge message in response to the handover request message, wherein the handover request acknowledge message indicates accepting at least one of the at least one bearer; and

transmit transport blocks comprising:

MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device; and

data transport blocks of the at least one of the at least one bearer.

9. The base station of claim 8, wherein the second base station receives, from the wireless device, at least one radio resource control (RRC) message comprising the one or more TMGIs of the one or more MBMS services.

10. The base station of claim 8, wherein the handover request message further comprises one or more MBMS parameters for at least one of the one or more MBMS services, the one or more MBMS parameters comprising at least one of:

    an MBMS frequency;

    an MBMS session identifier;

    a group-radio network temporary identifier (G-RNTI);

    a destination layer-2 identifier;

    an MBMS service priority; or

    a V2X service priority.

11. The base station of claim 8, wherein the second base station transmits, to the wireless device, a handover command message comprising one or more MBMS configuration parameters for the at least one of the one or more MBMS services, the one or more MBMS configuration parameters received from the base station via the handover request acknowledge message.

12. The base station of claim 8, wherein the instructions, when executed, further cause the base station to transmit at least one message of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message, the at least one message comprising one or more parameters for at least one of the one or more MBMS services.

13. The base station of claim 8, wherein the instructions, when executed, further cause the base station to update one or more traffic parameters of at least one of the one or more MBMS services.

14. The base station of claim 8, wherein the instructions, when executed, further cause the base station to increase a priority of at least one of the one or more MBMS services.

15. A method comprising:

receiving, by a first base station from a wireless device, at least one radio resource control (RRC) message comprising one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive;

making, by the first base station, a handover decision for the wireless device;

sending, by the first base station to a second base station in response to the handover decision, a handover request message for the wireless device, wherein the handover request message comprises the one or more TMGIs;

receiving, by the first base station from the second base station, a handover request acknowledge message in response to the handover request message; and

transmitting, by the second base station, MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device.

16. The method of claim 1, wherein the handover request message further comprises one or more MBMS parameters for at least one of the one or more MBMS services, the one or more MBMS parameters comprising at least one of:

an MBMS frequency;

an MBMS session identifier;

a group-radio network temporary identifier (G-RNTI);

a destination layer-2 identifier;

an MBMS service priority; or

a V2X service priority.

17. The method of claim 1, further comprising transmitting, by the first base station to the wireless device, a handover command message comprising one or more MBMS configuration parameters for the at least one of the one or more MBMS services, the one or more MBMS configuration parameters received from the second base station via the handover request acknowledge message.

18. The method of claim 1, further comprising transmitting, by the second base station, at least one message of a system information block type 20 (SIB20) or a single cell point to multipoint (SCPTM) configuration message, the at least one message comprising one or more parameters for at least one of the one or more MBMS services.

19. The method of claim 1, further comprising updating, by the second base station, one or more traffic parameters of at least one of the one or more MBMS services.

20. The method of claim 1, further comprising increasing, by the second base station, a priority of at least one of the one or more MBMS services.

ABSTRACT

A first base station receives from a second base station, a handover request message for a wireless device. The handover request message comprises: one or more temporary mobile group identities (TMGIs) of one or more multimedia broadcast multicast service (MBMS) services that the wireless device is receiving or interested to receive; and at least one bearer identifier of at least one bearer for the wireless device. The first base station sends to the second base station, a handover request acknowledge message in response to the handover request message. The handover request acknowledge message indicates accepting at least one of the at least one bearer. The first base station transmits transport blocks comprising: MBMS transport blocks providing at least one of the one or more MBMS services to the wireless device; and data transport blocks of the at least one of the at least one bearer.

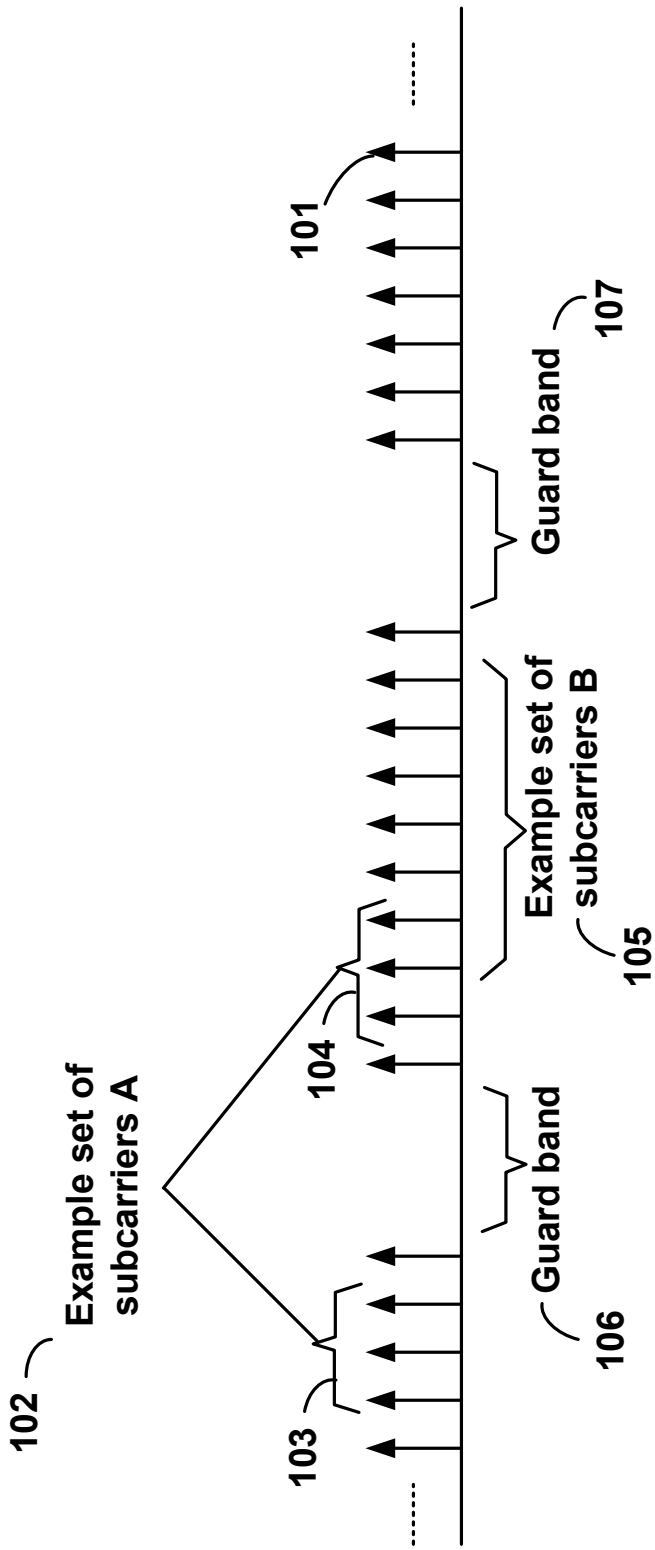

101
Guard band
107
Example set of subcarriers B
105
104
Example set of subcarriers A
102
Guard band
106
103

FIG. 1

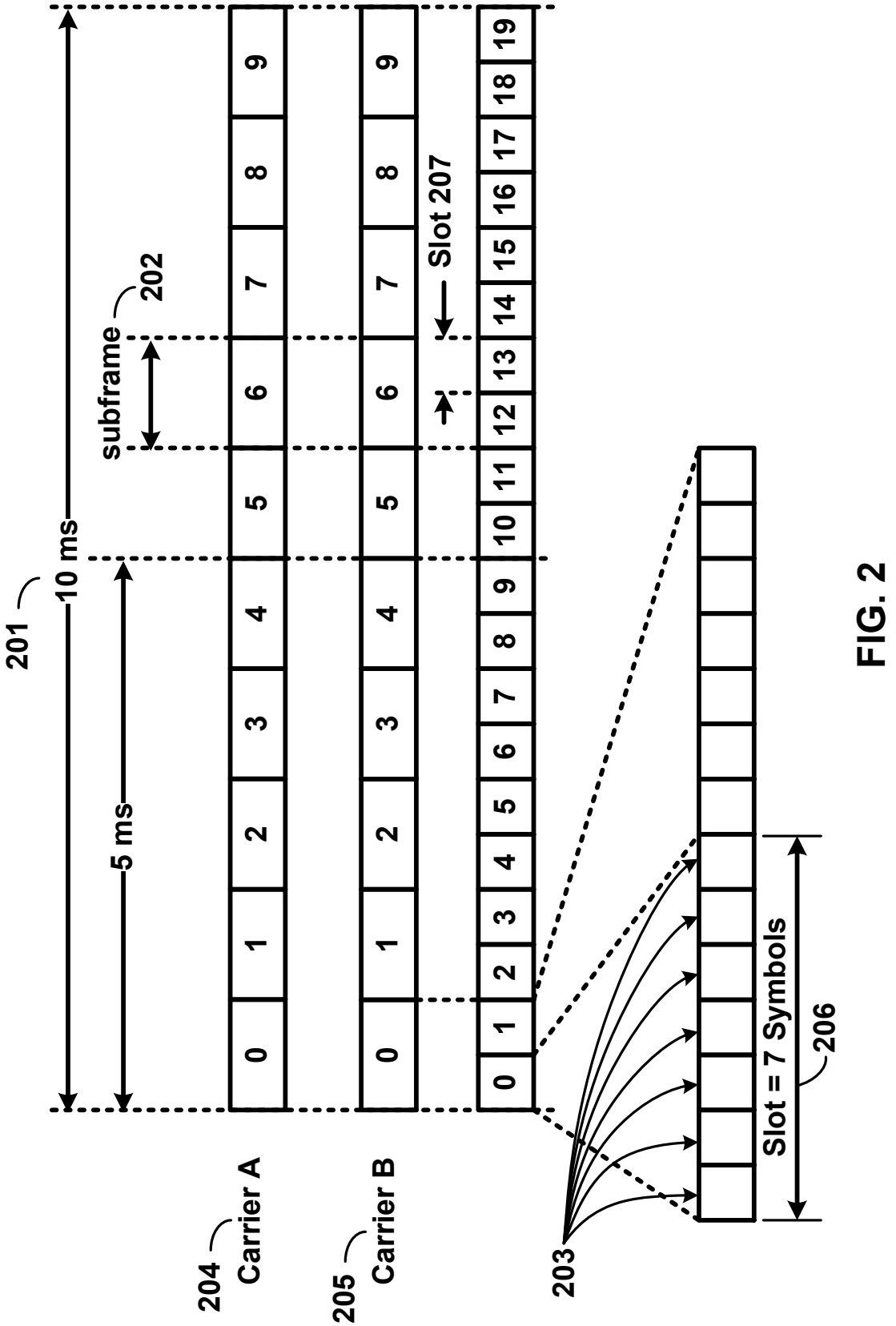

201
10 ms
5 ms
subframe
202
Slot 207
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Carrier A
204
Carrier B
205
203
Slot = 7 Symbols
206

FIG. 2

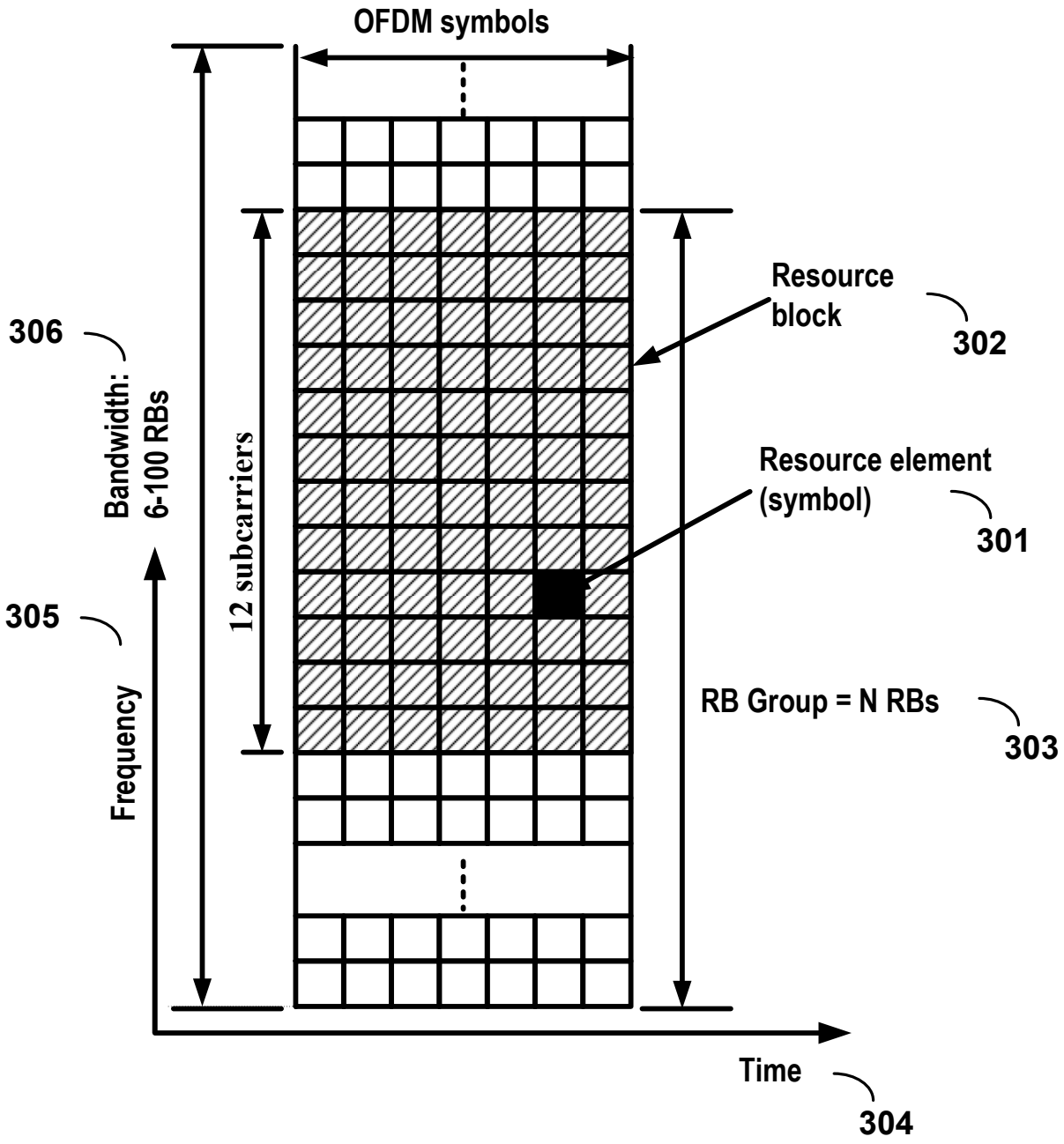

OFDM symbols
Resource block
302
306
Bandwidth: 6-100 RBs
12 subcarriers
Resource element (symbol)
301
305
Frequency
RB Group = N RBs
303
Time
304

FIG. 3

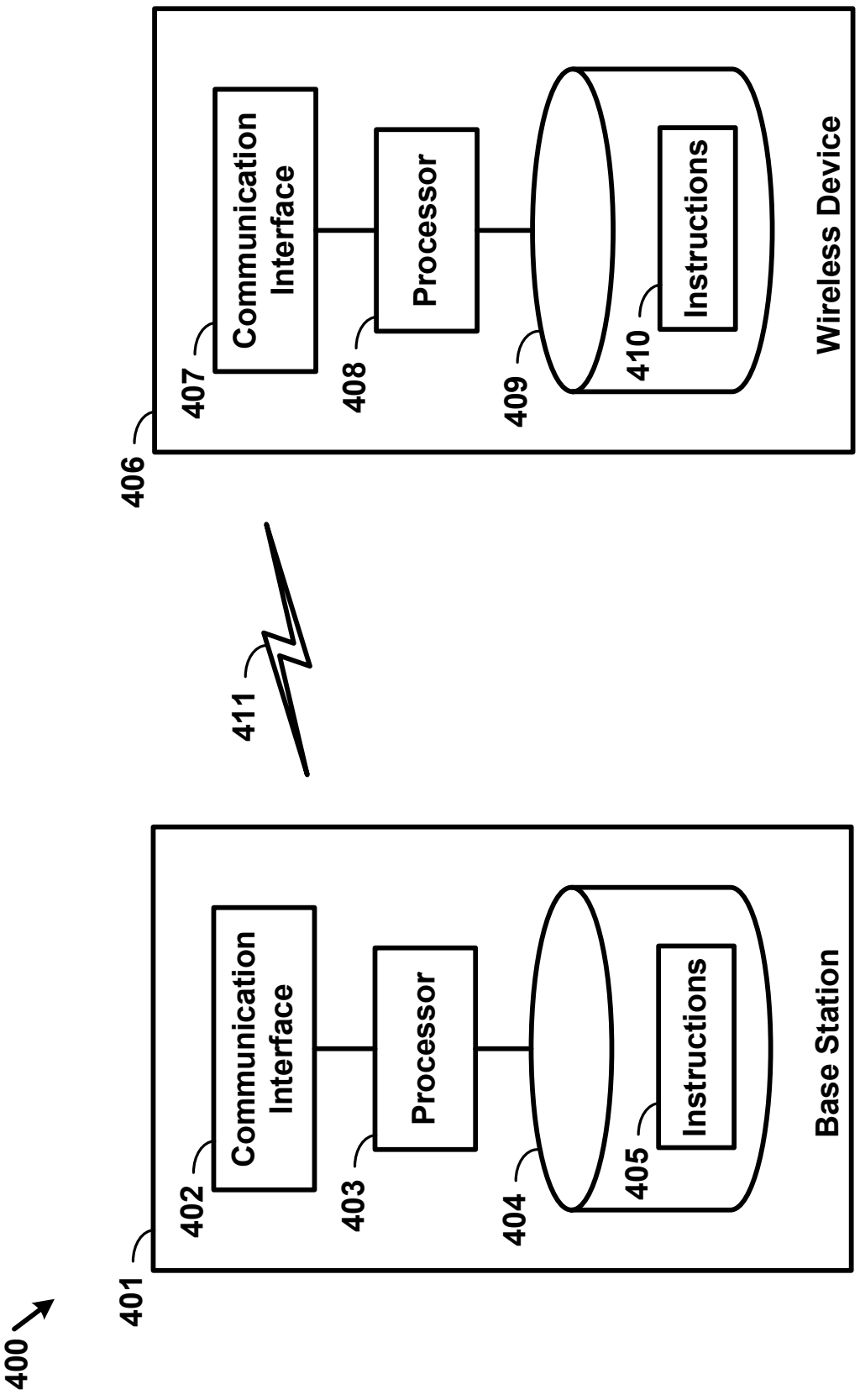

400
401
Base Station
402
Communication Interface
403
Processor
404
405
Instructions
411
406
Wireless Device
407
Communication Interface
408
Processor
409
410
Instructions

FIG. 4

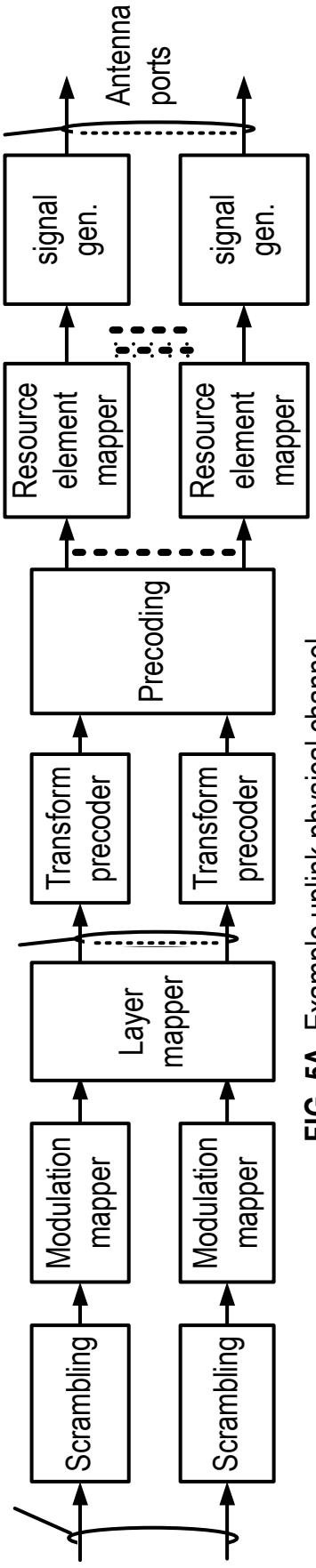


FIG. 5A Example uplink physical channel

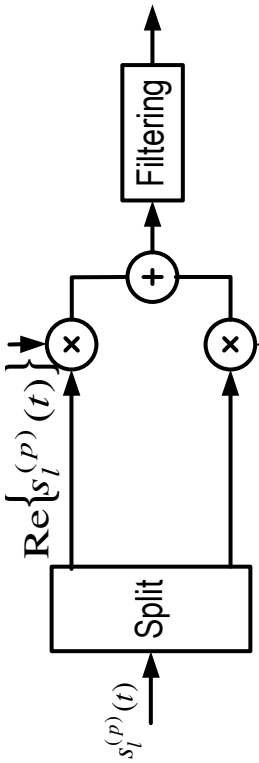


FIG. 5B Example uplink modulation

FIG. 5D Example downlink modulation

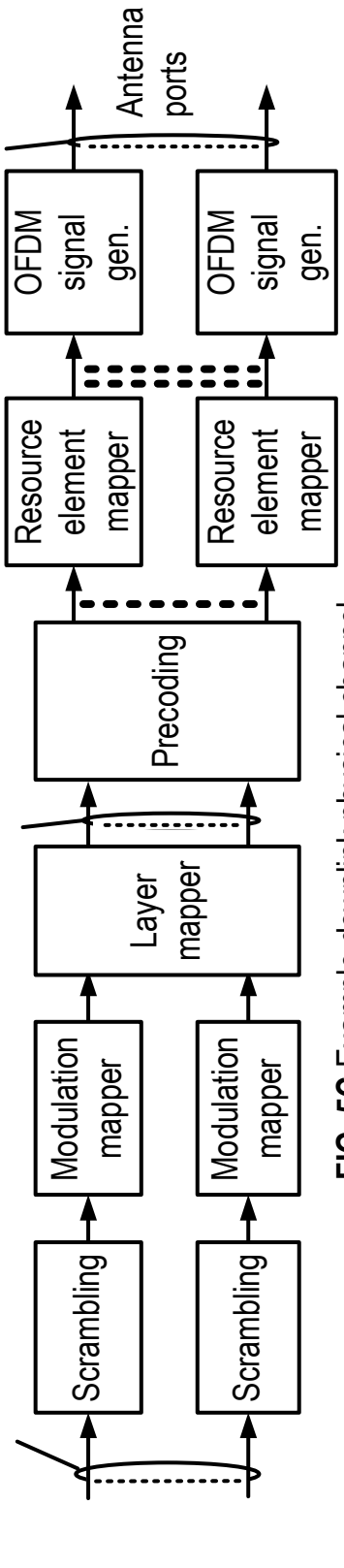
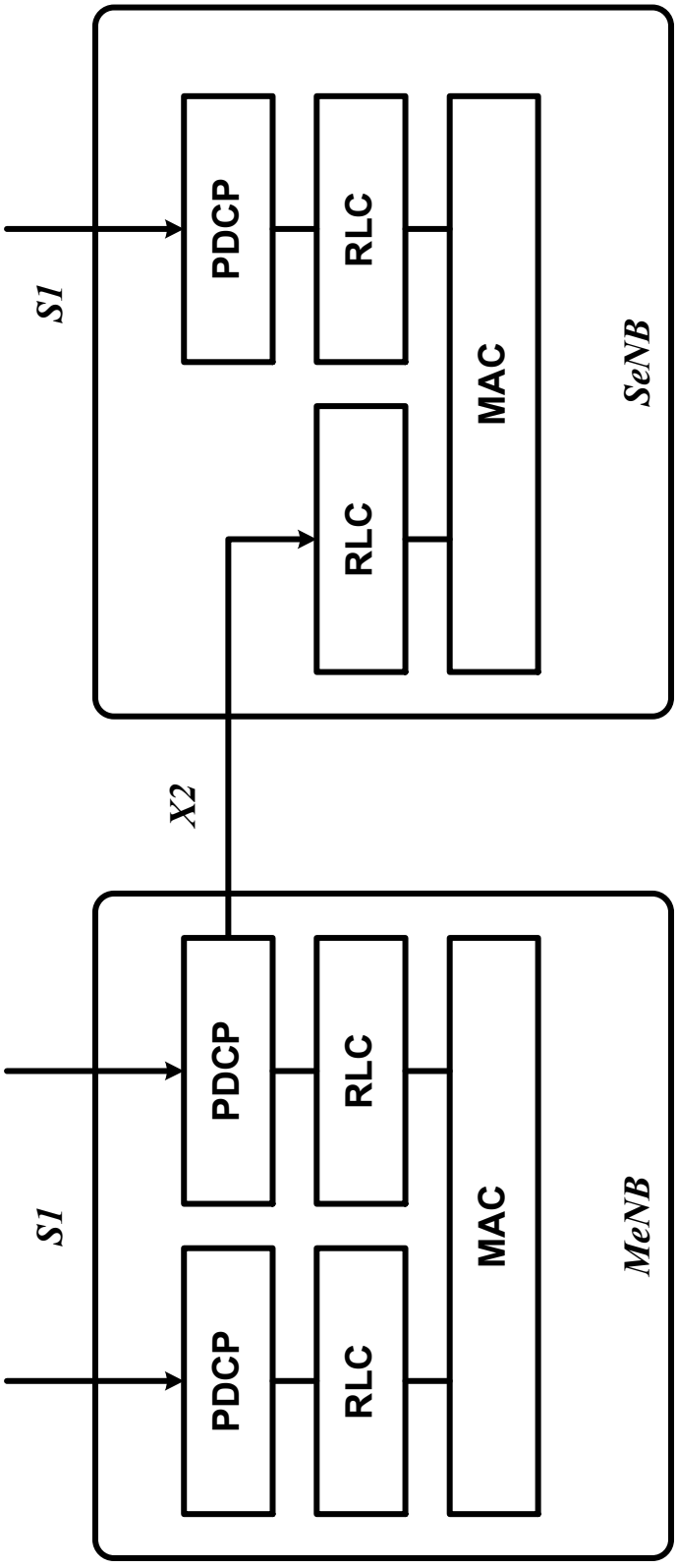
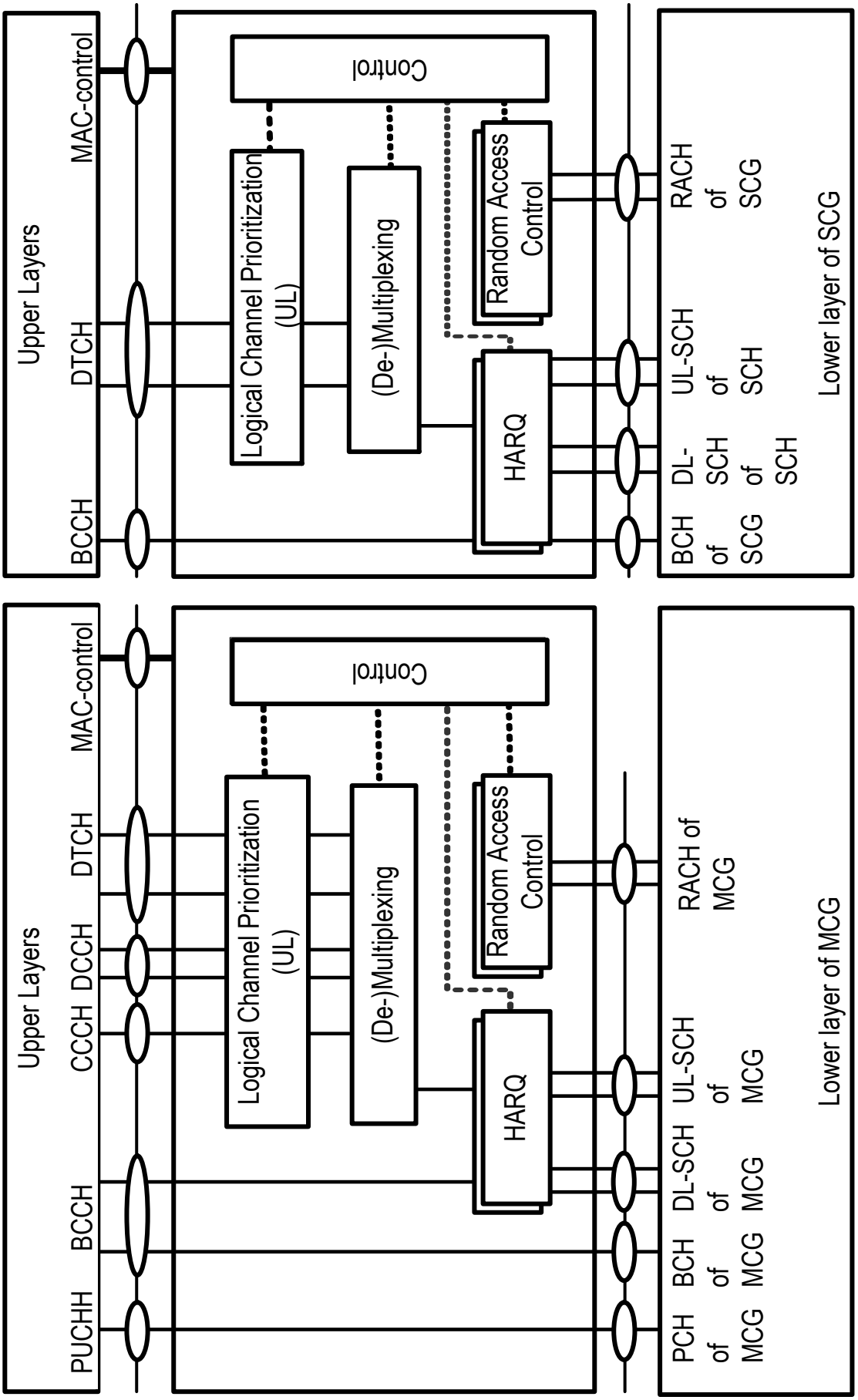


FIG. 5C Example downlink physical channel



Dual-Connectivity at eNB

FIG. 6



Dual-Connectivity- two MAC entities at UE side

FIG. 7

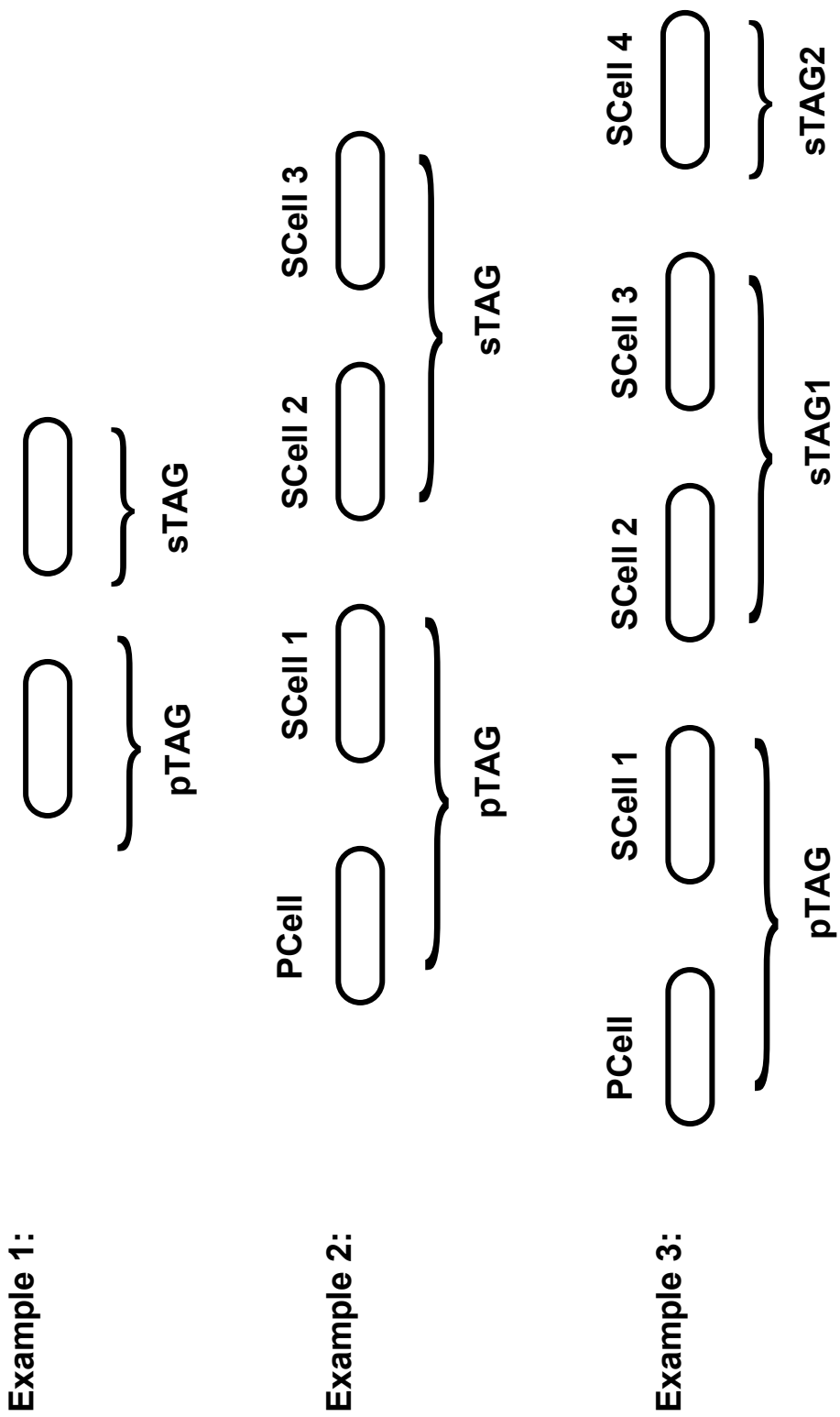

Example 1:
PCell
SCell 1
pTAG
sTAG
Example 2:
PCell
SCell 1
SCell 2
SCell 3
pTAG
sTAG
Example 3:
PCell
SCell 1
SCell 2
SCell 3
SCell 4
pTAG
sTAG1
sTAG2

FIG. 8

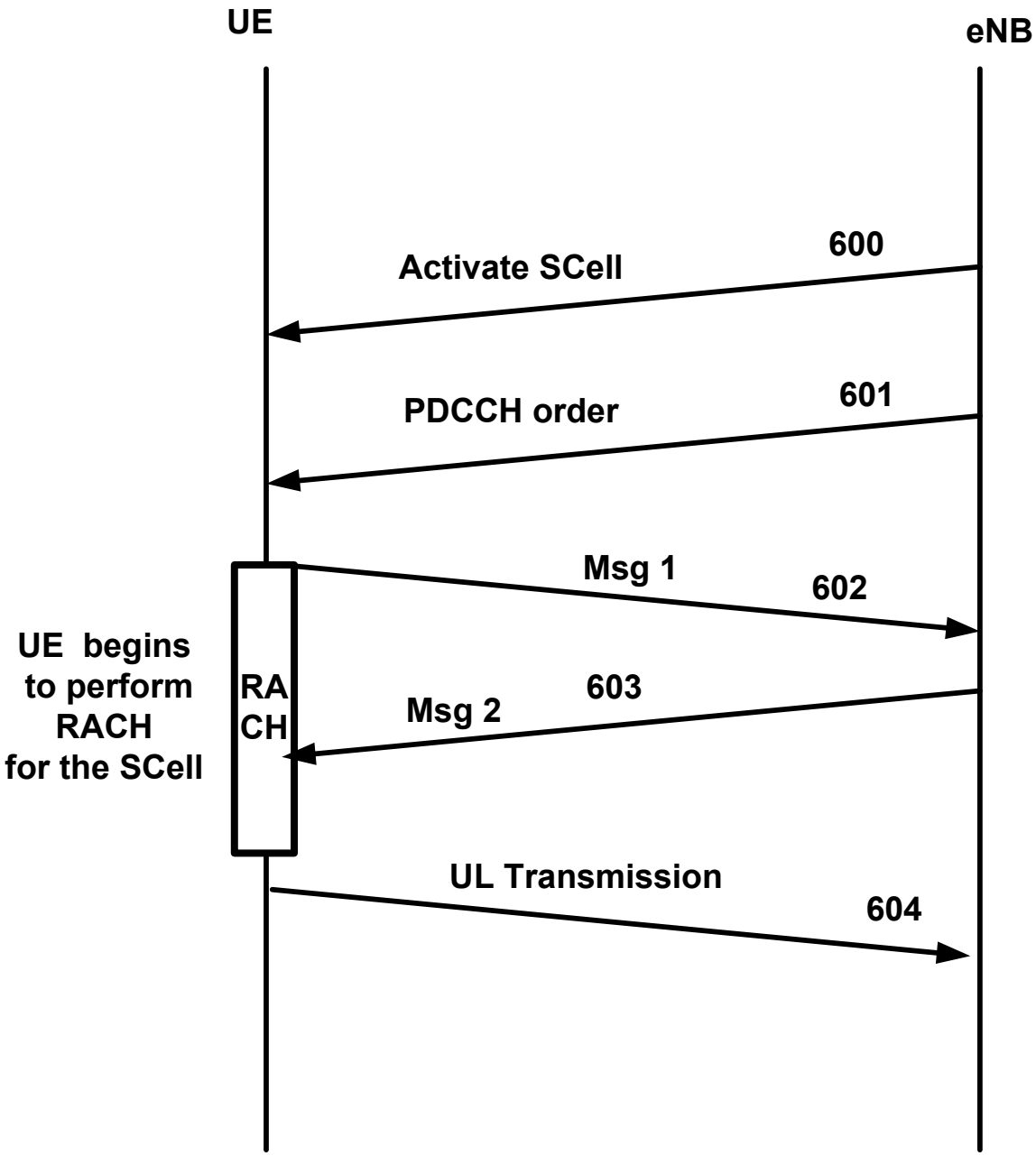

UE
eNB
600
Activate SCell
601
PDCCH order
Msg 1
602
UE begins to perform RACH for the SCell
RA CH
603
Msg 2
UL Transmission
604

FIG. 9

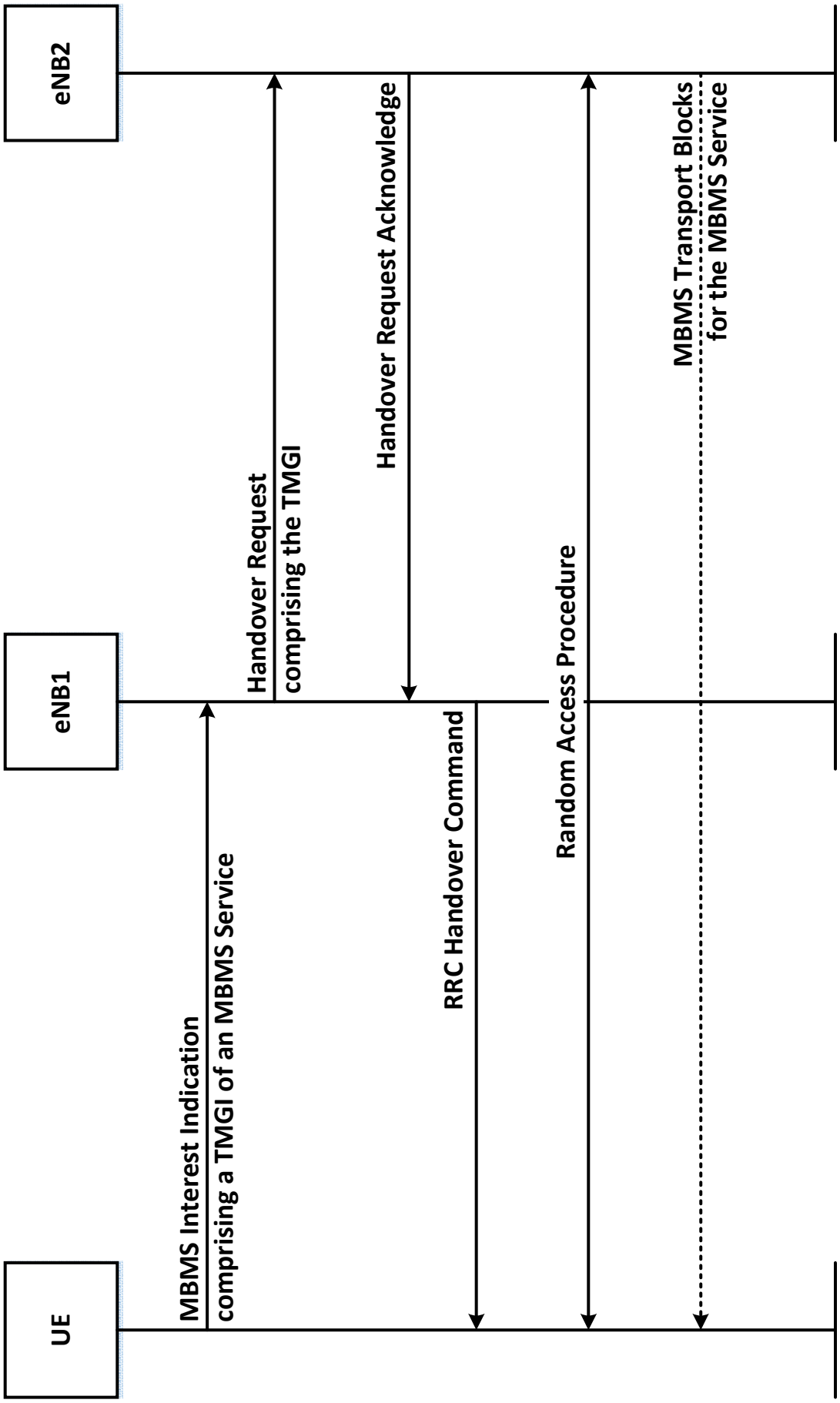

eNB2
eNB1
UE
Handover Request
comprising the TMGI
Handover Request Acknowledge
MBMS Transport Blocks
for the MBMS Service
MBMS Interest Indication
comprising a TMGI of an MBMS Service
RRC Handover Command
Random Access Procedure

FIG. 10

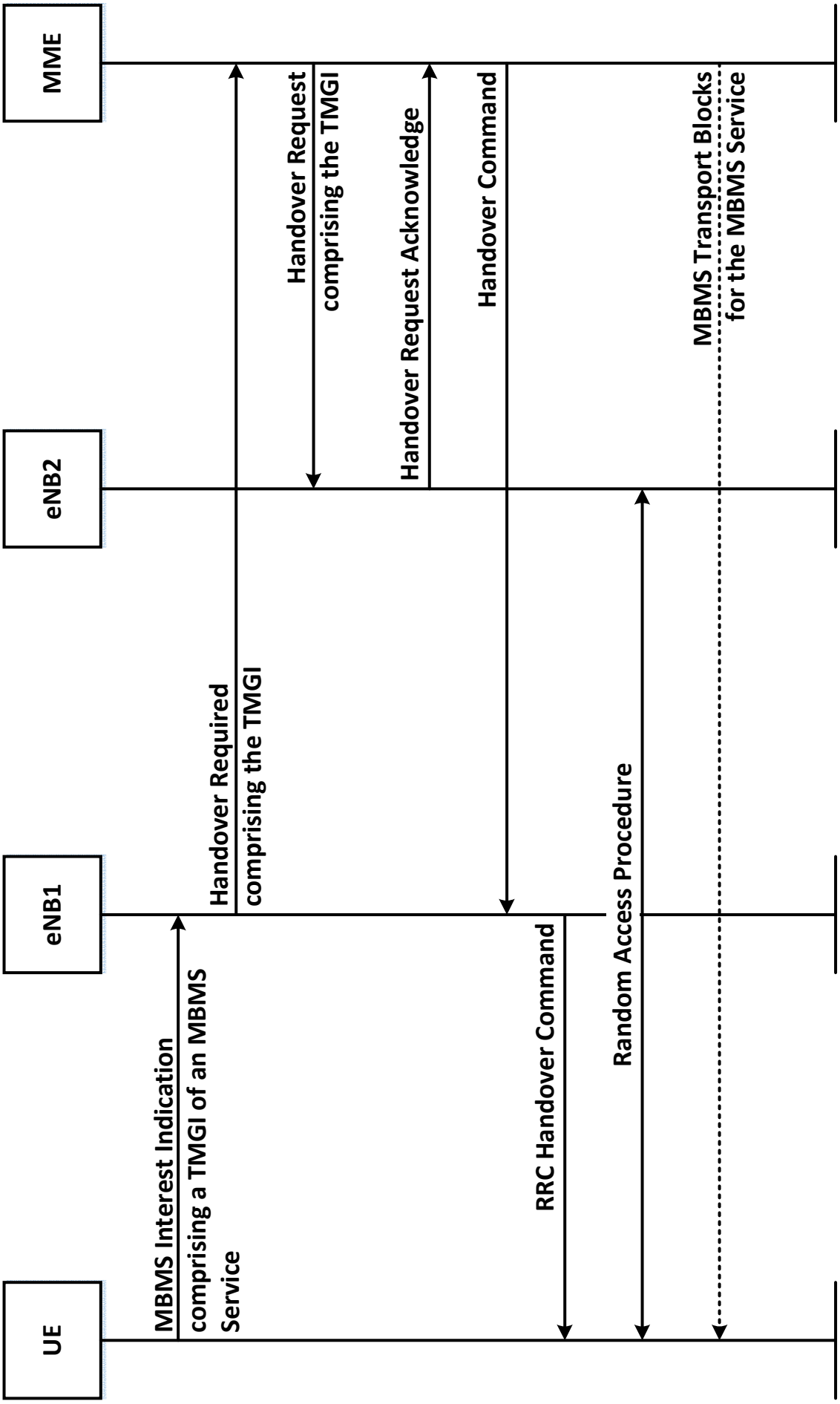

MME
eNB2
eNB1
UE
Handover Request comprising the TMGI
Handover Request Acknowledge
Handover Command
MBMS Transport Blocks for the MBMS Service
Handover Required comprising the TMGI
MBMS Interest Indication comprising a TMGI of an MBMS Service
RRC Handover Command
Random Access Procedure

FIG. 11

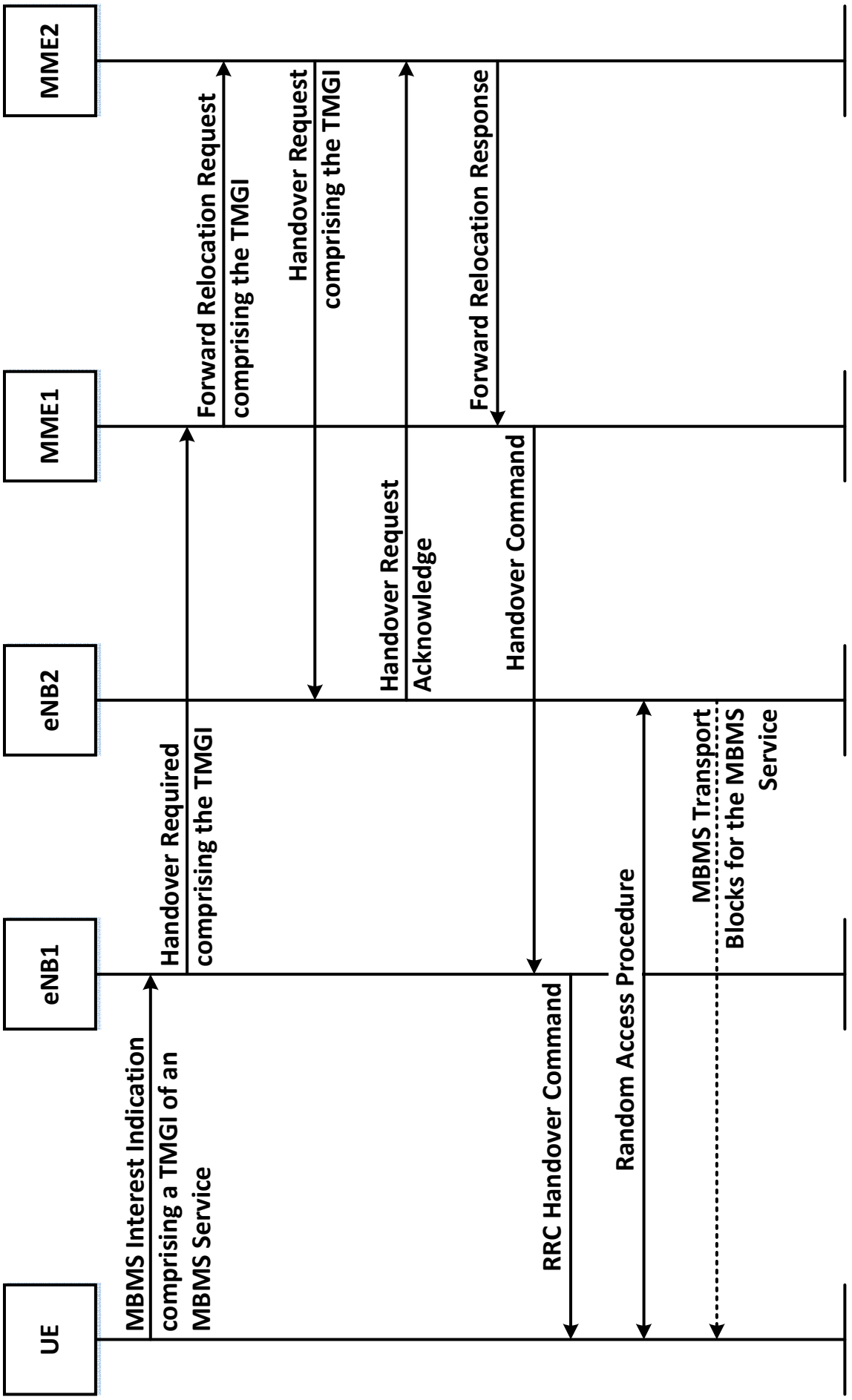

UE
eNB1
eNB2
MME1
MME2
MBMS Interest Indication
comprising a TMGI of an
MBMS Service
Handover Required
comprising the TMGI
Forward Relocation Request
comprising the TMGI
Handover Request
comprising the TMGI
Handover Request
Acknowledge
Forward Relocation Response
Handover Command
RRC Handover Command
Random Access Procedure
MBMS Transport
Blocks for the MBMS
Service

FIG. 12

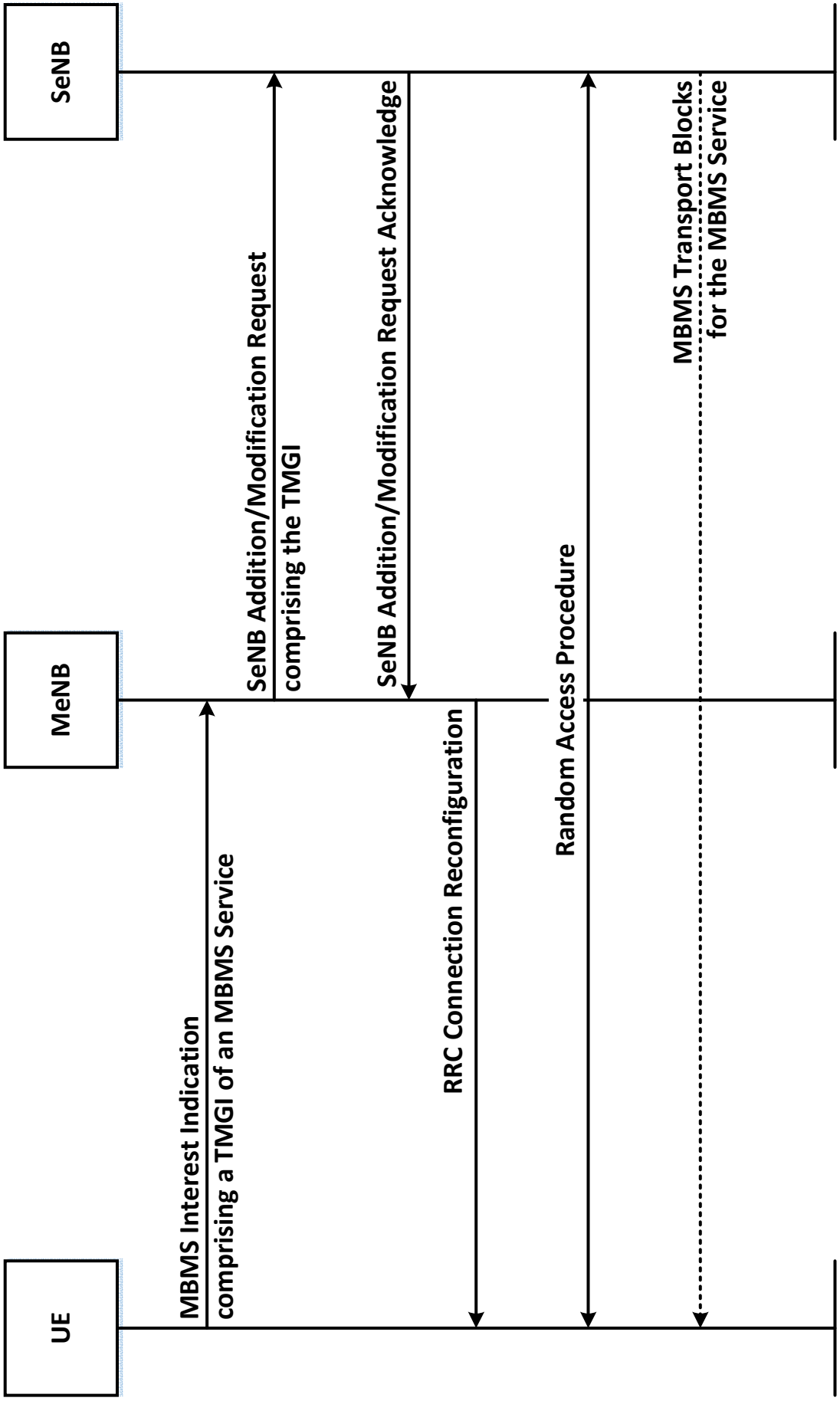

SeNB
MeNB
UE
SeNB Addition/Modification Request
comprising the TMGI
SeNB Addition/Modification Request Acknowledge
MBMS Transport Blocks
for the MBMS Service
MBMS Interest Indication
comprising a TMGI of an MBMS Service
RRC Connection Reconfiguration
Random Access Procedure

FIG. 13

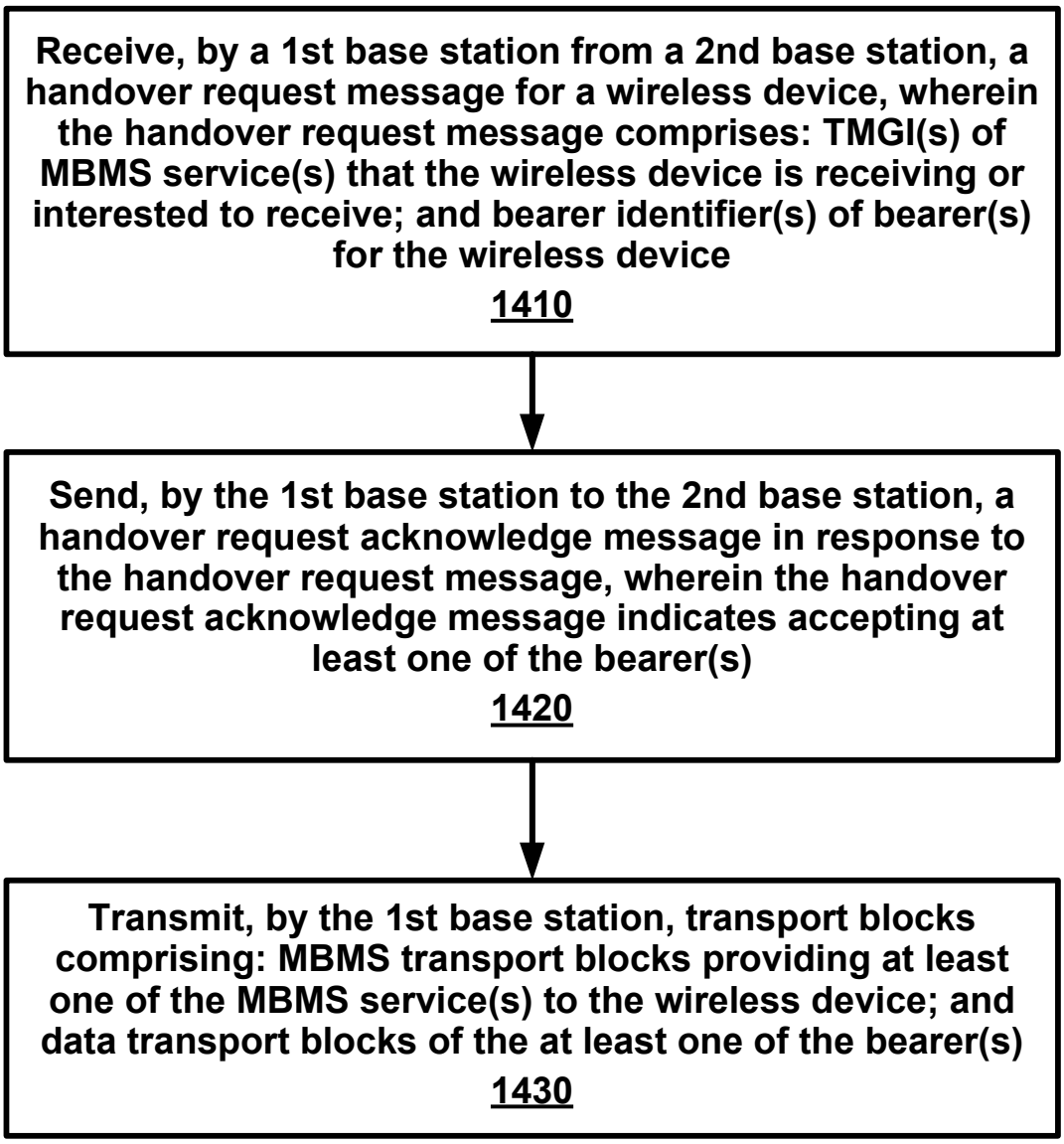

Receive, by a 1st base station from a 2nd base station, a handover request message for a wireless device, wherein the handover request message comprises: TMGI(s) of MBMS service(s) that the wireless device is receiving or interested to receive; and bearer identifier(s) of bearer(s) for the wireless device
1410
Send, by the 1st base station to the 2nd base station, a handover request acknowledge message in response to the handover request message, wherein the handover request acknowledge message indicates accepting at least one of the bearer(s)
1420
Transmit, by the 1st base station, transport blocks comprising: MBMS transport blocks providing at least one of the MBMS service(s) to the wireless device; and data transport blocks of the at least one of the bearer(s)
1430

FIG. 14

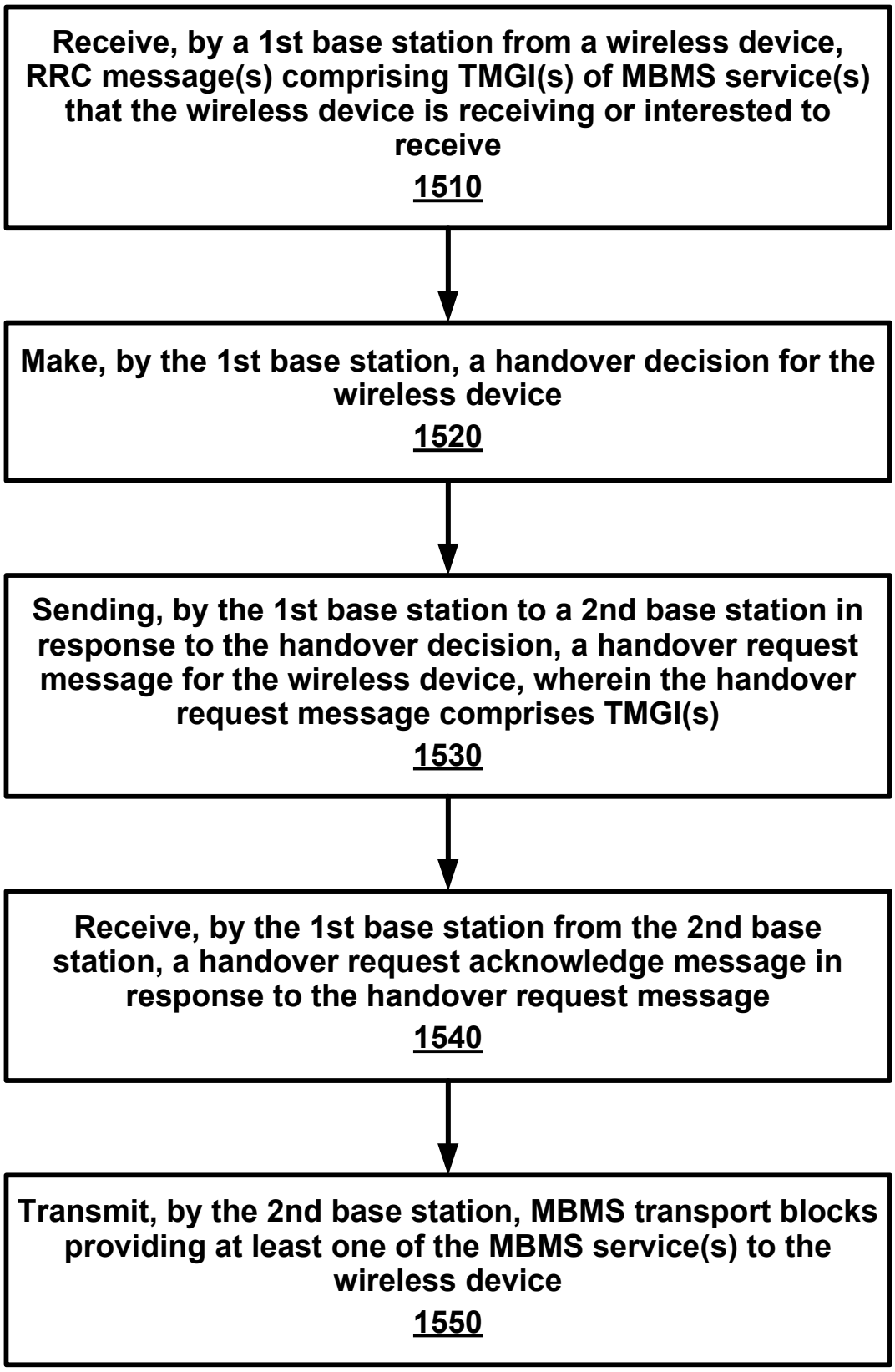

Receive, by a 1st base station from a wireless device, RRC message(s) comprising TMGI(s) of MBMS service(s) that the wireless device is receiving or interested to receive
1510
Make, by the 1st base station, a handover decision for the wireless device
1520
Sending, by the 1st base station to a 2nd base station in response to the handover decision, a handover request message for the wireless device, wherein the handover request message comprises TMGI(s)
1530
Receive, by the 1st base station from the 2nd base station, a handover request acknowledge message in response to the handover request message
1540
Transmit, by the 2nd base station, MBMS transport blocks providing at least one of the MBMS service(s) to the wireless device
1550

FIG. 15

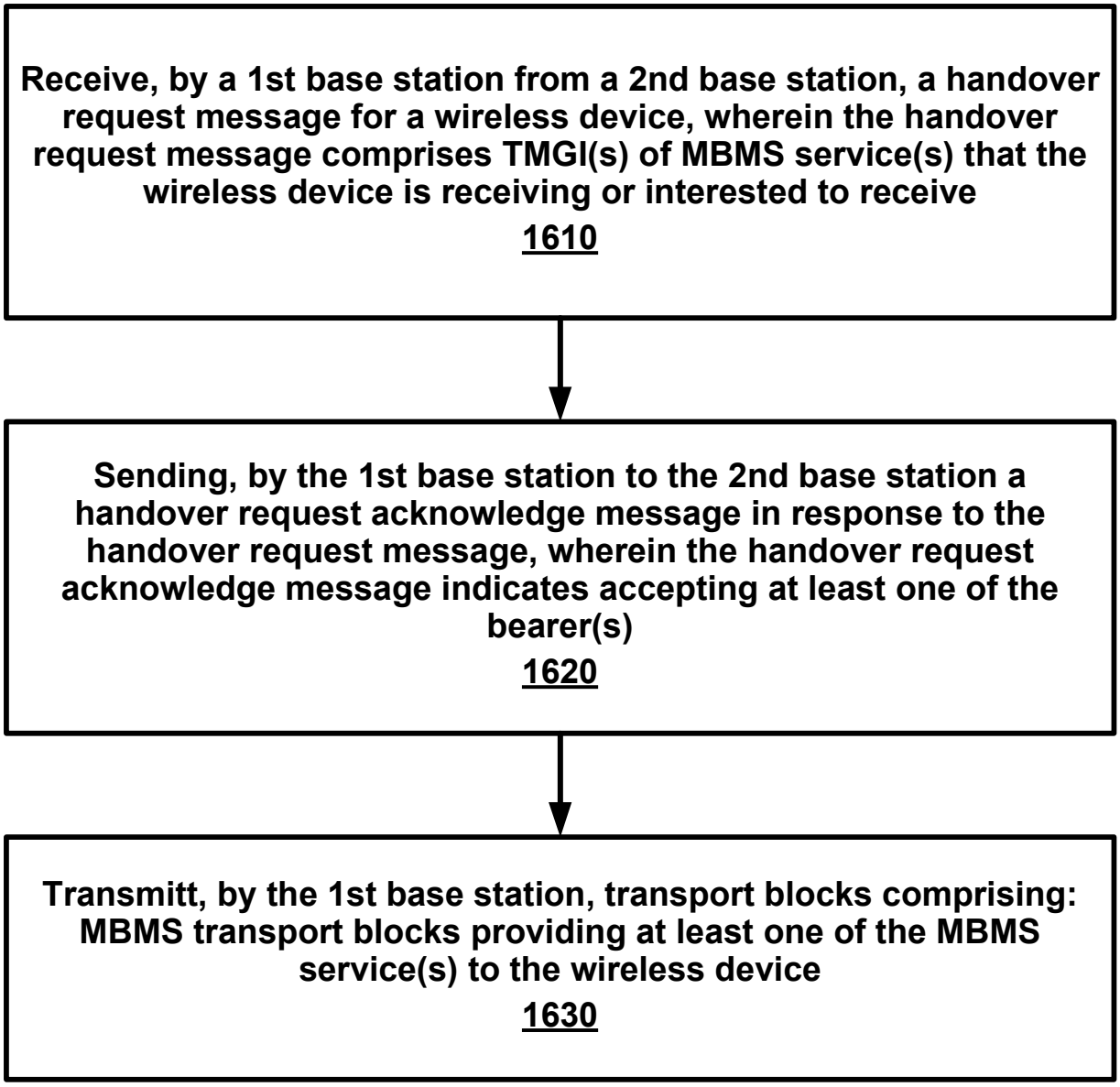

Receive, by a 1st base station from a 2nd base station, a handover request message for a wireless device, wherein the handover request message comprises TMGI(s) of MBMS service(s) that the wireless device is receiving or interested to receive
1610
Sending, by the 1st base station to the 2nd base station a handover request acknowledge message in response to the handover request message, wherein the handover request acknowledge message indicates accepting at least one of the bearer(s)
1620
Transmitt, by the 1st base station, transport blocks comprising: MBMS transport blocks providing at least one of the MBMS service(s) to the wireless device
1630

FIG. 16

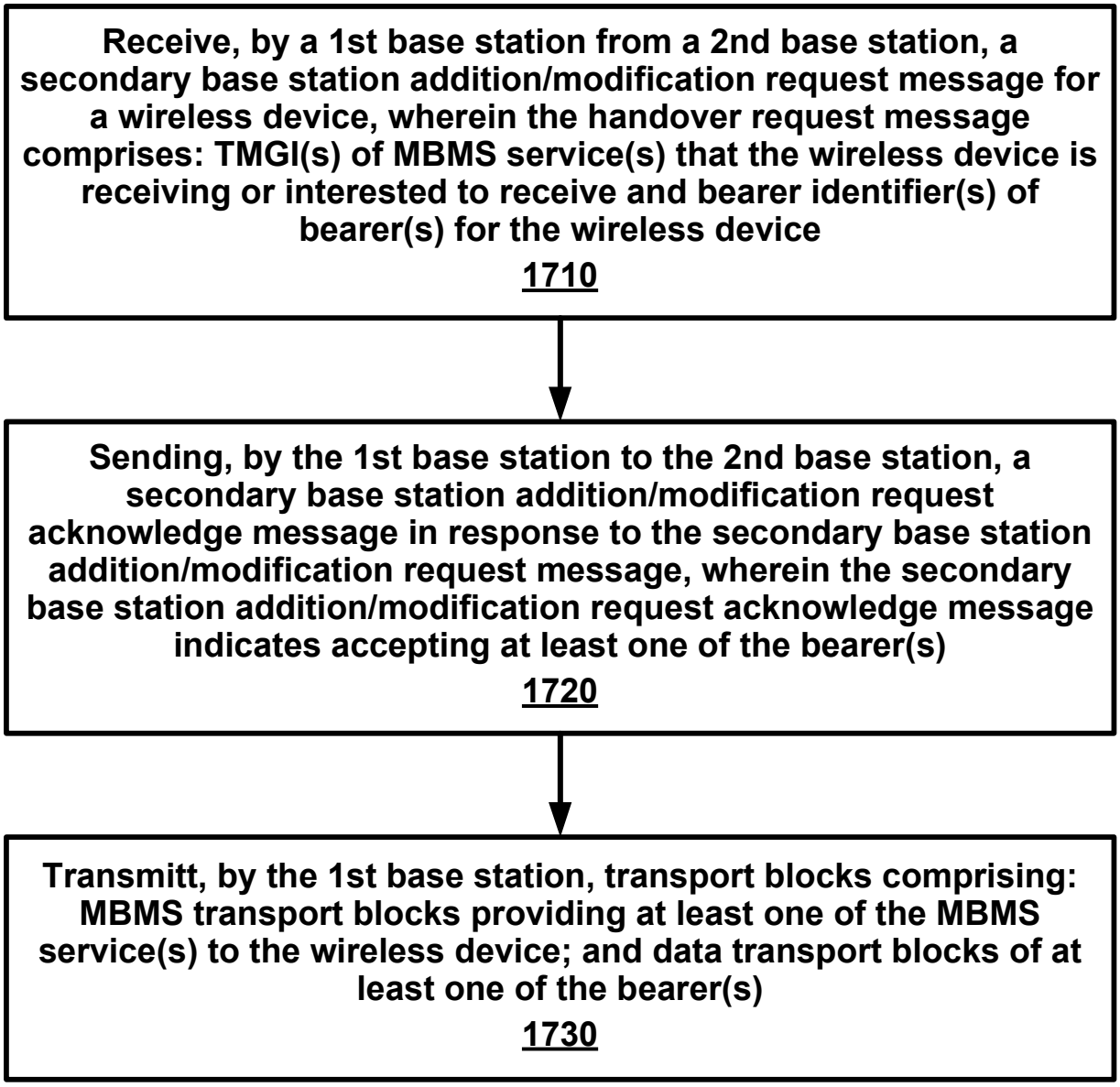

Receive, by a 1st base station from a 2nd base station, a secondary base station addition/modification request message for a wireless device, wherein the handover request message comprises: TMGI(s) of MBMS service(s) that the wireless device is receiving or interested to receive and bearer identifier(s) of bearer(s) for the wireless device
1710
Sending, by the 1st base station to the 2nd base station, a secondary base station addition/modification request acknowledge message in response to the secondary base station addition/modification request message, wherein the secondary base station addition/modification request acknowledge message indicates accepting at least one of the bearer(s)
1720
Transmitt, by the 1st base station, transport blocks comprising: MBMS transport blocks providing at least one of the MBMS service(s) to the wireless device; and data transport blocks of at least one of the bearer(s)
1730

FIG. 17

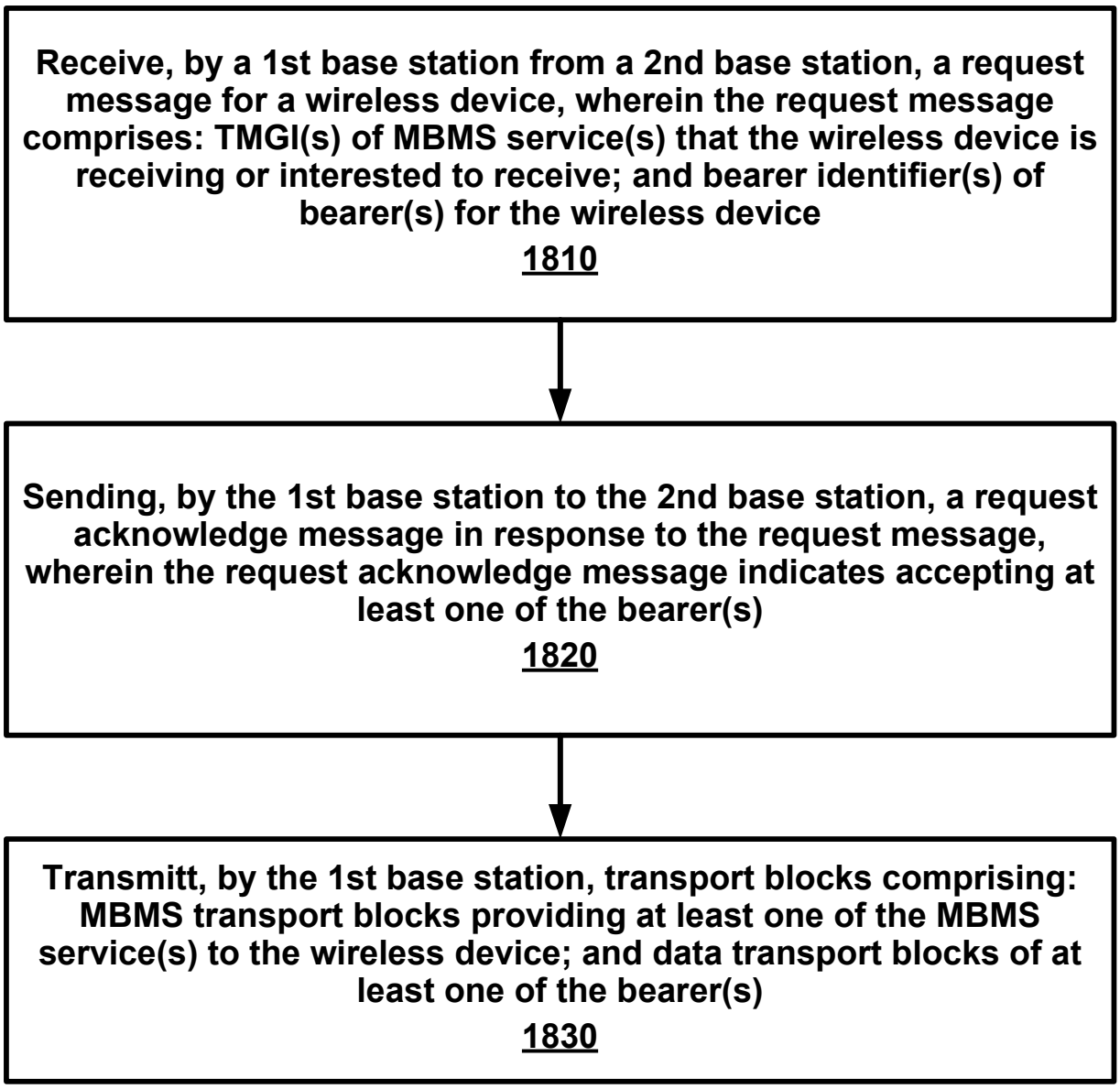

Receive, by a 1st base station from a 2nd base station, a request message for a wireless device, wherein the request message comprises: TMGI(s) of MBMS service(s) that the wireless device is receiving or interested to receive; and bearer identifier(s) of bearer(s) for the wireless device
1810
Sending, by the 1st base station to the 2nd base station, a request acknowledge message in response to the request message, wherein the request acknowledge message indicates accepting at least one of the bearer(s)
1820
Transmitt, by the 1st base station, transport blocks comprising: MBMS transport blocks providing at least one of the MBMS service(s) to the wireless device; and data transport blocks of at least one of the bearer(s)
1830

FIG. 18