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(54) **DUAL CONNECTIVITY SCHEDULING REQUEST FOR WIRELESS NETWORK AND WIRELESS DEVICE**

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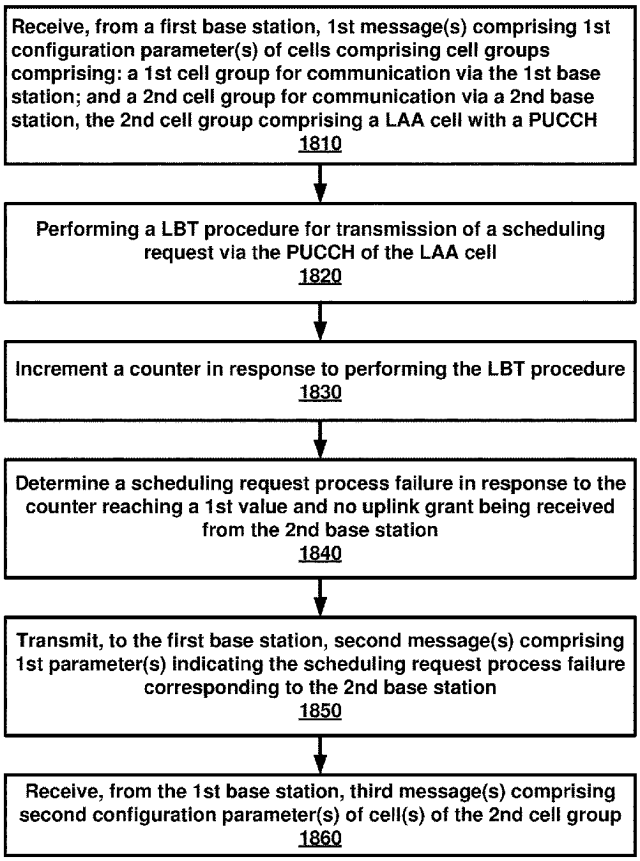
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(57) **ABSTRACT**

First message(s) are received from a first base-station. The first message(s) comprise first configuration parameter(s) of cells comprising: a first cell group for communication via the first base-station; and a second cell group for communication via a second base-station. The second cell group comprises an LAA cell with a PUCCH. An LBT procedure for transmission of a scheduling request via the PUCCH of the LAA cell is performed. A counter is incremented in response to the LBT. A scheduling request process failure is determined in response to the counter reaching a first value and no uplink grant received from the second base-station. Second message(s) are transmitted to the first base-station. The second message(s) comprise first parameter(s) indicating the scheduling request process failure corresponding to the second base-station. Third message(s) are received from the first base-station. The third message(s) comprise second configuration parameter(s) of cell(s) of the second cell group.



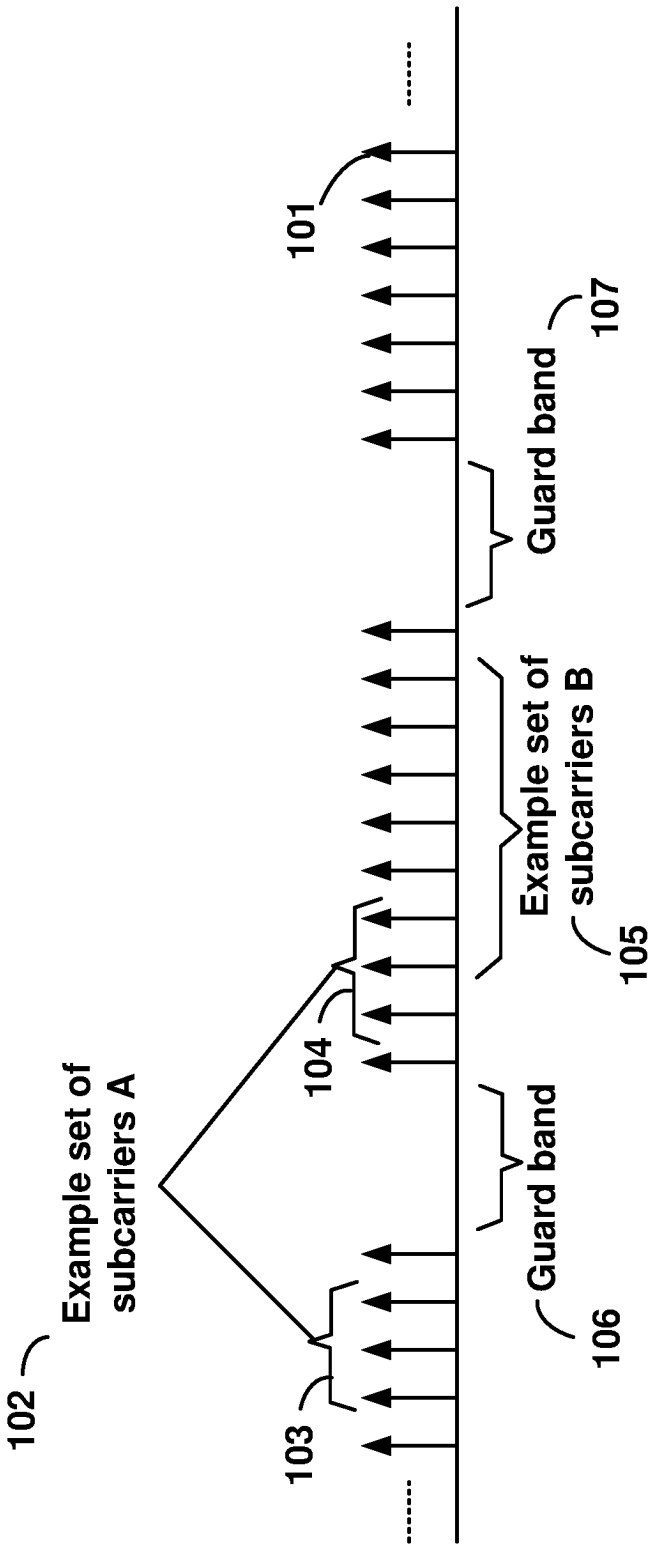

101
Guard band
107
Example set of subcarriers B
105
104
Guard band
106
Example set of subcarriers A
102
103

FIG. 1

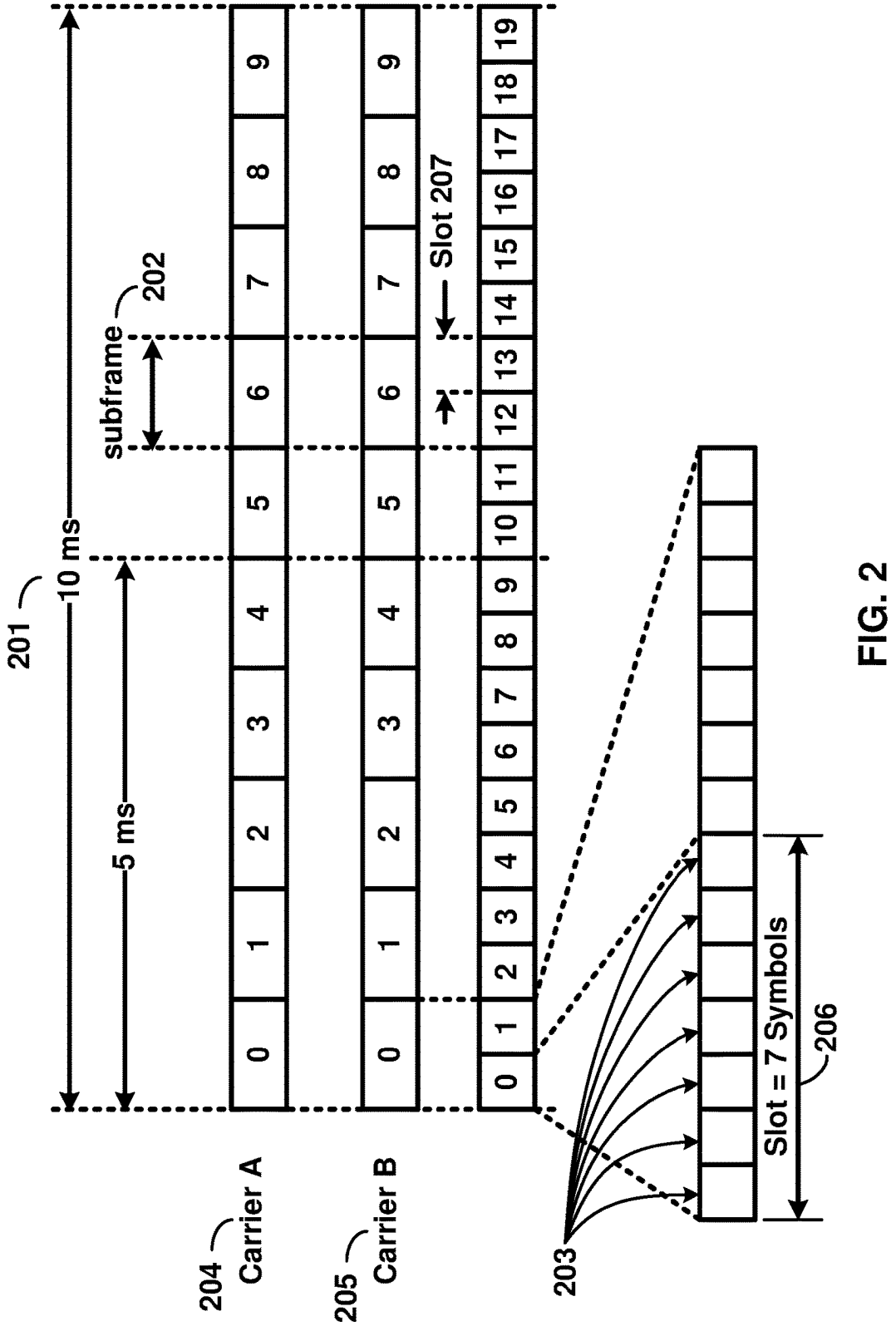

201
10 ms
5 ms
subframe
202
Slot 207
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
204
Carrier A
205
Carrier B
203
Slot = 7 Symbols
206

FIG. 2

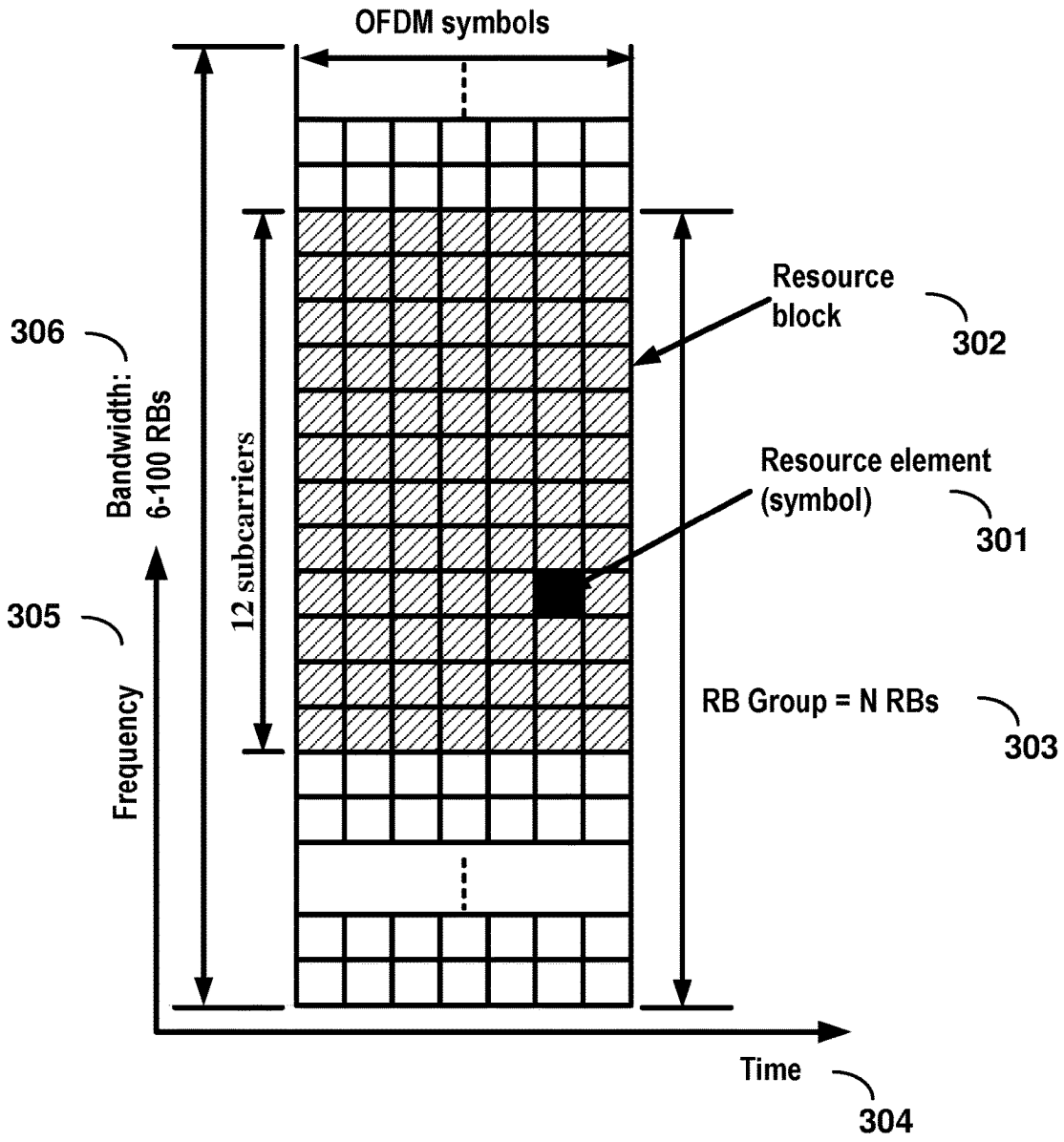

OFDM symbols
Resource block
302
306
Bandwidth: 6-100 RBs
12 subcarriers
Resource element (symbol)
301
305
Frequency
RB Group = N RBs
303
Time
304

FIG. 3

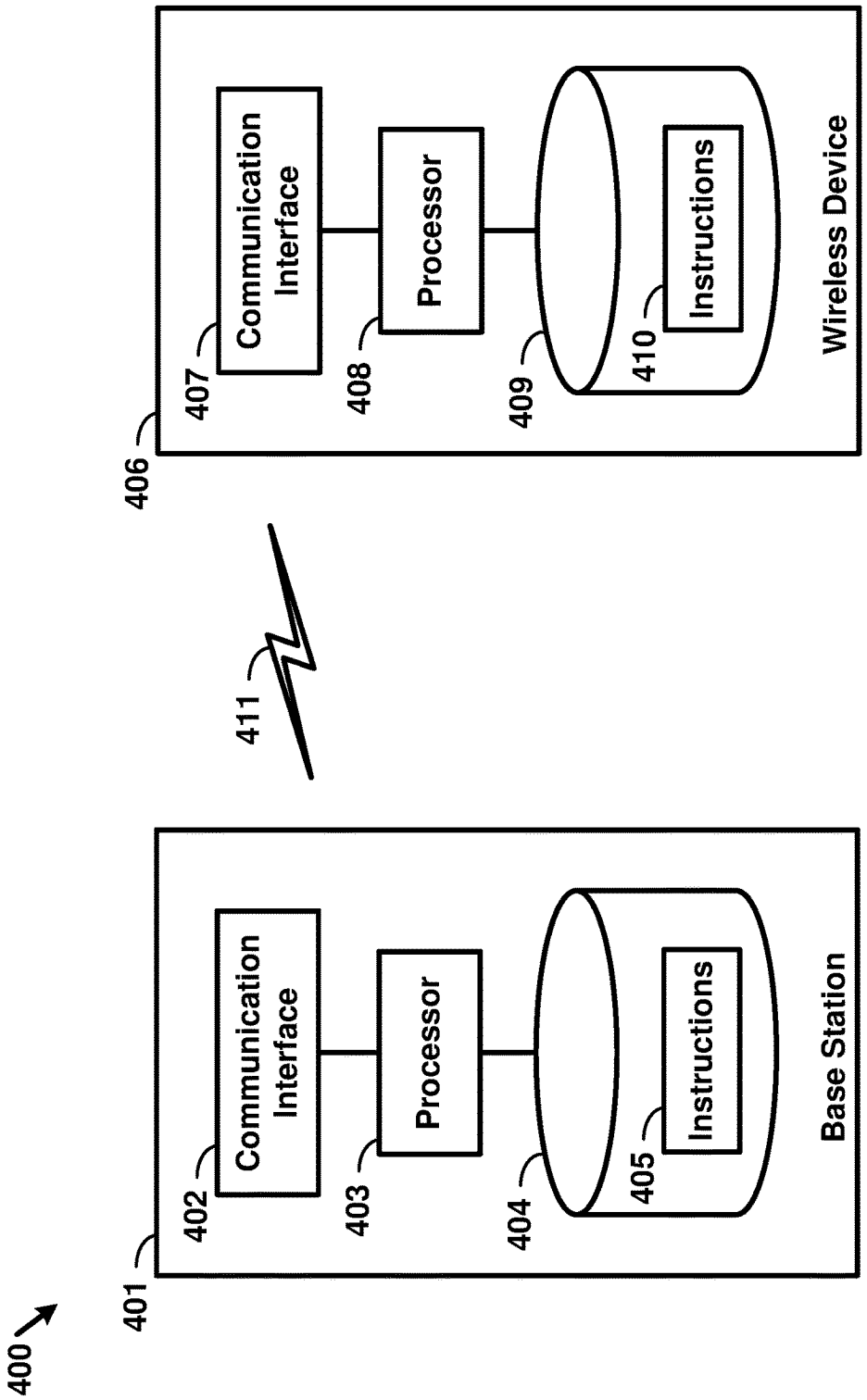

400
401
Base Station
402
Communication Interface
403
Processor
404
405
Instructions
411
406
Wireless Device
407
Communication Interface
408
Processor
409
410
Instructions

FIG. 4

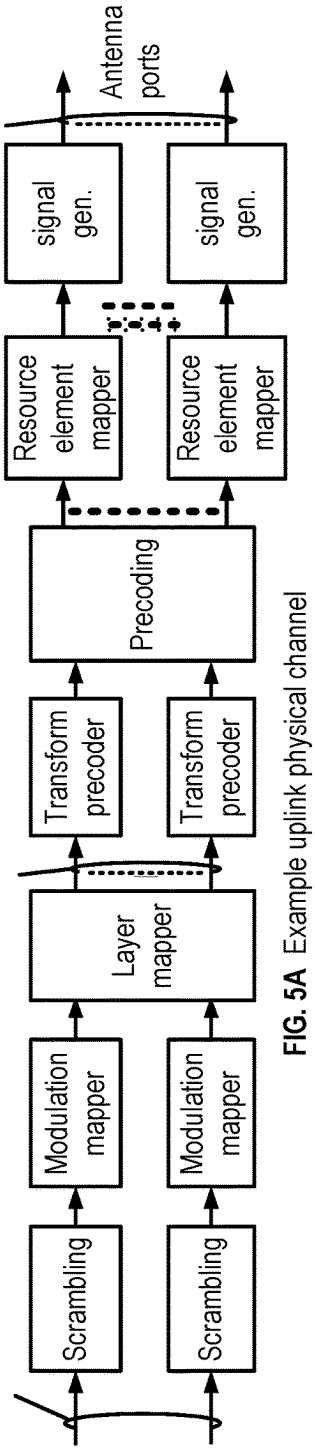


FIG. 5A Example uplink physical channel

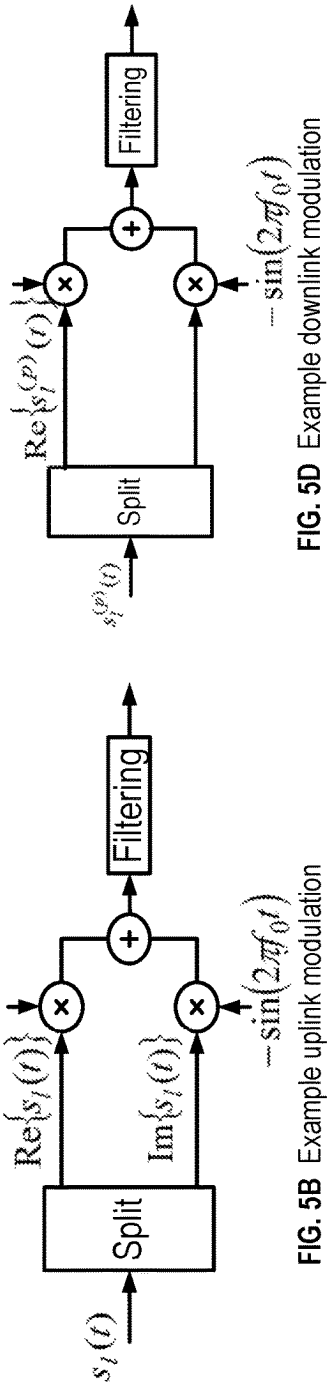


FIG. 5B Example uplink modulation

FIG. 5D Example downlink modulation

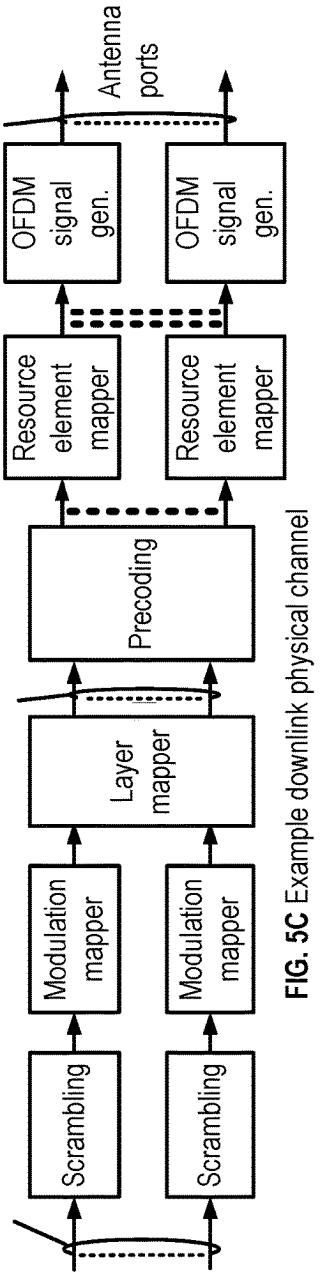
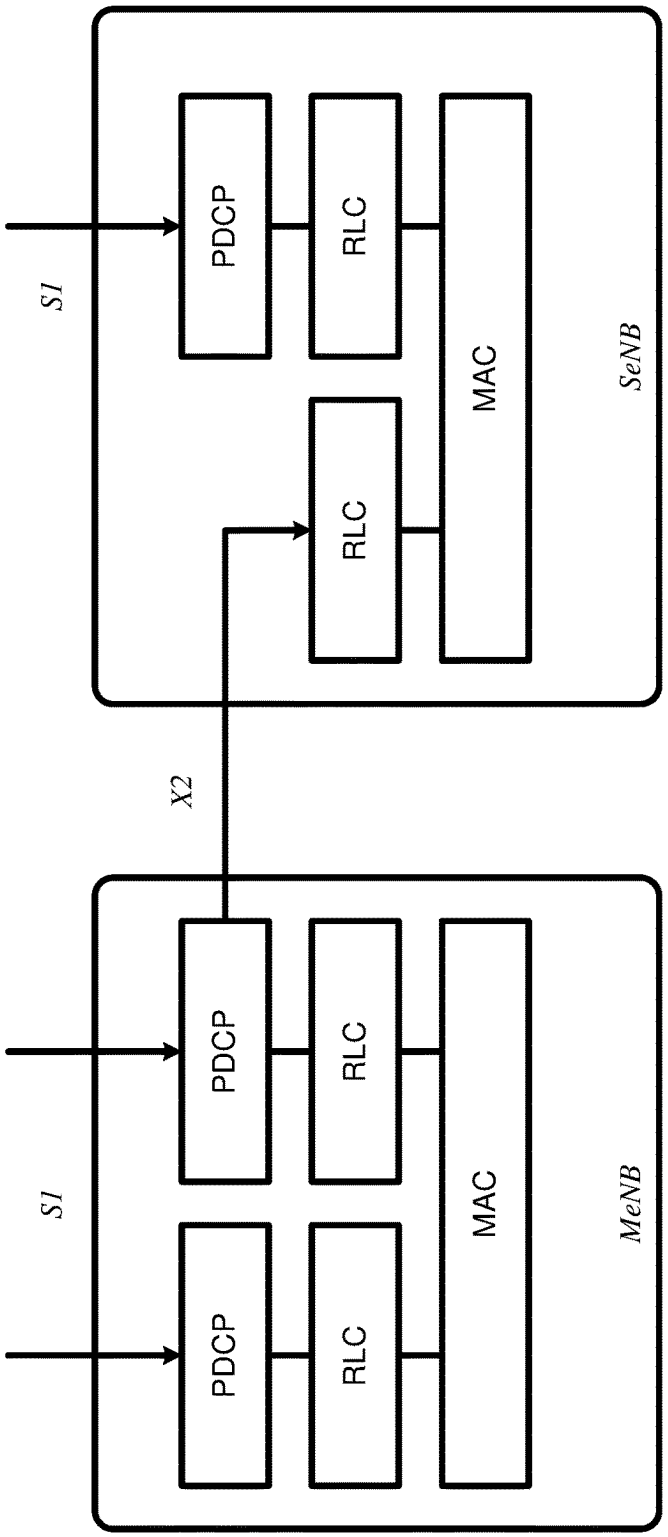
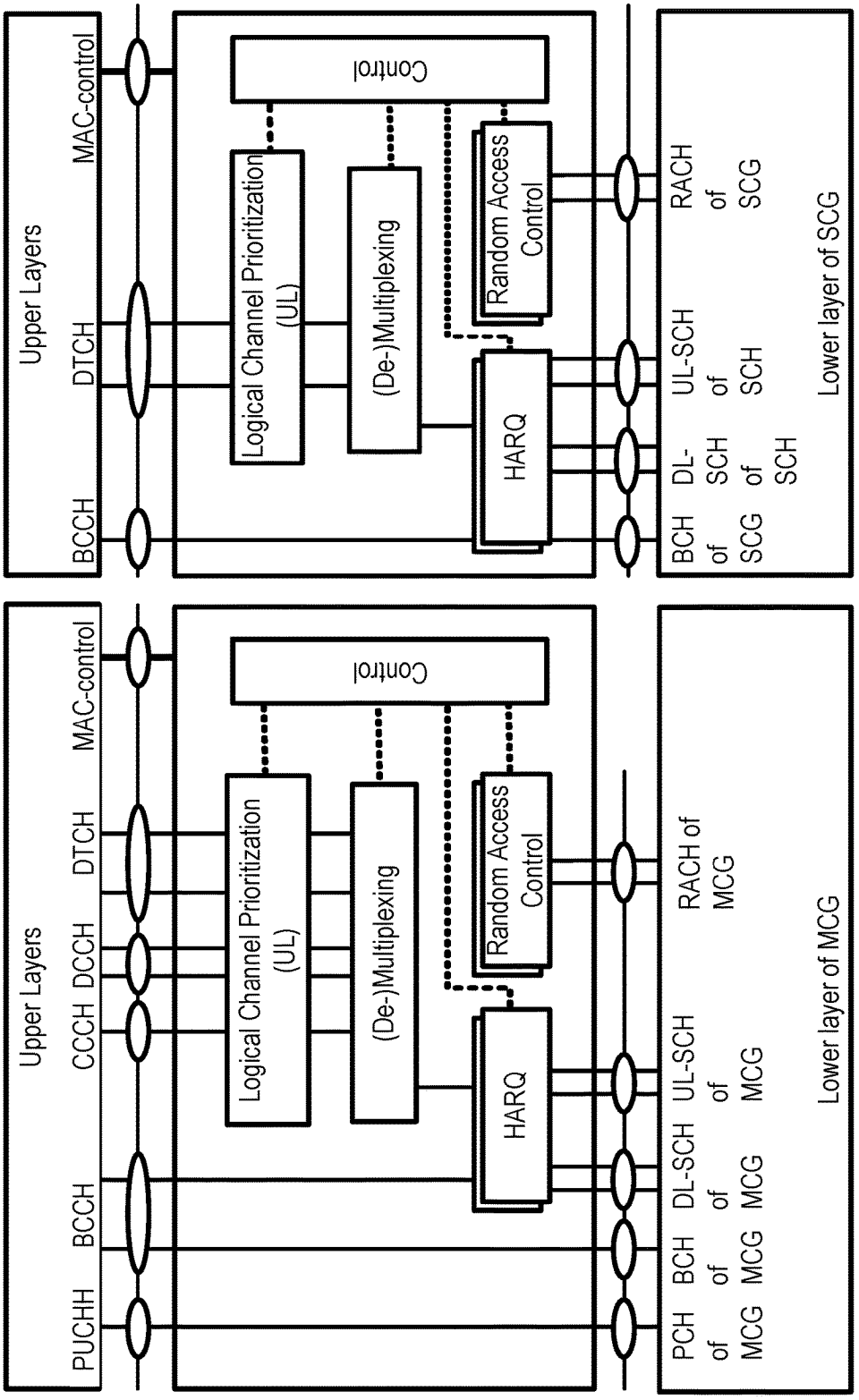


FIG. 5C Example downlink physical channel



Dual-Connectivity at eNB

FIG. 6



Dual-Connectivity- two MAC entities at UE side

FIG. 7

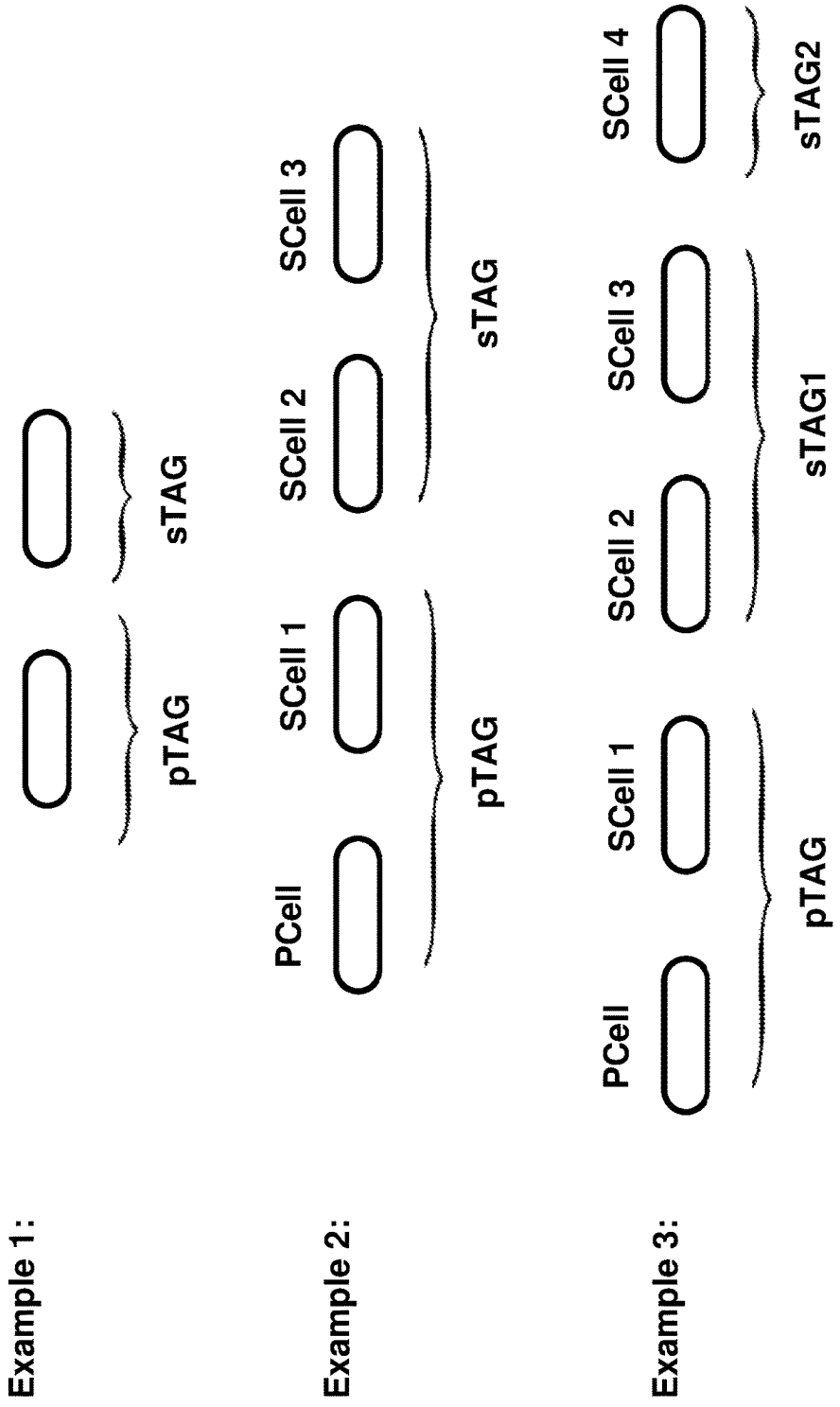

Example 1:
PCell
SCell 1
pTAG
sTAG
Example 2:
PCell
SCell 1
SCell 2
SCell 3
pTAG
sTAG
Example 3:
PCell
SCell 1
SCell 2
SCell 3
SCell 4
pTAG
sTAG1
sTAG2

FIG. 8

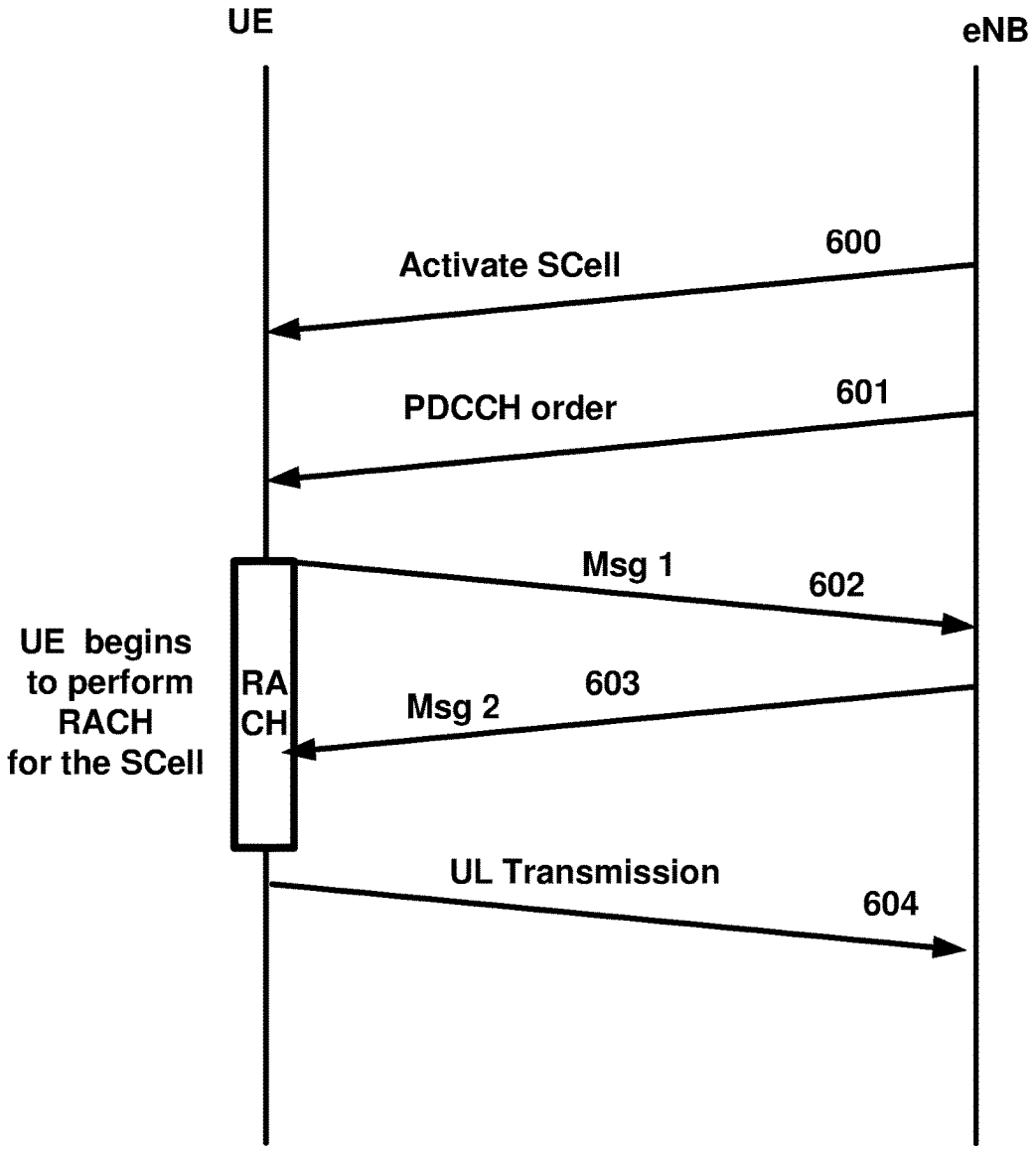

UE
eNB
Activate SCell
600
PDCCH order
601
Msg 1
602
UE begins to perform RACH for the SCell
RA CH
Msg 2
603
UL Transmission
604

FIG. 9

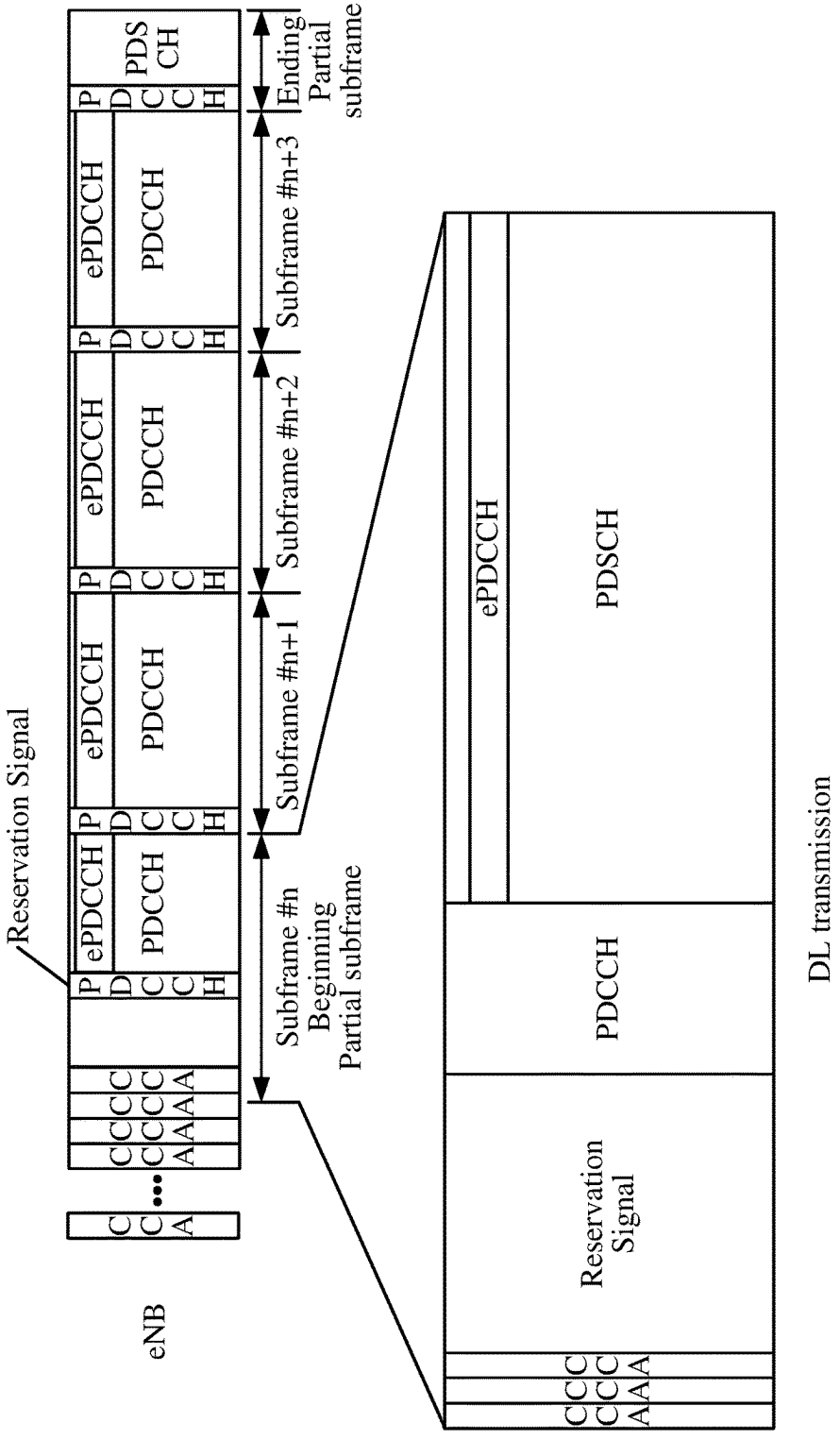

eNB
C
C
A
CCCC
CCCC
AAAA
Reservation Signal
P
D
C
C
H
ePDCCH
PDCCH
PDS CH
Subframe #n
Beginning Partial subframe
Subframe #n+1
Subframe #n+2
Subframe #n+3
Ending Partial subframe
DL transmission
Reservation Signal
PDCCH
ePDCCH
PDSCH

FIG. 10

SR configuration index I_{SR}	SR periodicity (ms) $SR_{PERIODICITY}$	SR subframe offset $N_{OFFSET,SR}$
0 – 4	5	I_{SR}
5 – 14	10	$I_{SR} - 5$
15 – 34	20	$I_{SR} - 15$
35 – 74	40	$I_{SR} - 35$
75 – 154	80	$I_{SR} - 75$
155 – 156	2	$I_{SR} - 155$
157	1	$I_{SR} - 157$

FIG. 11

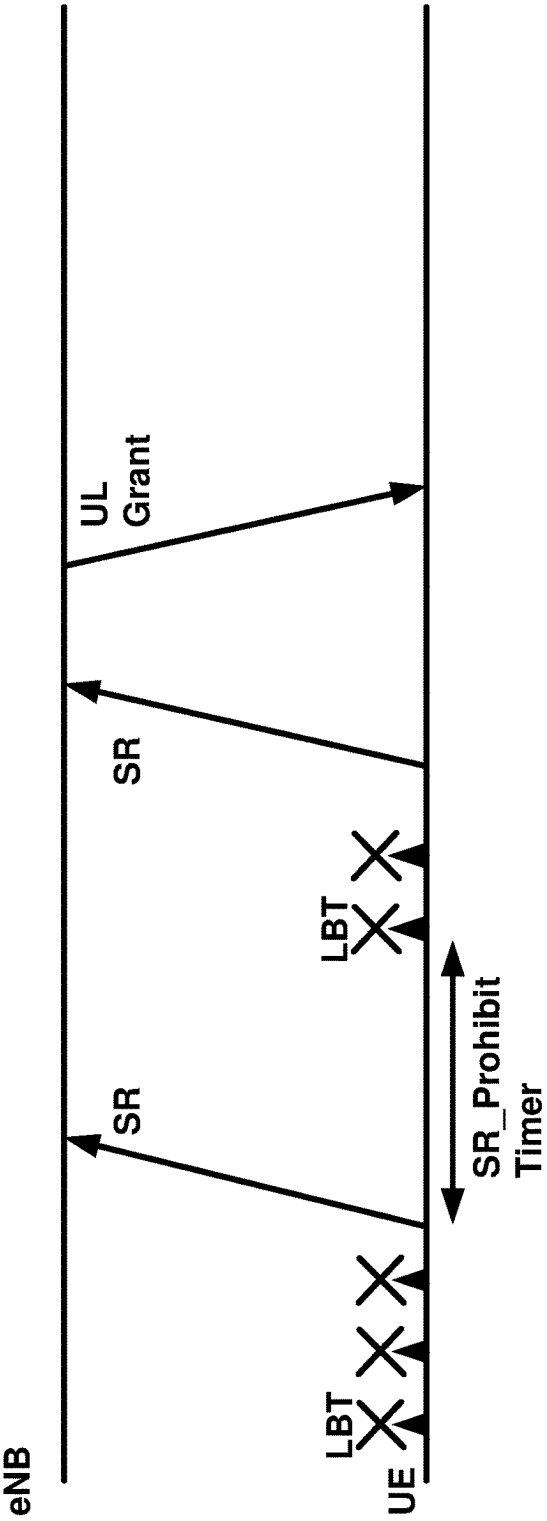


FIG. 12

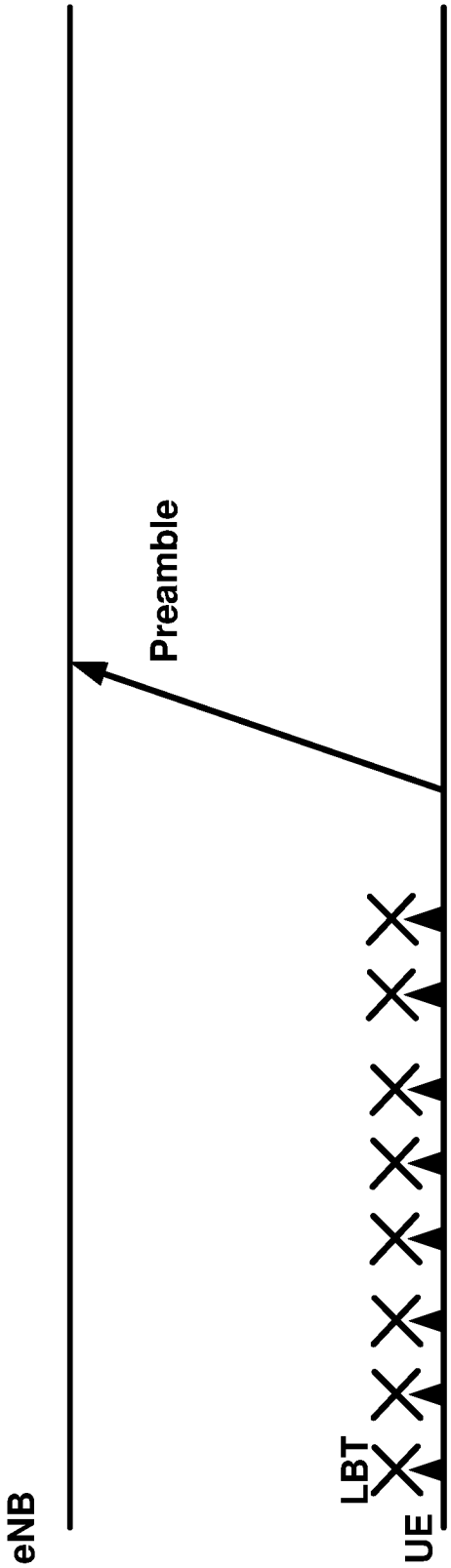


FIG. 13

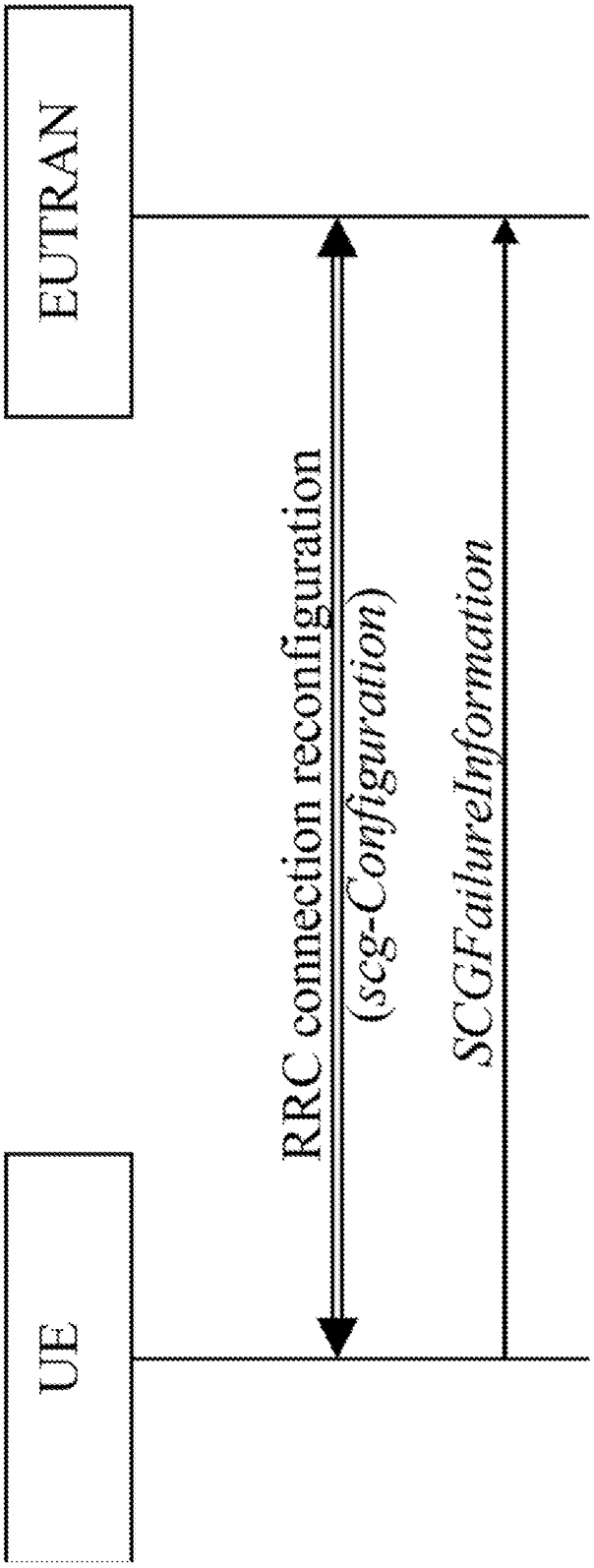

EUTRAN
UE
RRC connection reconfiguration
(scg-Configuration)
SCGFailureInformation

FIG. 14

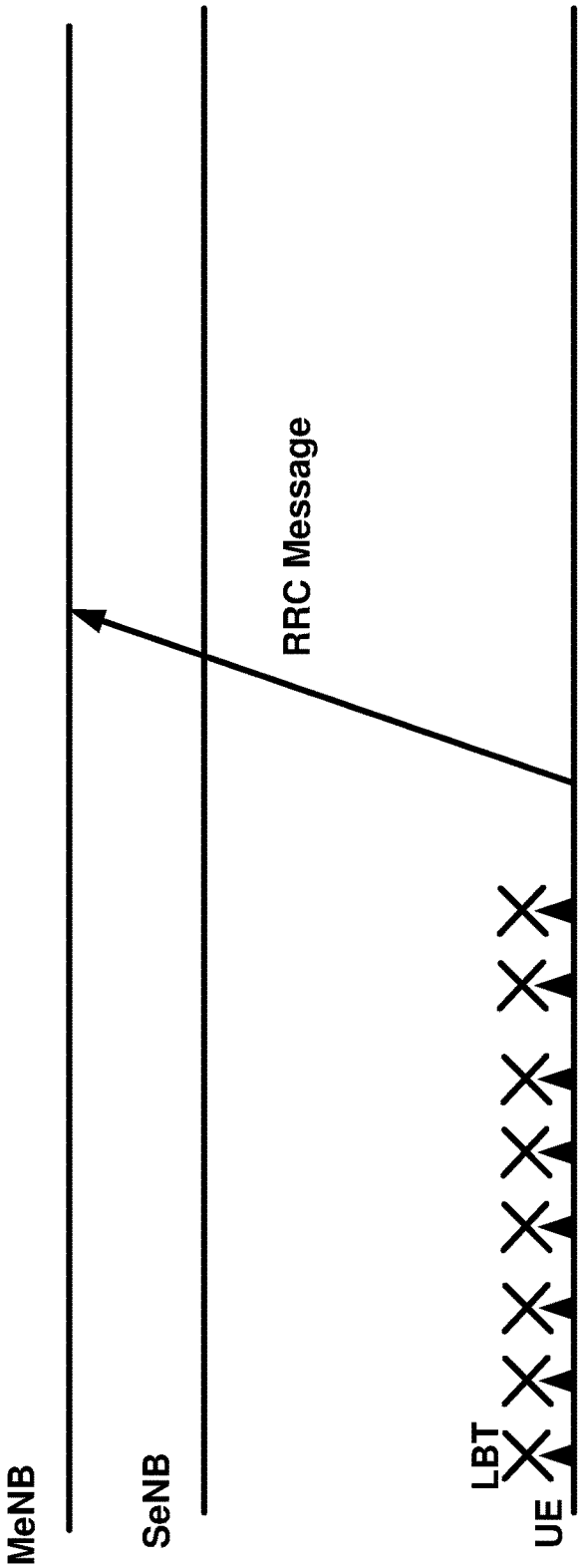


FIG. 15

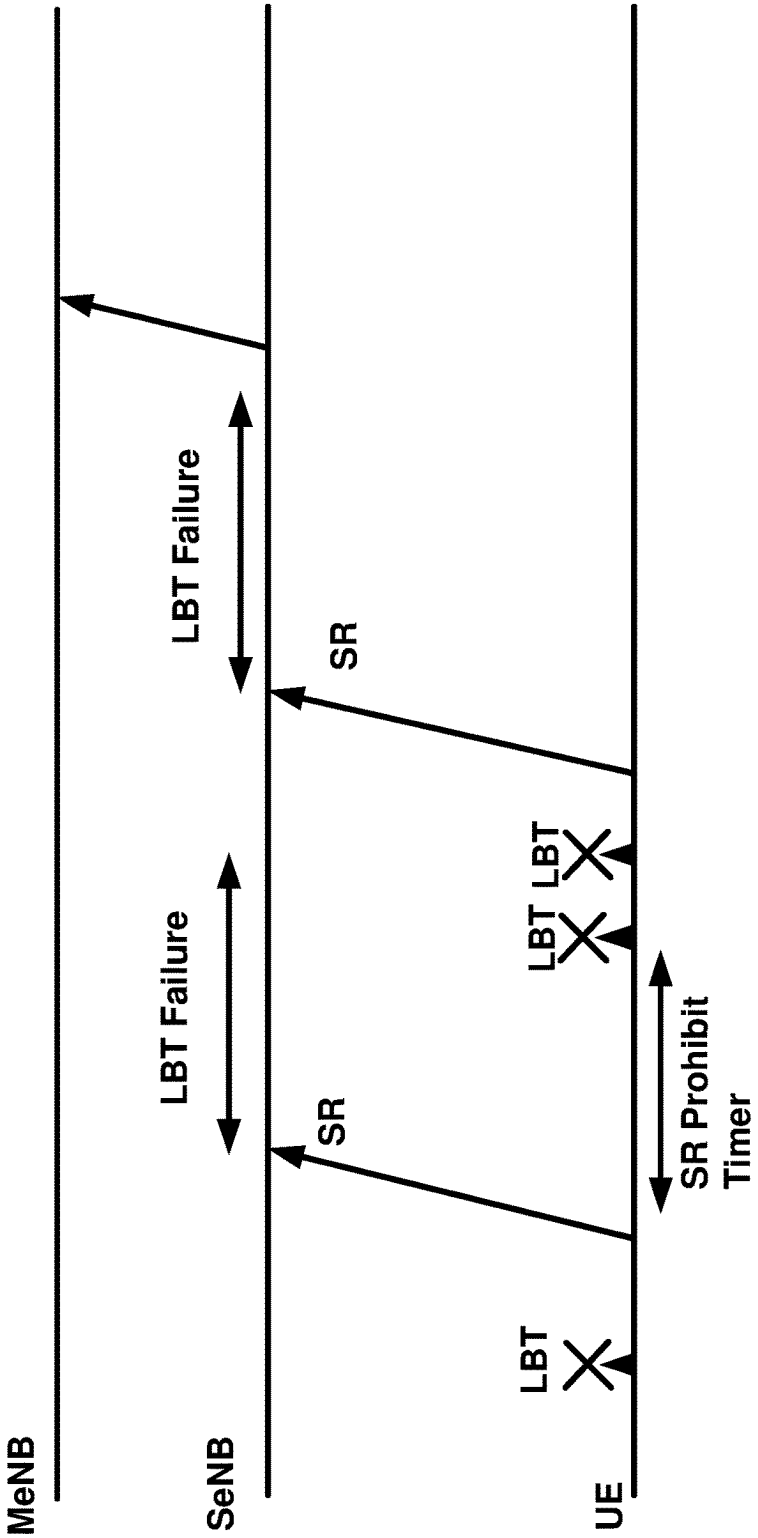

MeNB
SeNB
UE
LBT Failure
SR
LBT Failure
SR
LBT
LBT
LBT
SR Prohibit Timer

FIG. 16

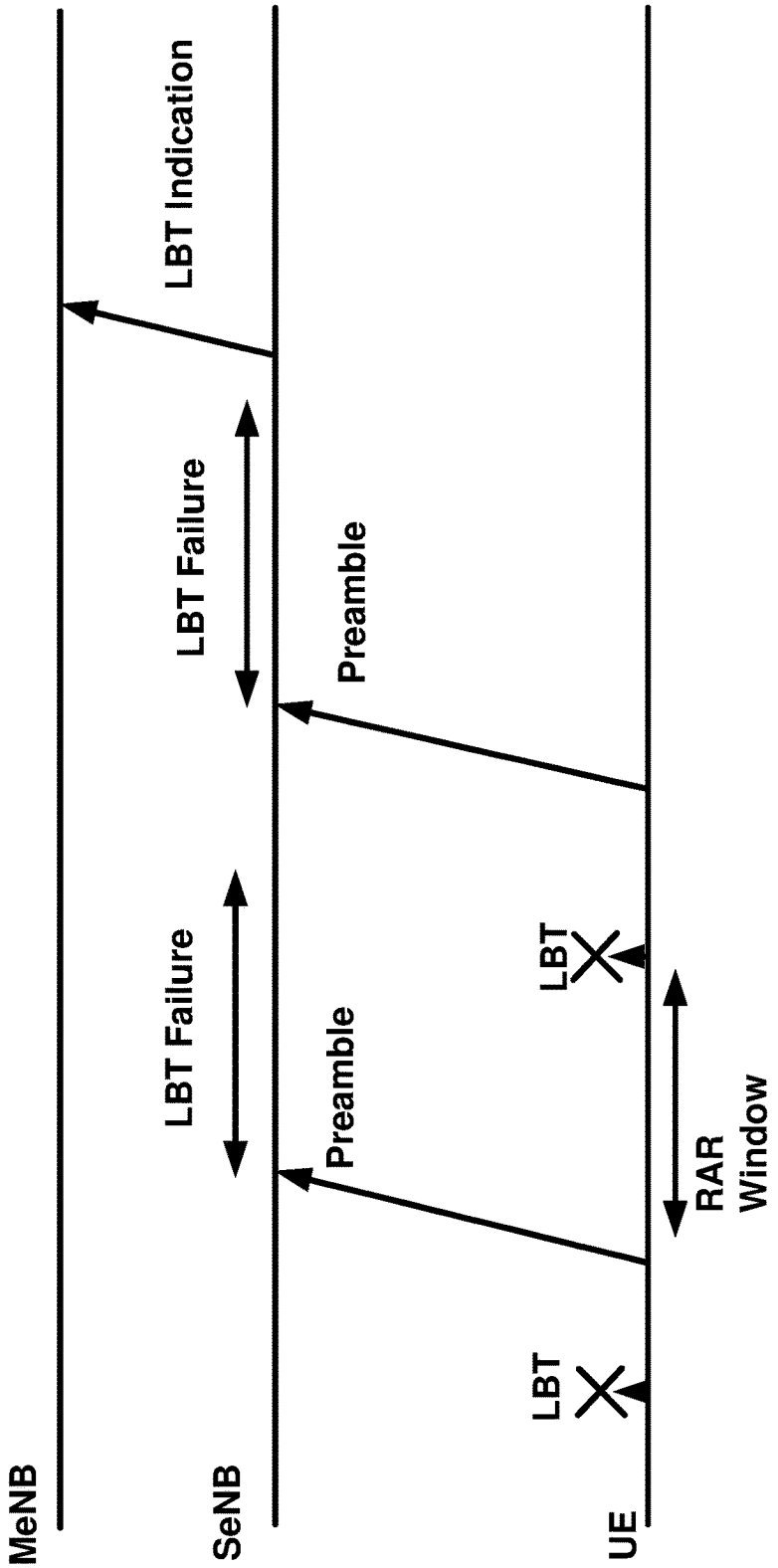

MeNB
SeNB
UE
LBT Indication
LBT Failure
Preamble
LBT
LBT Failure
Preamble
LBT
RAR Window

FIG. 17

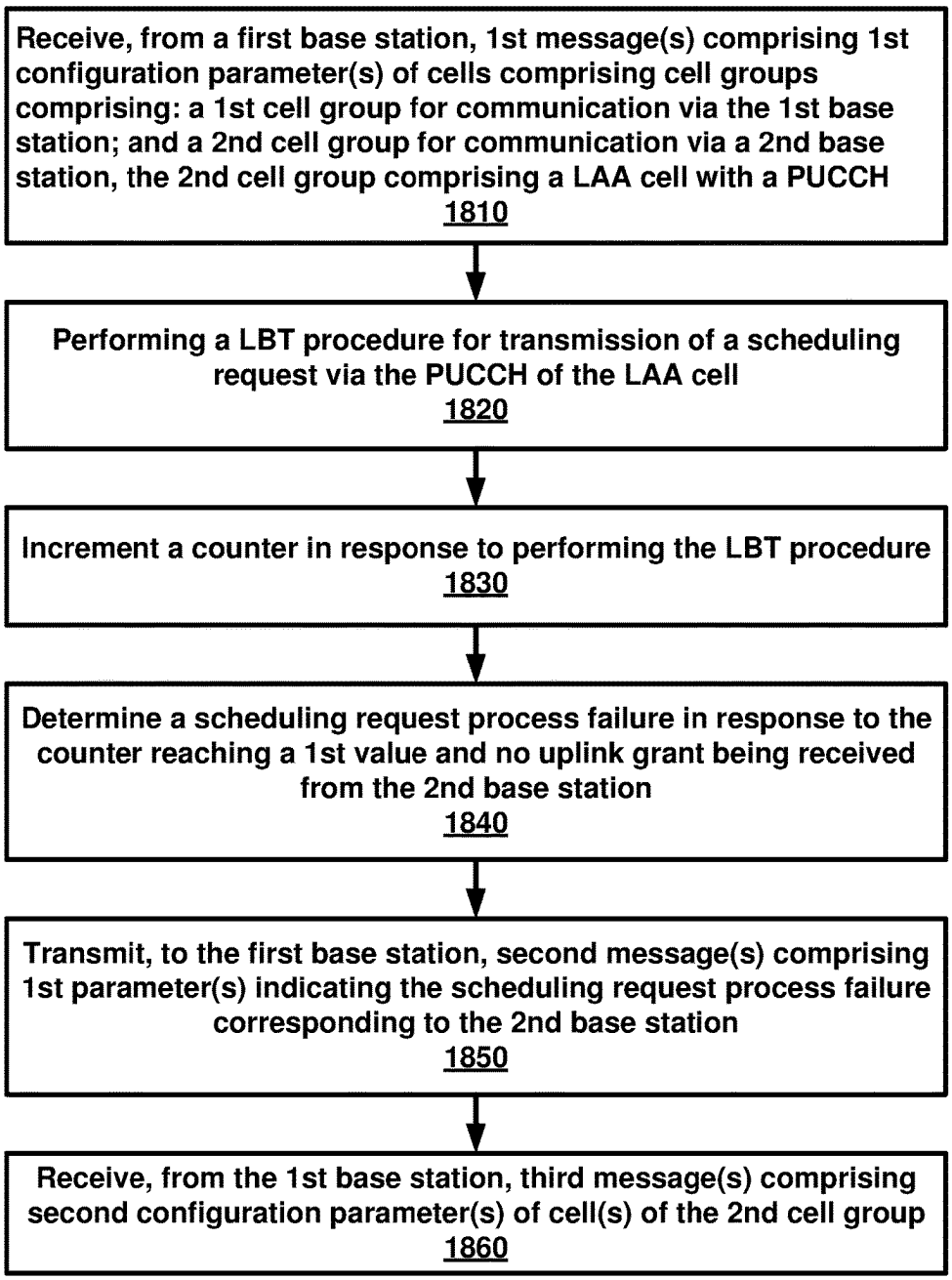

Receive, from a first base station, 1st message(s) comprising 1st configuration parameter(s) of cells comprising cell groups comprising: a 1st cell group for communication via the 1st base station; and a 2nd cell group for communication via a 2nd base station, the 2nd cell group comprising a LAA cell with a PUCCH
1810
Performing a LBT procedure for transmission of a scheduling request via the PUCCH of the LAA cell
1820
Increment a counter in response to performing the LBT procedure
1830
Determine a scheduling request process failure in response to the counter reaching a 1st value and no uplink grant being received from the 2nd base station
1840
Transmit, to the first base station, second message(s) comprising 1st parameter(s) indicating the scheduling request process failure corresponding to the 2nd base station
1850
Receive, from the 1st base station, third message(s) comprising second configuration parameter(s) of cell(s) of the 2nd cell group
1860

FIG. 18

DUAL CONNECTIVITY SCHEDULING REQUEST FOR WIRELESS NETWORK AND WIRELESS DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/414,697, filed Oct. 29, 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 disclosure 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 an example diagram depicting OFDM radio resources as per an aspect of an embodiment of the present disclosure.

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

[0007] FIG. **5**A, FIG. **5**B, FIG. **5**C and FIG. **5**D 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 diagram depicting a downlink burst as per an aspect of an embodiment of the present disclosure.

[0013] FIG. **11** is an example Table indicating scheduling request parameters.

[0014] FIG. **12** is an example diagram depicting transmission of scheduling request as per an aspect of an embodiment of the present disclosure.

[0015] FIG. **13** is an example diagram depicting LBT failure and preamble transmission as per an aspect of an embodiment of the present disclosure.

[0016] FIG. **14** is an example diagram depicting SCG failure information transmission as per an aspect of an embodiment of the present disclosure.

[0017] FIG. **15** is an example diagram depicting LBT failure and RRC message transmission as per an aspect of an embodiment of the present disclosure.

[0018] FIG. **16** is an example diagram depicting LBT failure and SeNB-MeNB message transmission as per an aspect of an embodiment of the present disclosure.

[0019] FIG. **17** is an example diagram depicting LBT failure and SeNB-MeNB message transmission 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 disclosure enable operation of carrier aggregation. Embodiments of the technology disclosed herein may be employed in the technical field of multicarrier communication systems.

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

[0023] ASIC application-specific integrated circuit

[0024] BPSK binary phase shift keying

[0025] CA carrier aggregation

[0026] CSI channel state information

[0027] CDMA code division multiple access

[0028] CSS common search space

[0029] CPLD complex programmable logic devices

[0030] CC component carrier

[0031] DL downlink

[0032] DCI downlink control information

[0033] DC dual connectivity

[0034] EPC evolved packet core

[0035] E-UTRAN evolved-universal terrestrial radio access network

[0036] FPGA field programmable gate arrays

[0037] FDD frequency division multiplexing

[0038] HDL hardware description languages

[0039] HARQ hybrid automatic repeat request

[0040] IE information element

[0041] LAA licensed assisted access

[0042] LTE long term evolution

[0043] MCG master cell group

[0044] MeNB master evolved node B

[0045] MIB master information block

[0046] MAC media access control

[0047] MAC media access control

[0048] MME mobility management entity

[0049] NAS non-access stratum

[0050] OFDM orthogonal frequency division multiplexing

[0051] PDCP packet data convergence protocol

[0052] PDU packet data unit

[0053] PHY physical

[0054] PDCCH physical downlink control channel

[0055] PHICH physical HARQ indicator channel

[0056] PUCCH physical uplink control channel

[0057] PUSCH physical uplink shared channel

[0058] PCell primary cell

[0059] PCell primary cell

[0060] PCC primary component carrier

[0061] PSCell primary secondary cell

[0062] pTAG primary timing advance group

[0063] QAM quadrature amplitude modulation

[0064] QPSK quadrature phase shift keying

[0065] RBG Resource Block Groups

[0066] RLC radio link control

[0067] RRC radio resource control

[0068] RA random access

[0069] RB resource blocks

[0070] SCC secondary component carrier

[0071] SCell secondary cell

[0072] Scell secondary cells
[0073] SCG secondary cell group
[0074] SeNB secondary evolved node B
[0075] sTAGs secondary timing advance group
[0076] SDU service data unit
[0077] S-GW serving gateway
[0078] SRB signaling radio bearer
[0079] SC-OFDM single carrier-OFDM
[0080] SFN system frame number
[0081] SIB system information block
[0082] TAI tracking area identifier
[0083] TAT time alignment timer
[0084] TDD time division duplexing
[0085] TDMA time division multiple access
[0086] TA timing advance
[0087] TAG timing advance group
[0088] TB transport block
[0089] UL uplink
[0090] UE user equipment
[0091] VHDL VHSIC hardware description language

[0092] Example embodiments of the disclosure 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.

[0093] FIG. **1** is a diagram depicting example sets of OFDM subcarriers as per an aspect of an embodiment of the present disclosure. 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.

[0094] 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 disclosure. 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, the 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 0.5 msec, 1 msec, 2 msec, and 5 msec may also be supported. Subframe(s) may consist of two or more slots (for example, 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.

[0095] FIG. **3** is a diagram depicting OFDM radio resources as per an aspect of an embodiment of the present disclosure. 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 to 100 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).

[0096] FIG. **5**A, FIG. **5**B, FIG. **5**C and FIG. **5**D are example diagrams for uplink and downlink signal transmission as per an aspect of an embodiment of the present disclosure. FIG. **5**A 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.

[0097] 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

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complex-valued PRACH baseband signal is shown in FIG. **5**B. Filtering may be employed prior to transmission.

[0098] An example structure for Downlink Transmissions is shown in FIG. **5**C. 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.

[0099] Example modulation and up-conversion to the carrier frequency of the complex-valued OFDM baseband signal for each antenna port is shown in FIG. **5**D. Filtering may be employed prior to transmission.

[0100] 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 disclosure. 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 aspects of an 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.

[0101] 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.

[0102] 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.

[0103] According to various aspects of an embodiment, an LTE network may include a multitude of base stations, providing a user plane PDCP/RLC/MAC/PHY and control plane (RRC) protocol terminations towards the wireless device. The base station(s) may be interconnected with other base station(s) (for example, interconnected employing an X2 interface). Base stations may also be connected employing, for example, an S1 interface to an EPC. For example, 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, the carrier corresponding to the PCell 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.

[0104] 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

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apply, for example, to carrier activation. When the specification indicates that a first carrier is activated, the specification may also mean that the cell comprising the first carrier is activated.

[0105] 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.

[0106] 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.

[0107] 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 disclosure. 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.

[0108] 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 disclosure.

[0109] 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 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 may have a configured UL CC and one of them, named PSCell (or PCell of SCG, or sometimes called PCell), may be 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 may be stopped, and a MeNB may be informed by the UE of a SCG failure type. For split bearer, the DL data transfer over the MeNB may be maintained. The RLC AM bearer may be configured for the split bearer. Like a PCell, a PSCell may not be de-activated. A PSCell may be changed with a SCG change (for example, with a 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 may be supported.

[0110] 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, (for example, 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 RRC containers (inter-node messages) carried in X2 messages. The SeNB may initiate a reconfiguration of its existing serving cells (for example, a 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, (for example, for the purpose of DRX alignment and identification of a measurement gap). In an example, when adding a new SCG SCell, dedicated RRC signaling 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.

[0111] 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

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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.

[0112] FIG. **8** shows example TAG configurations as per an aspect of an embodiment of the present disclosure. In Example 1, pTAG comprises a PCell, and an sTAG comprises SCell**1**. In Example 2, a pTAG comprises a PCell and SCell**1**, and an sTAG comprises SCell**2** and SCell**3**. In Example 3, pTAG comprises PCell and SCell**1**, and an sTAG**1** includes SCell**2** and SCell**3**, and sTAG**2** comprises SCell**4**. 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.

[0113] 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).

[0114] 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. An eNB transmits an activation command **600** to activate an SCell. A preamble **602** (Msg**1**) 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 **1**A. Msg**2** 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.

[0115] According to an embodiment, 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.

[0116] 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 various aspects of an embodiment, 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.

[0117] The purpose of an RRC connection reconfiguration procedure may be to modify an RRC connection, (for example, 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.

[0118] In LTE Release-10 and Release-11 CA, a PUCCH may only be 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.

[0119] 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.

[0120] 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

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Random Access Response message for a serving cell belonging to a TAG and/or if 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.

[0121] 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.

[0122] Example embodiments of the disclosure 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.

[0123] 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 may require not only high capacity in the network, but also provisioning very high data rates to meet customers' expectations on interactivity and responsiveness. More spectrum may therefore be needed for cellular operators to meet the increasing demand. Considering user expectations of high data rates along with seamless mobility, it may be beneficial that more spectrum be made available for deploying macro cells as well as small cells for cellular systems.

[0124] 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, may be an effective complement to licensed spectrum for cellular operators to help addressing the traffic explosion in some scenarios, such as hotspot areas. LAA may offer 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.

[0125] 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 may utilize 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.

[0126] 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, and/or the like.

[0127] In an example embodiment, a 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.

[0128] An LBT procedure may be employed for fair and friendly coexistence of LAA with other operators and technologies operating in an unlicensed spectrum. LBT procedures on a node attempting to transmit on a carrier in an unlicensed spectrum may 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, for example, in Europe, may 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. For example, LAA may employ a mechanism to adaptively lower the energy detection threshold from an upper bound. Adaptation mechanism(s) may not preclude static or semi-static setting of the threshold. In an example a Category 4 LBT mechanism or other type of LBT mechanisms may be implemented.

[0129] 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 (for example, 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 (for example, LBT with random back-

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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 (for example, 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 the contention window may be specified by a 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 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.

[0130] LAA may employ uplink LBT at the UE. The UL LBT scheme may be different from the DL LBT scheme (for example, by using different LBT mechanisms or parameters), since the LAA UL may be 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.

[0131] 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. A 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, a UL transmission burst may be defined from a UE perspective. In an example, a 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.

[0132] In an example embodiment, in an unlicensed cell, a downlink burst may be started in a subframe. When an eNB accesses the channel, the eNB may transmit for a duration of one or more subframes. The duration may depend on a maximum configured burst duration in an eNB, the data available for transmission, and/or eNB scheduling algorithm. FIG. **10** shows an example downlink burst in an unlicensed (e.g. licensed assisted access) cell. The maximum configured burst duration in the example embodiment may be configured in the eNB. An eNB may transmit the maximum configured burst duration to a UE employing an RRC configuration message.

[0133] The wireless device may receive from a base station at least one message (for example, an RRC) comprising configuration parameters of a plurality of cells. The plurality of cells may comprise at least one cell of a first type (e.g. license cell) and at least one cell of a second type (e.g. unlicensed cell, an LAA cell). The configuration parameters of a cell may, for example, comprise configuration parameters for physical channels, (for example, a ePDCCH, PDSCH, PUSCH, PUCCH and/or the like). The wireless device may determine transmission powers for one or more uplink channels. The wireless device may transmit uplink signals via at least one uplink channel based on the determined transmission powers.

[0134] In an example embodiment, LTE transmission time may include frames, and a frame may include many subframes. The size of various time domain fields in the time domain may be expressed as a number of time units $T_s=1/(15000\times2048)$ seconds. Downlink, uplink and sidelink transmissions may be organized into radio frames with $T_f=307200\times T_s=10$ ms duration.

In an example LTE implementation, at least three radio frame structures may be supported: Type 1, applicable to FDD, Type 2, applicable to TDD, Type 3, applicable to LAA secondary cell operation. LAA secondary cell operation applies to frame structure type 3.

[0135] Transmissions in multiple cells may be aggregated where one or more secondary cells may be used in addition to the primary cell. In case of multi-cell aggregation, different frame structures may be used in the different serving cells.

[0136] Frame structure type 1 may be applicable to both full duplex and half duplex FDD. A radio frame is $T_f=207200\cdot T_s=10$ ms long and may comprise 20 slots of length $T_{slot}=15360\cdot T_s=0.5$ ms, numbered from 0 to 19. A subframe may include two consecutive slots where subframe i comprises of slots $2i$ and $2i+1$.

[0137] For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in a 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE may not transmit and receive at the same time while there may not be such restrictions in full-duplex FDD.

[0138] Frame structure type 2 may be applicable to TDD. A radio frame of length $T_f=307200\cdot T_s=10$ ms may comprise of two half-frames of length $153600\cdot T_s=5$ ms. A half-frame may comprise five subframes of length $30720\cdot T_s=1$ ms. A subframe i may comprise two slots, $2i$ and $2i+1$, of length $T_{slot}=15360\cdot T_s=0.5$ ms.

[0139] The uplink-downlink configuration in a cell may vary between frames and controls in which subframes uplink or downlink transmissions may take place in the current frame. The uplink-downlink configuration in the current frame is obtained via control signaling.

[0140] An example subframe in a radio frame, "may be a downlink subframe reserved for downlink transmissions, may be an uplink subframe reserved for uplink transmissions or may be a special subframe with the three fields DwPTS, GP and UpPTS. The length of DwPTS and UpPTS are subject to the total length of DwPTS, GP and UpPTS being equal to $30720\cdot T=1$ ms.

[0141] Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity may be supported. In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe may exist in both half-frames. In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe may exist in the first half-frame.

[0142] Subframes **0** and **5** and DwPTS may be reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe may be reserved for uplink transmission.

[0143] In an example, in case multiple cells are aggregated, the UE may assume that the guard period of the special subframe in the cells using frame structure Type 2 have an overlap of at least $1456 \cdot T_s$.

[0144] In an example, in case multiple cells with different uplink-downlink configurations in the current radio frame are aggregated and the UE is not capable of simultaneous reception and transmission in the aggregated cells, the following constraints may apply. if the subframe in the primary cell is a downlink subframe, the UE may not transmit any signal or channel on a secondary cell in the same subframe. If the subframe in the primary cell is an uplink subframe, the UE may not be expected to receive any downlink transmissions on a secondary cell in the same subframe. If the subframe in the primary cell is a special subframe and the same subframe in a secondary cell is a downlink subframe, the UE may not be expected to receive PDSCH/EPDCCH/PMCH/PRS transmissions in the secondary cell in the same subframe, and the UE may not be expected to receive any other signals on the secondary cell in OFDM symbols that overlaps with the guard period or UpPTS in the primary cell.

[0145] Frame structure type 3 may be applicable to LAA secondary cell operation with normal cyclic prefix. A radio frame is $T_f = 307200 \cdot T_s = 10$ ms long and comprises of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms, numbered from 0 to 19. A subframe may comprise as two consecutive slots where subframe i comprises slots $2i$ and $2i+1$.

[0146] The 10 subframes within a radio frame are available for downlink transmissions. Downlink transmissions occupy one or more consecutive subframes, starting anywhere within a subframe and ending with the last subframe either fully occupied or following one of the DwPTS durations. Subframes may be available for uplink transmission when LAA uplink is supported.

[0147] The scheduling request (SR) is used for requesting UL-SCH resources for new transmission(s). In DC, scheduling request (SR) may be directly transmitted from UE to SeNB via PSCell. This may reduce scheduling delay and related signaling load.

[0148] In an example embodiment, an eNB may transmit to a wireless device one or more message comprising configuration parameters of a plurality of cells comprising a plurality of cell groups. The plurality of cell groups may comprise a first cell group for communication via the first base station (e.g. MeNB) and a second cell group for communication via a second base station (e.g. SeNB). The second cell group may comprise a licensed assisted access (LAA) cell with a physical uplink control channel (PUCCH). In an example, an LAA may be called unlicensed cells or some other names. In an example, an eNB may communicate to a wireless device via LAA cells. In an example embodiment, a UE may be configured with PUCCH on an LAA cell of an SeNB. In an example embodiment, operation employing stand-alone unlicensed cells may be supported. In an example embodiment, DC operation employing an MeNB including licensed cells and/or unlicensed cells, and an SeNB including LAA cells (e.g. only LAA cells) may be supported. Example embodiments provide SR procedures on an LAA cell. SR signal transmission may be subject to LBT. There is a need to enhance existing SR procedures to support SR procedure on an LAA cell.

[0149] When PUCCH groups are configured, SR resources may be configured on PCell, PUCCH SCell, or both. The possibility to have SR resources in PUCCH SCell(s) may allow improved distribution of SR load among the serving cells. In an example configuration, an SR for a UE may be transmitted on a serving cell, e.g. either on the PCell or on a given PUCCH SCell. In some scenarios, there may be more capacity available on the SCell, and this may be a reason to allocate more SR resources on an PUCCH SCell. If PUCCH on an SCell carries SR signals, the chance of a UE initiated RA on the PCell due to a scheduling request may be reduced and signalling overhead and RACH resource usage may be reduced.

[0150] An SR load may be shared among PUCCH SCell and PCell. SR resources may be configured on PUCCH SCell. Whether to configure SR resources on PCell, on the PUCCH SCell, or on both PCell and the PUCCH SCell may be up to eNB and/or UE implementation. SR resources may be configured on both PCell and PUCCH SCell. An SR counter may be increased when SR is sent on either PUCCH SCell or PCell and sr-ProhibitTimer may be implemented to control the timing of SR transmission. An SR process may employ SR resources on both PCell and PUCCH SCell.

[0151] In an example embodiment, SR resources may be configured by one or more information elements in an RRC message. For example, SchedulingRequestConfig IE may be employed for configuration of PUCCH resources on the PCell, PSCell and/or on a PUCCH SCell. The SchedulingRequestConfig IE may be used to specify some of the scheduling request related parameters. The SchedulingRequestConfig IE may be included in a dedicated physical layer configuration IE of a UE configuration.

[0152] The SchedulingRequestConfig IE may comprise an information element to set up or release scheduling resources and other parameters. SchedulingRequestConfig IE may comprise PUCCH resource Index (sr-ConfigIndex), SR configuration index (sr-ConfigIndex), and SR maximum transmission (dsr-TransMax) IEs. At least one RRC message may include a first SchedulingRequestConfig IE for configuration of SR resources on PCell, and a second SchedulingRequestConfig IE for configuration of SR resources on PUCCH SCell. sr-ConfigIndex may be defined and sr-PUCCH-ResourceIndex (e.g. sr-PUCCH-ResourceIndex, sr-PUCCH-ResourceIndexP**1**) may be defined according to 3GPP TS 36.213 v.14 specifications. E-UTRAN may configure sr-PUCCH-ResourceIndexP**1** if sr-PUCCHResourceIndex is configured. FIG. **11** shows examples of SR resource periodicity and SR subframe offset corresponding to different SR configuration indexes.

[0153] When a PUCCH SCell is configured, SchedulingRequestConfigSCell may comprise: sr-PUCCH-ResourceIndex, sr-PUCCH-ResourceIndexP**1**, sr-ConfigIndex, and/or dsr-TransMax for configuration of SR resources on the PUCCH.

[0154] A UE may be configured by higher layers to transmit the SR on one antenna port or two antenna ports of the selected SCell. The scheduling request may be transmitted on the PUCCH resource(s) $n_{PUCCH}^{(1,\tilde{p})} = n_{PUCCH,SRI}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port p, where $n_{PUCCH,SRI}^{(1,\tilde{p})}$ may be configured by higher layers unless the SR coincides in time with the transmission of HARQ-ACK using PUCCH Format 3 in which case the SR may be multiplexed with HARQ-ACK. The SR configuration for SR transmission periodicity $SR_{PERIODICITY}$ and SR subframe offset $N_{OFFSET,SR}$

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$_{SR}$ may be defined by the parameter sr-ConfigIndex I_{SR} given by higher layers. SR transmission instances are the uplink subframes satisfying $(10\times n_f+\lfloor n_s/2\rfloor-N_{OFFSET,SR}) \bmod SR_{PERIODICITY}=0$.

[0155] When an SR is triggered, it may be considered as pending until it is cancelled. Pending SR(s) may be cancelled and sr-ProhibitTimer may be stopped when a MAC PDU is assembled and this PDU includes a BSR which contains buffer status up to (and including) the last event that triggered a BSR, or, if pending SR(s) are triggered by Sidelink BSR, when a MAC PDU is assembled and this PDU includes a Sidelink BSR which contains buffer status up to (and including) the last event that triggered a Sidelink BSR, or, if pending SR(s) are triggered by Sidelink BSR, when upper layers configure autonomous resource selection, or when the UL grant(s) can accommodate pending data available for transmission.

[0156] If an SR is triggered and there is no other SR pending, the MAC entity may set the SR counter to 0.

[0157] As long as one SR is pending, the MAC entity may for a TTI: if no UL-SCH resources are available for a transmission in this TTI perform the following tasks.

[0158] If the MAC entity has no valid PUCCH resource for SR configured in any TTI: the UE (e.g. MAC entity) may initiate a Random Access procedure on the SpCell and cancel pending SRs.

[0159] If the MAC entity has valid PUCCH resource for SR and if the MAC entity has at least one valid PUCCH resource for SR configured for this TTI and if this TTI is not part of a measurement gap or Sidelink Discovery Gap for Transmission and if sr-ProhibitTimer is not running, the following actions may be performed.

[0160] If a counter (e.g. SR counter)<a maximum value (e.g. dsr-TransMax): the MAC entity may instruct the physical layer to signal the SR on one valid resource for SR. In an example embodiment, the physical layer may perform LBT for SR transmission. In an example embodiment, the LBT process may succeed or fail. If LBT process for SR procedure succeeds, the PHY layer may signal the SR on one valid resource for SR. If LBT process for SR procedure fails, the PHY layer may not signal the SR on one valid resource for SR. The PHY layer may inform the MAC entity about the result of the LBT process. For example, the PHY layer may inform the MAC entity that the LBT process for transmitting SR failed.

[0161] In an example embodiment, the MAC entity may increment an SR Counter by one regardless of the result of the LBT process. The MAC entity may start the sr-prohibitTimer if no LBT failure is indicated by the physical layer. In an example embodiment, if LBT failure is indicated by the PHY layer, the MAC entity may not restart the sr-prohibitTimer. When the SR counter reaches a maximum value (e.g. SR counter>=dsr-TransMax), the SR process may be unsuccessfully completed.

[0162] In an example embodiment, a counter, for example SR_LBT counter (or may be called by any other names, e.g. SR_attempt counter, etc) may be introduced. The MAC entity may increment an SR_LBT counter by 1 regardless of the result of the LBT process. The MAC entity may start the sr-prohibitTimer if no LBT failure is indicated by the physical layer. In an example embodiment, if LBT failure is indicated by the PHY layer, the MAC entity may not restart the sr-prohibitTimer. The MAC entity may increment an SR__ Counter by 1 and start the SR-prohibitTimer when LBT process succeeds. When the SR counter reaches dsr-TransMax (SR counter>=dsr-TransMax), the SR process may be unsuccessfully completed. In an example, when the SR_LBT counter reaches SR_LBT counter_MAX (SR_LBT counter=SR_LBT counter_MAX), the SR process may be unsuccessfully completed. In an example embodiment, SR_LBT counter_MAX may have the same value as dsr-TransMax and/or may be configured by the same RRC IE. In an example, an RRC message configuring the LAA cell and/or SR configuration parameters may comprise one or more IEs comprising a parameter indicating the value of SR_LBT counter_MAX.

[0163] In an example embodiment, a counter, for example SR_LBT counter (or may be called by any other names, e.g. SR_attempt counter, etc) may be introduced. The MAC entity may increment an SR_LBT counter by 1 when MAC instructs PHY to signal SR and PHY performs LBT to transmit the SR (regardless of whether LBT is successful or not). The MAC entity may start the sr-prohibitTimer if no LBT failure is indicated by the physical layer. In an example embodiment, if LBT failure is indicated by the PHY layer, the MAC entity may not restart the sr-prohibitTimer. The MAC entity may increment an SR counter by 1 and start the SR prohibitTimer when LBT process succeeds. When the SR COUNTER reaches dsr-TransMax (e.g. SR counter>=dsr-TransMax), the SR process may be unsuccessfully completed. In an example, when the SR_LBT counter reaches SR_LBT counter_MAX (SR_LBT counter=SR_LBT counter_MAX), the SR process may be unsuccessfully completed. In an example embodiment, SR_LBT counter_MAX may have the same value as dsr-TransMax and/or may be configured by the same RRC IE. In an example, an RRC message configuring the LAA cell and/or SR configuration parameters may comprise an IE comprising a parameter indicating the value of SR_LBT counter_MAX.

[0164] FIG. **12** shows an example embodiment, wherein SR_prohibit_Timer is restarted when LBT process for SR succeeds and SR is transmitted. In an example, when LBT process fails, the SR_prohibit_timer may not be restarted. When the SR counter and/or SR_LBT counter reaches a maximum value, the SR process may be unsuccessfully completed.

[0165] In an example embodiment, SR_LBT counter is introduced, SR_LBT counter may be set to zero or 1 (depending on the implementation), at a beginning of an SR process. SR_LBT counter may be set to zero or 1 (depending on the implementation) when sr-ProhibitTimer is restarted/started.

[0166] In response to determination that SR_LBT counter reaches a maximum value (e.g. configured by RRC), the UE may perform a procedure related to reaching the maximum value.

[0167] In an example, when SR_LBT counter reaches a maximum value, the UE may perform one or more of the following tasks: start the sr-ProhibitTimer, increment SR counter by 1; and/or set SR_LBT counter to zero (or one).

[0168] In an example, when SR_LBT counter reaches a maximum value, the UE may perform one or more of the following tasks: start an sr-ProhibitTimer_LBT, increment SR counter_LBT by 1; and/or set SR_LBT counter to zero (or one). The parameters sr-ProhibitTimer_LBT and/or SR counter_LBT may be introduced to count set of one or more LBTs for SR transmission. The timer sr-ProhibitTimer_LBT may act like a back off timer when the channel is busy, and

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SR counter_LBT may count such event. The UE may start LBT in response to sr-ProhibitTimer_LBT expiring. The UE may trigger an action when SR counter_LBT reaches a maximum value, for example may terminate the SR process.

[0169] In an example, values of sr-ProhibitTimer_LBT, increment SR counter_LBT may be configured by one or more RRC parameters in an RRC message.

[0170] In an example embodiment, SR_LBT counter is configured, SR_LBT counter may be set to zero or 1 (depending on the implementation), at beginning of an SR process. The SR_LBT counter may not be reset as long as the SR process is pending.

[0171] In an example, in response to determination that SR_LBT counter reaches a maximum value (e.g. configured by an RRC IE in an RRC message), a UE may perform a procedure related to reaching the maximum value, e.g. the UE may unsuccessfully terminate the SR procedure.

[0172] In an example, an SR_Timer_MAX may be configured by an RRC parameter. An RRC message may comprise an IE indicating the maximum value of the SR_Timer_Max. This parameter may for example indicate a duration for an SR period.

[0173] In an example, the MAC entity may start/restart an SR_Timer_MAX when the SR procedure is started, e.g. when the UE transmitted the first SR signal, attempted LBT to transmit the first SR signal, and/or when SR process is triggered.

[0174] In response to determination that SR_Timer_MAX expires, the MAC entity may perform one or more action related to SR_Timer_MAX expires.

[0175] In an example embodiment, when SR_LBT counter_MAX and/or SR_Timer_MAX reaches a maximum value, the UE may terminate the SR procedure and start a random access procedure.

[0176] In an example embodiment, when SR process is terminated because SR counter reaches a maximum value, the UE may perform at least one of the following: notify RRC to release PUCCH for serving cells, notify RRC to release SRS for serving cells, clear any configured downlink assignments and uplink grants, and/or initiate a Random Access procedure on the SpCell and cancel all pending SRs.

[0177] In an example embodiment, when SR process is terminated because SR_LBT counter or SR_Timer_MAC timer reaches a maximum value, and/or UE determines that SR procedure is terminated because of LBT failures, the UE may perform at least one of the following: clear any configured downlink assignments and uplink grants, and/or initiate a random access procedure on the SpCell and cancel all pending SRs.

[0178] In an example, the UE may not notify RRC to release PUCCH for serving cells and may not notify RRC to release SRS for all serving cells.

[0179] FIG. **13** shows an example when UE initiates a random access procedure when SR process is unsuccessfully terminated.

[0180] In an example embodiment, when SR_LBT counter_MAX and/or SR_Timer_MAX reaches a maximum value, the UE may terminate the SR procedure and start a random access procedure.

[0181] In an example embodiment, when SR process is terminated because SR counter reaches a maximum value, the UE may perform at least one of the following: notify RRC to release PUCCH for serving cells, notify RRC to release SRS for serving cells, clear any configured downlink assignments and uplink grants, and/or initiate a random access procedure on the SpCell and cancel pending SRs.

[0182] In an example embodiment, when SR process is terminated because SR_LBT counter or SR_Timer_MAC timer reaches a maximum value, and/or UE determines that SR procedure is terminated because of LBT failures, the UE may perform at least one of the following: clear any configured downlink assignments and uplink grants and/or cancel pending SRs.

[0183] In an example, the UE may not notify RRC to release PUCCH for serving cells may not notify RRC to release SRS for all serving cells, and/or may not initiate a Random Access procedure on the SpCell.

[0184] FIG. **14** is an example of SCG failure notification procedure. The eNB may transmit to the UE one or more RRC messages comprising configuration of a plurality of cell groups comprising a primary cell group and a secondary cell group. This procedure may inform E-UTRAN about an SCG failure that the UE has experienced e.g. SCG radio link failure, SCG change failure. In an example, a UE may initiate the procedure to report SCG failures when SCG transmission is not suspended. In example, the UE may transmit SCG failure information to the MeNB when at least one of the following conditions is met: upon detecting radio link failure for the SCG, upon SCG change failure, upon stopping uplink transmission towards the PSCell due to exceeding the maximum uplink transmission timing difference when powerControlMode is configured to 1, unsuccessful completion of SR process, unsuccessful termination of a random access process, and/or excessive LBT with at least one LAA cell of the SeNB. In an example, upon initiating the procedure, the UE may: suspend SCG DRBs and suspend SCG transmission for split DRBs, reset SCG-MAC, and/or initiate transmission of the SCG Failure Information message.

[0185] In an example, if the UE initiates transmission of the SCG Failure Information message to provide SCG radio link failure or other radio link issues: the UE may include a failureType parameter in the message. The failure type may comprise one or more parameters indicating failure type, and one more parameters including statistical information about the failure, e.g. the number of LBT failure, the failure duration, one or more counters related to radio link parameters (e.g. LBT counters, transmission counters, etc.).

[0186] In an example, the MeNB may transmit a message to an SeNB to indicate one or more failure information, and/or updated configuration parameters for one or more cells of the SeNB. In an example, the SeNB may transmit a response message to MeNB comprising or confirming one or more configuration parameters. In an example, the MeNB may transmit to the UE one or more RRC messages comprising configuration parameters of one or more cells of the SCG. The UE may communicate with the SeNB via one or more cells with updated configuration parameters.

[0187] In response to unsuccessful termination of an SR process because of excessive LBT (e.g. SR_LBT counter reaches a first value), the UE may transmit an RRC message to the MeNB indicating that LBT process is failed. In an example, the RRC message may indicate that an SR procedure in SeNB failed, e.g., due to successive LBT failures. In an example, the UE may send the value of one or more counters and timers of the SR process (e.g. SR counter, and/or SR_LBT counter) or an indication as a function of

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these parameters to the MeNB. The RRC message may be SCG Failure Information message transmitted by the UE to an MeNB.

[0188] FIG. **15** shows an example, in which the UE sends an RRC message to the MeNB indicating failure in an SR procedure, and/or failure in successive LBTs. In an example, the MeNB may start a SCG configuration change in response to this message. The MeNB may transmit a message to SeNB to reconfigure SCG as described in the specification. The MeNB may transmit to the UE at least one RRC message to reconfigure SCG.

[0189] In an example embodiment, the UE may successfully transmit an SR signal to an eNB, but the eNB may not be able to transmit an uplink grant, since LBT in the eNB fails. In an example, the UE may transmit one or more SR signals to the eNB, and may not receive an uplink grant. In an example, the UE may not be aware that the eNB is not receiving an uplink grant because SR is not successfully received by the eNB, or the eNB is not able to transmit an uplink grant due to LBT.

[0190] In an example embodiment, when eNB LBT process indicates a busy channel, e.g., for responding to an SR request during a period, or for responding to Preamble Transmission (RAR) for a period, or any other type of downlink transmission for a long period. The SeNB may transmit a message to the MeNB. The message may comprise one or more parameters indicating to the MeNB that SeNB is not able to transmit signals to the UE due to LBT failure. For example, the SeNB may transmit a message to the MeNB requesting SCG configuration change. FIG. **16** shows an example wherein an SeNB receives one or more SR requests from a UE. The SeNB performs one or more LBT processes (for transmission of a response including uplink grant to the UE) to check whether a channel on an LAA cell is clear. In response to one or more LBT failures during a time period, the SeNB may transmit to MeNB a message comprising one or more parameters indicating LBT failure indication to the MeNB. FIG. **17** shows an example wherein SeNB receives one or more preambles from a UE. The SeNB performs one or more LBT processes (for transmission of a RAR including uplink grant to the UE) to check whether a channel on an LAA cell is clear. In response to one or more LBT failures during a time period, the SeNB may transmit to MeNB a message comprising one or more parameters indicating LBT failure indication to the MeNB.

[0191] 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.

[0192] FIG. **18** is an example flow diagram as per an aspect of an embodiment of the present disclosure. At **1810**, at least one first message may be received from a first base station. The at least one first message may comprise at least one first configuration parameter of a plurality of cells comprising a plurality of cell groups comprising: a first cell group for communication via the first base station; and a second cell group for communication via a second base station, the second cell group comprising a licensed assisted access (LAA) cell with a physical uplink control channel (PUCCH). At **1820**, a listen before talk (LBT) procedure for transmission of a scheduling request via the PUCCH of the LAA cell may be performed. At **1830**, a counter may be incremented in response to performing the LBT procedure. At **1840**, a scheduling request process failure may be determined in response to the counter reaching a first value and no uplink grant being received from the second base station. At **1850**, at least one second message may be transmitted to the first base station. The at least one second message may comprise at least one first parameter. The at least one first parameter may indicate the scheduling request process failure corresponding to the second base station. At **1860**, at least one third message may be received from the first base station. The at least one third message may comprise at least one second configuration parameter of one or more cells of the second cell group.

[0193] According to an embodiment, the second message may comprise at least one second parameter indicating the first value. According to an embodiment, the PUCCH may comprise radio resources for scheduling resources. According to an embodiment, the at least one first message may comprise a scheduling configuration index for the LAA cell. According to an embodiment, the at least one first message may comprise at least one third parameter indicating the first value. According to an embodiment, the first base station may transmit to the second base station a fourth message in response to receiving the at least one second message. According to an embodiment, the LBT procedure may indicate that a channel corresponding the LAA cell is busy. According to an embodiment, the counter may indicate a number of LBT procedures performed by the wireless device for transmission of the scheduling request. According to an embodiment, the determining the scheduling request process failure may be in response to the counter reaching the first value and no uplink grant being received from the second base station during a first time period. The at least one first message may comprise a fourth parameter indicating the first time period. According to an embodiment, the at least one first message comprises at least one fifth parameter for the LBT procedure.

[0194] 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: {can}, {cell2}, and {cell1, cell2}.

[0195] 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 param-

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eter 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.

[0196] 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 LabVIEW MathScript. 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.

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[0198] 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 the example(s) using LAA communication systems. However, one skilled in the art will recognize that embodiments of the disclosure may also be implemented in a system comprising one or more TDD cells (e.g. frame structure **2** and/or frame structure **1**). The disclosed methods and systems may be implemented in wireless or wireline systems. The features of various embodiments presented in this disclosure may be combined. One or many features (method or system) of one embodiment may be implemented in other embodiments. Only a limited number of example combinations are shown to indicate to one skilled in the art the possibility of features that may be combined in various embodiments to create enhanced transmission and reception systems and methods.

[0199] 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.

[0200] 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.

[0201] 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.

1. A method comprising:

receiving, by a wireless device from a first base station, at least one first message comprising at least one first configuration parameter of a plurality of cells comprising a plurality of cell groups comprising:

a first cell group for communication via the first base station; and

a second cell group for communication via a second base station, the second cell group comprising a licensed assisted access (LAA) cell with a physical uplink control channel (PUCCH);

performing a listen before talk (LBT) procedure for transmission of a scheduling request via the PUCCH of the LAA cell;

incrementing, by the wireless device, a counter in response to performing the LBT procedure;

determining, by the wireless device, a scheduling request process failure in response to the counter reaching a first value and no uplink grant being received from the second base station;

transmitting, by the wireless device to the first base station, at least one second message comprising at least one first parameter indicating the scheduling request process failure corresponding to the second base station; and

receiving, by the wireless device from the first base station, at least one third message comprising at least one second configuration parameter of one or more cells of the second cell group.

2. The method of claim **1**, wherein the second message comprises at least one second parameter indicating the first value.

3. The method of claim **1**, wherein the PUCCH comprises radio resources for scheduling resources.

4. The method of claim **1**, wherein the at least one first message comprises a scheduling configuration index for the LAA cell.

5. The method of claim **1**, wherein the at least one first message comprises at least one third parameter indicating the first value.

6. The method of claim 1, further comprising transmitting by the first base station to the second base station a fourth message in response to receiving the at least one second message.

7. The method of claim 1, wherein the LBT procedure indicates that a channel corresponding the LAA cell is busy.

8. The method of claim 1, wherein the counter indicates a number of LBT procedures performed by the wireless device for transmission of the scheduling request.

9. The method of claim 1, wherein the determining the scheduling request process failure is in response to the counter reaching the first value and no uplink grant being received from the second base station during a first time period, where the at least one first message comprises a fourth parameter indicating the first time period.

10. The method of claim 1, wherein the at least one first message comprises at least one fifth parameter for the LBT procedure.

11. A wireless device comprising:

one or more processors;

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

receive, from a first base station, at least one first message comprising at least one first configuration parameter of a plurality of cells comprising a plurality of cell groups comprising:

a first cell group for communication via the first base station; and

a second cell group for communication via a second base station, the second cell group comprising a licensed assisted access (LAA) cell with a physical uplink control channel (PUCCH);

performing a listen before talk (LBT) procedure for transmission of a scheduling request via the PUCCH of the LAA cell;

increment a counter in response to performing the LBT procedure;

determine a scheduling request process failure in response to the counter reaching a first value and no uplink grant being received from the second base station;

transmit, to the first base station, at least one second message comprising at least one first parameter indicating the scheduling request process failure corresponding to the second base station; and

receive, from the first base station, at least one third message comprising at least one second configuration parameter of one or more cells of the second cell group.

12. The wireless device of claim 11, wherein the second message comprises at least one second parameter indicating the first value.

13. The wireless device of claim 11, wherein the PUCCH comprises radio resources for scheduling resources.

14. The wireless device of claim 11, wherein the at least one first message comprises a scheduling configuration index for the LAA cell.

15. The wireless device of claim 11, wherein the at least one first message comprises at least one third parameter indicating the first value.

16. The wireless device of claim 11, further comprising transmitting by the first base station to the second base station a fourth message in response to receiving the at least one second message.

17. The wireless device of claim 11, wherein the LBT procedure indicates that a channel corresponding the LAA cell is busy.

18. The wireless device of claim 11, wherein the counter indicates a number of LBT procedures performed by the wireless device for transmission of the scheduling request.

19. The wireless device of claim 11, wherein the determining the scheduling request process failure is in response to the counter reaching the first value and no uplink grant being received from the second base station during a first time period, where the at least one first message comprises a fourth parameter indicating the first time period.

20. The wireless device of claim 11, wherein the at least one first message comprises at least one fifth parameter for the LBT procedure.

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