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(54) **RANDOM ACCESS CHANNEL RESPONSE HANDLING WITH AGGREGATED COMPONENT CARRIERS**

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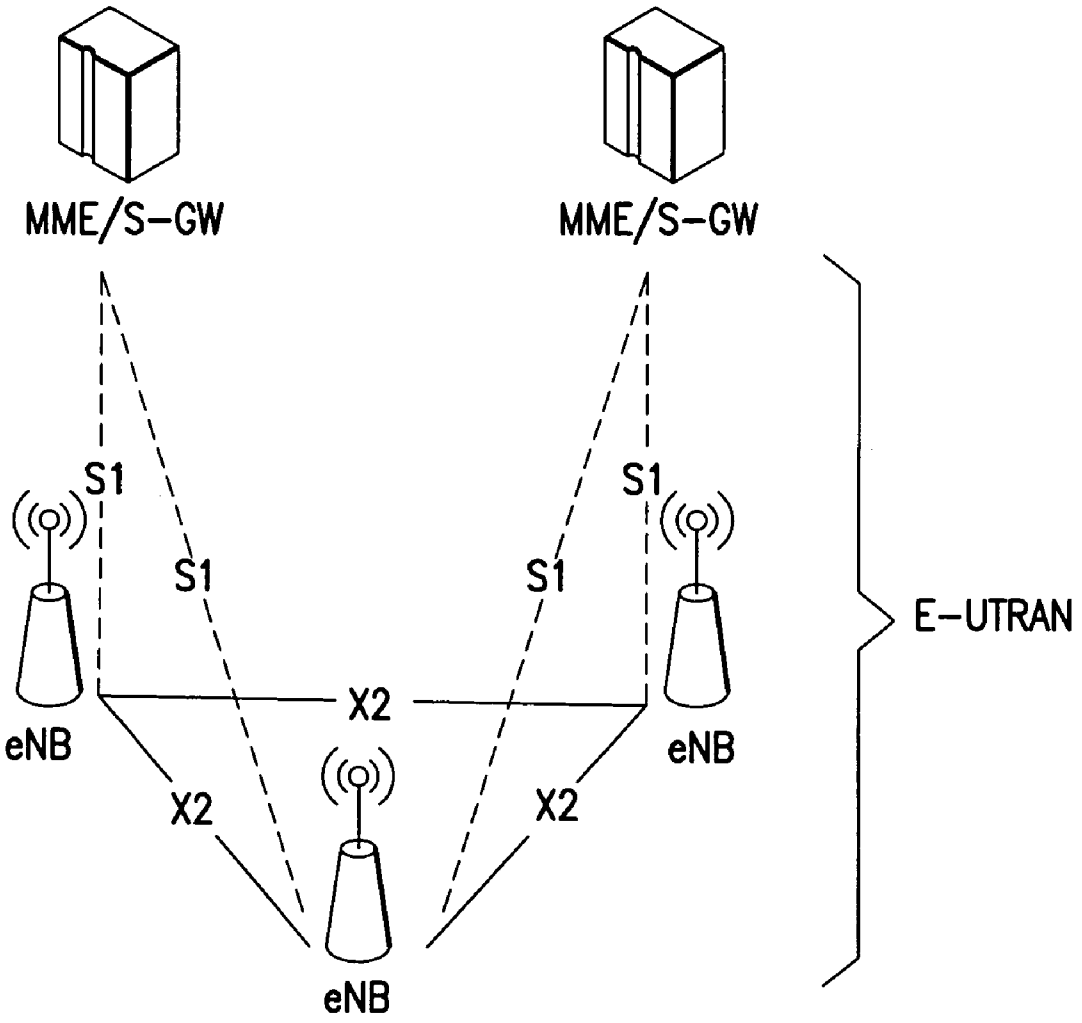
(57) **ABSTRACT**

Disclosed herein are methods, computer program instructions and apparatus for performing random access procedures in a wireless communication system. A method includes receiving at a network access node, in different time and frequency resources that are allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments; and transmitting a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.



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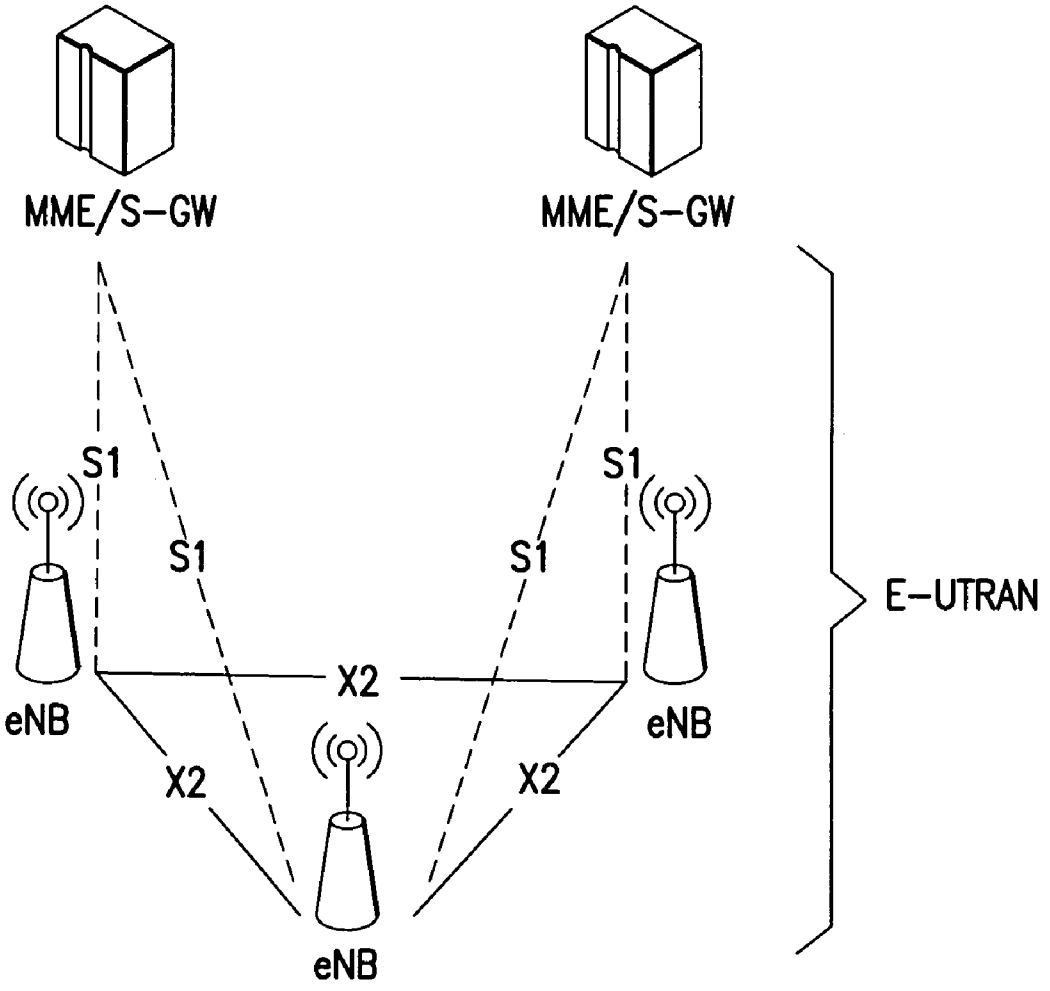

FIG. 1A

UPLINK-DOWNLINK CONFIGURATION	DOWNLINK-TO-UPLINK SWITCH-POINT PERIODICITY	SUBFRAME NUMBER									
		0	1	2	3	4	5	6	7	8	9
0	5ms	D	S	U	U	U	D	S	U	U	U
1	5ms	D	S	U	U	D	D	S	U	U	D
2	5ms	D	S	U	D	D	D	S	U	D	D
3	10ms	D	S	U	U	U	D	D	D	D	D
4	10ms	D	S	U	U	D	D	D	D	D	D
5	10ms	D	S	U	D	D	D	D	D	D	D
6	5ms	D	S	U	U	U	D	S	U	U	D

FIG.1B

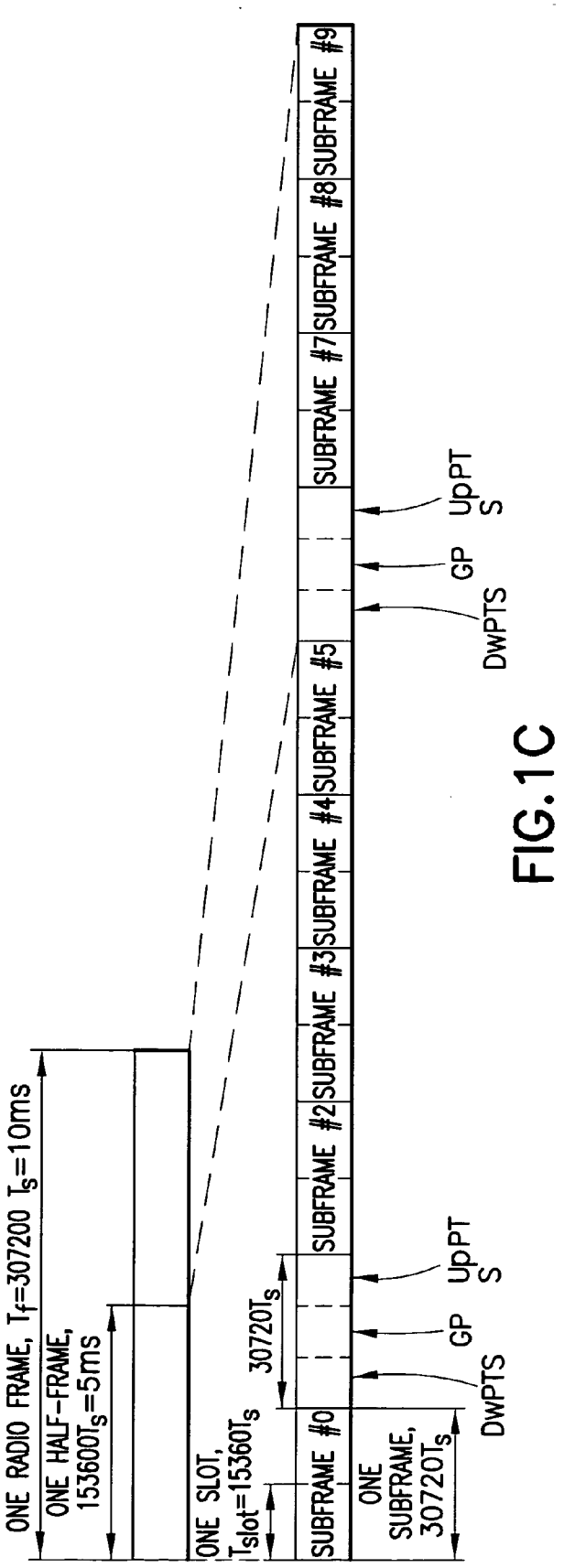

FIG.1C

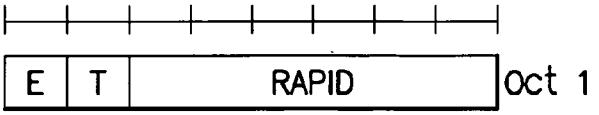

FIG.1D

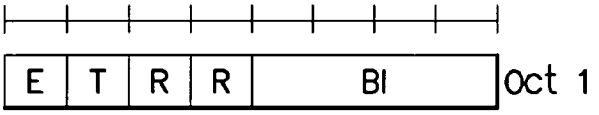

FIG.1E

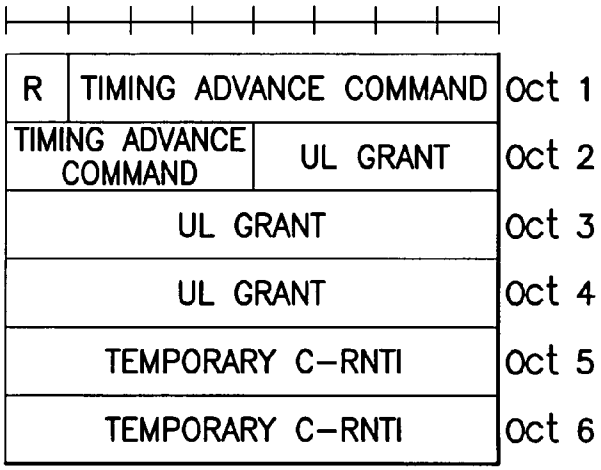

FIG.1F

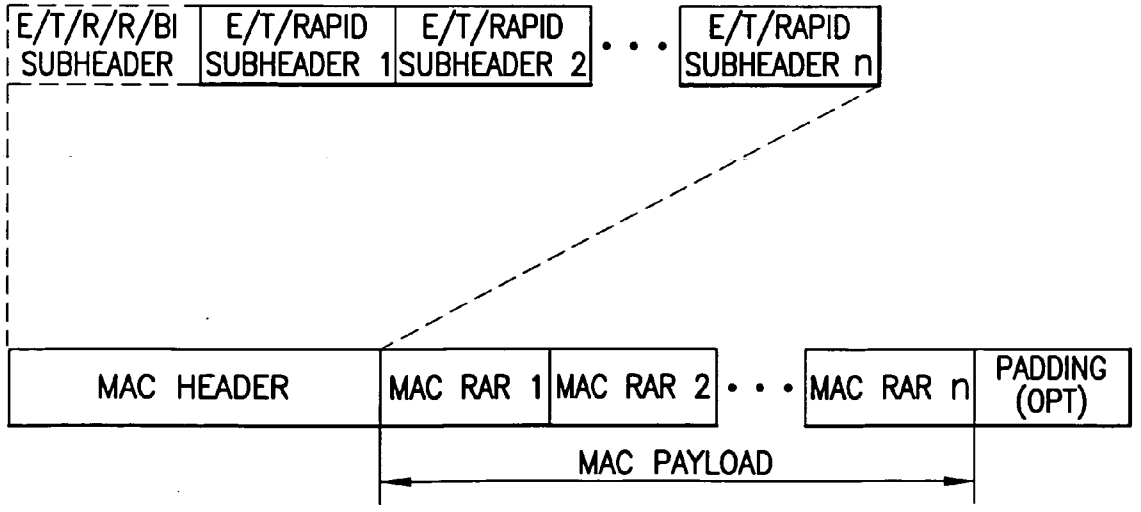

FIG.1G

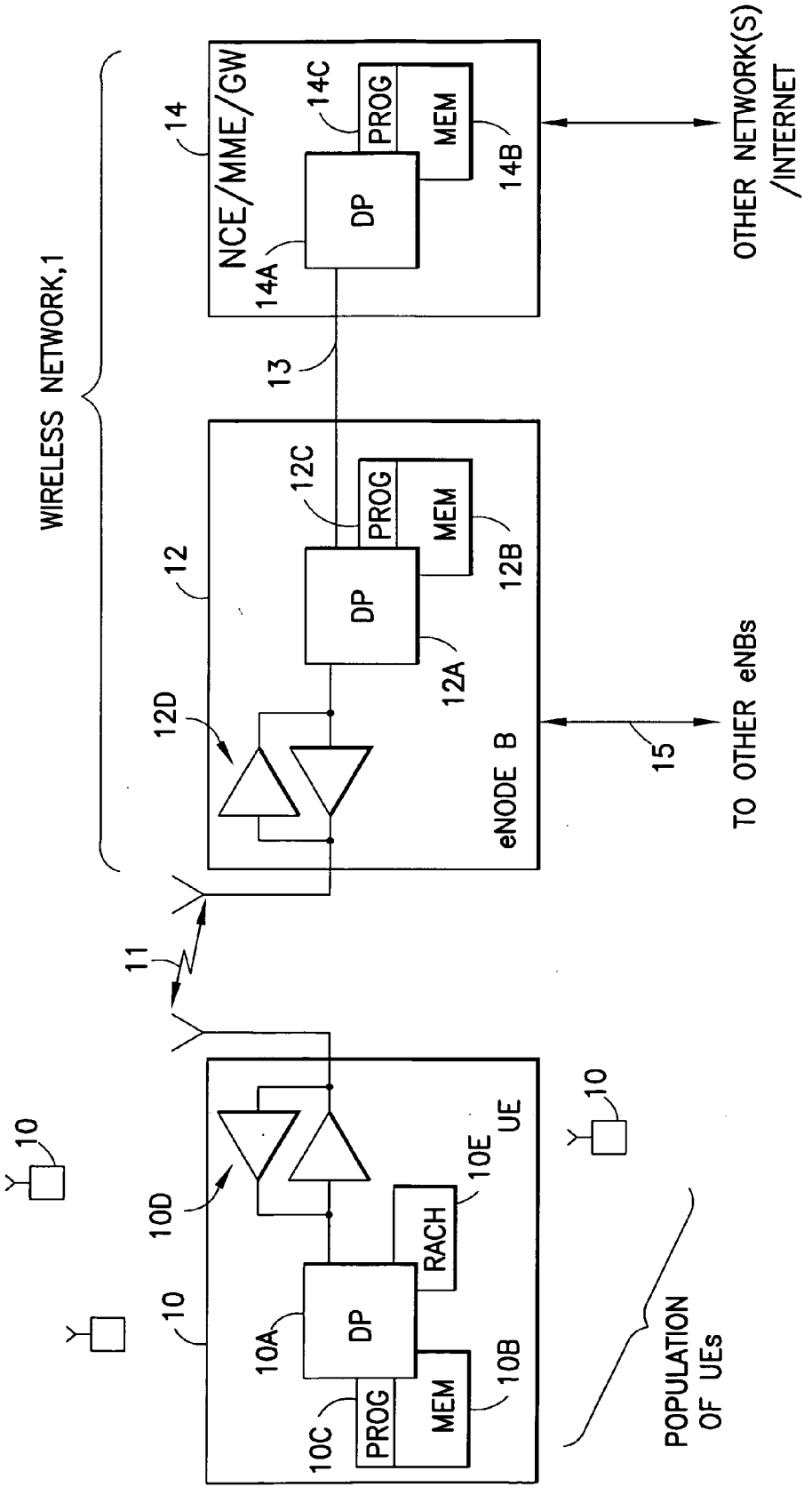
WIRELESS NETWORK,1
NCE/MME/GW
14
14C
PROG
MEM
14B
DP
14A
OTHER NETWORK(S)
/INTERNET
13
12
12C
PROG
MEM
12B
DP
12A
12D
eNODE B
15
TO OTHER eNBs
11
10
10D
10E
UE
RACH
10A
DP
10C
PROG
MEM
10B
POPULATION
OF UEs

FIG.2A

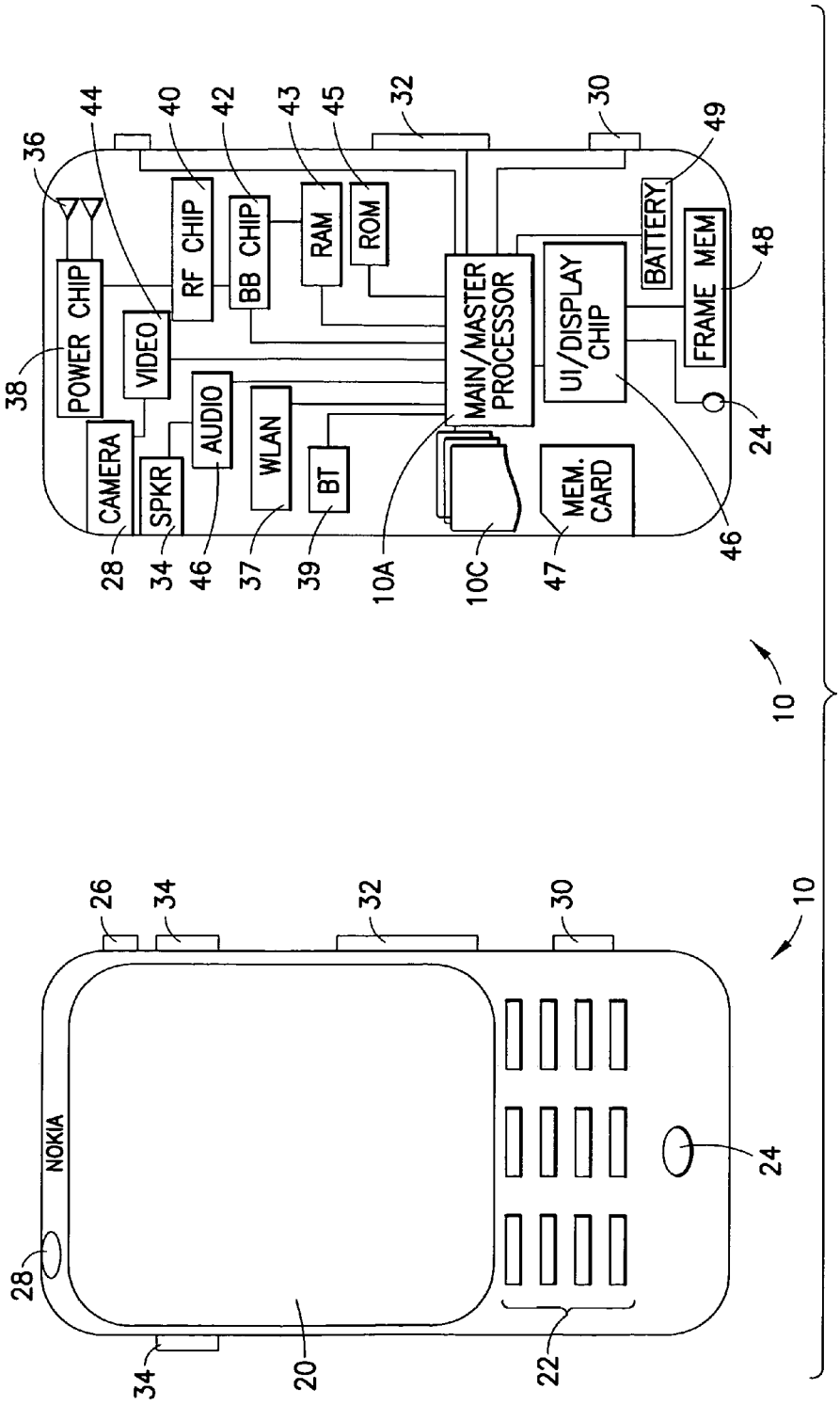
36
44
40
42
43
45
32
30
49
RF CHIP
BB CHIP
RAM
ROM
BATTERY
FRAME MEM
48
POWER CHIP
VIDEO
MAIN/MASTER PROCESSOR
UI/DISPLAY CHIP
38
AUDIO
WLAN
BT
24
CAMERA
SPKR
MEM. CARD
28
34
46
37
39
10A
10C
47
46
10
26
34
32
30
10
NOKIA
28
24
34
20
22

FIG.2B

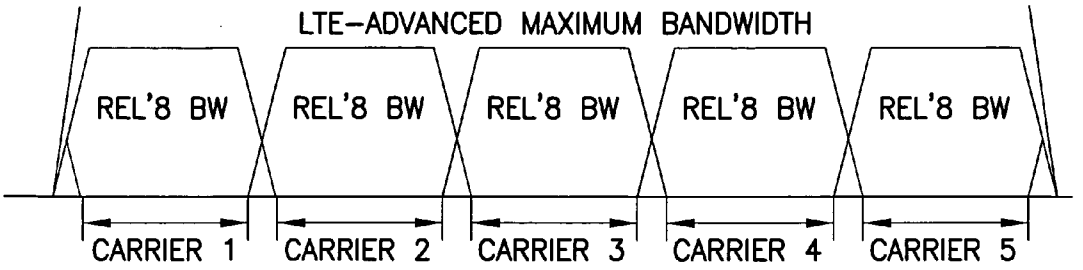

FIG.3

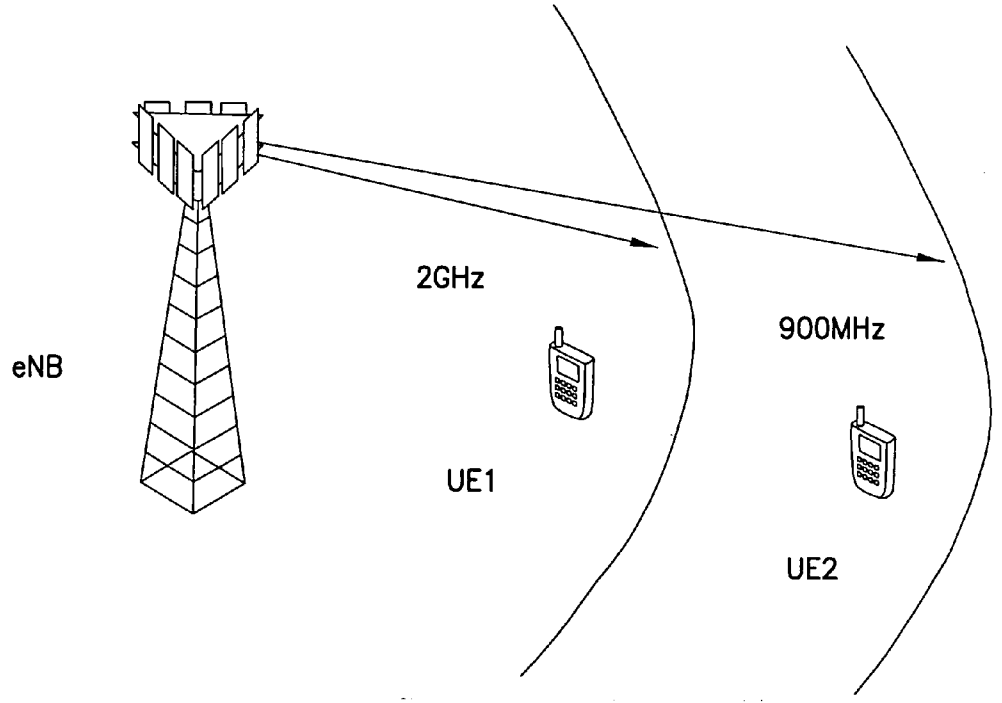

FIG.4

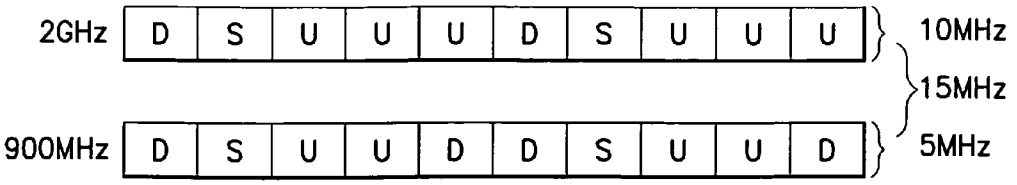

FIG.5

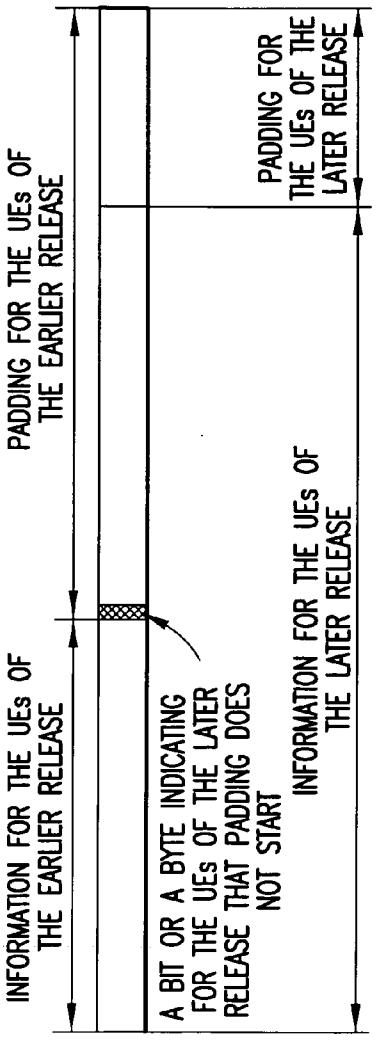
INFORMATION FOR THE UEs OF THE EARLIER RELEASE
A BIT OR A BYTE INDICATING FOR THE UEs OF THE LATER RELEASE THAT PADDING DOES NOT START
PADDING FOR THE UEs OF THE EARLIER RELEASE
INFORMATION FOR THE UEs OF THE LATER RELEASE
PADDING FOR THE UEs OF THE LATER RELEASE

FIG.6

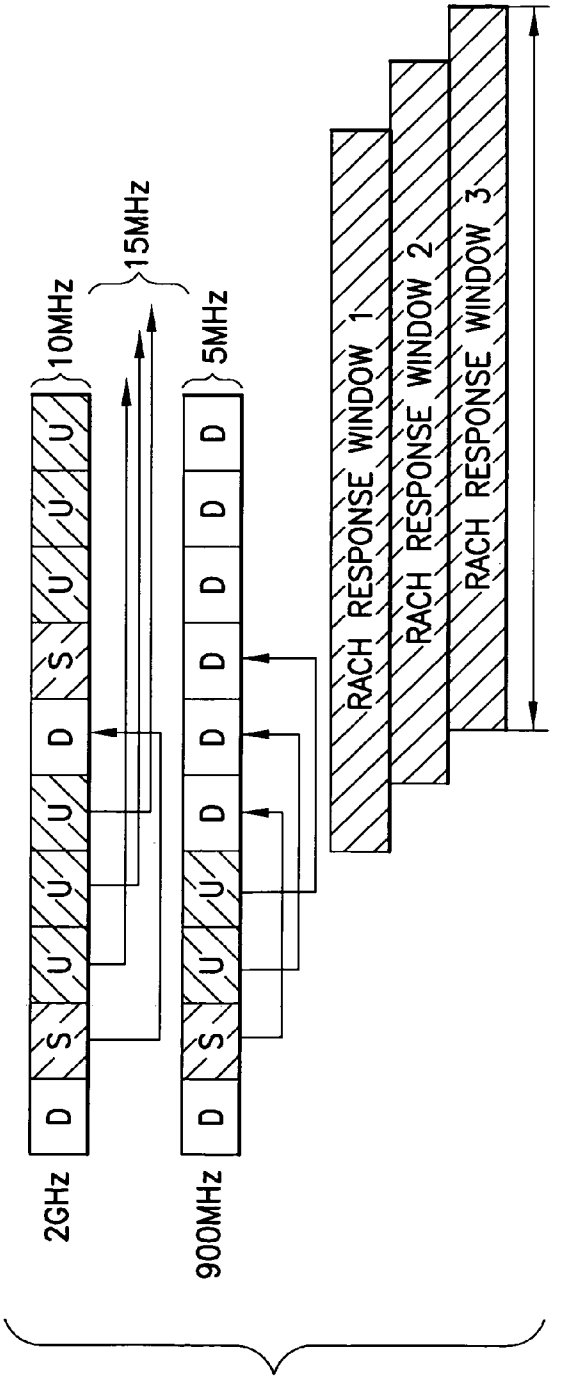
2GHz
900MHz
10MHz
5MHz
15MHz
RACH RESPONSE WINDOW 1
RACH RESPONSE WINDOW 2
RACH RESPONSE WINDOW 3

FIG.7

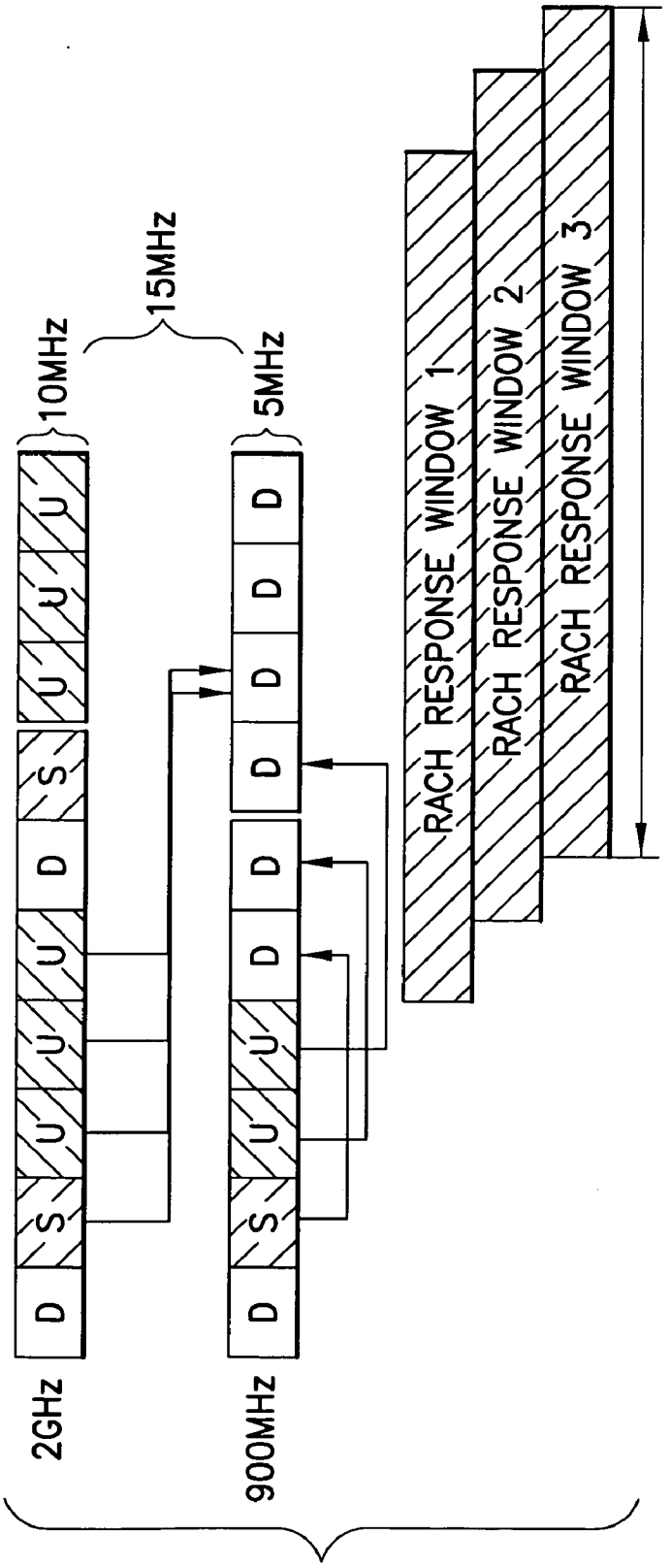
10MHz
15MHz
5MHz
RACH RESPONSE WINDOW 1
RACH RESPONSE WINDOW 2
RACH RESPONSE WINDOW 3
2GHz
900MHz
D
S
U

FIG.8

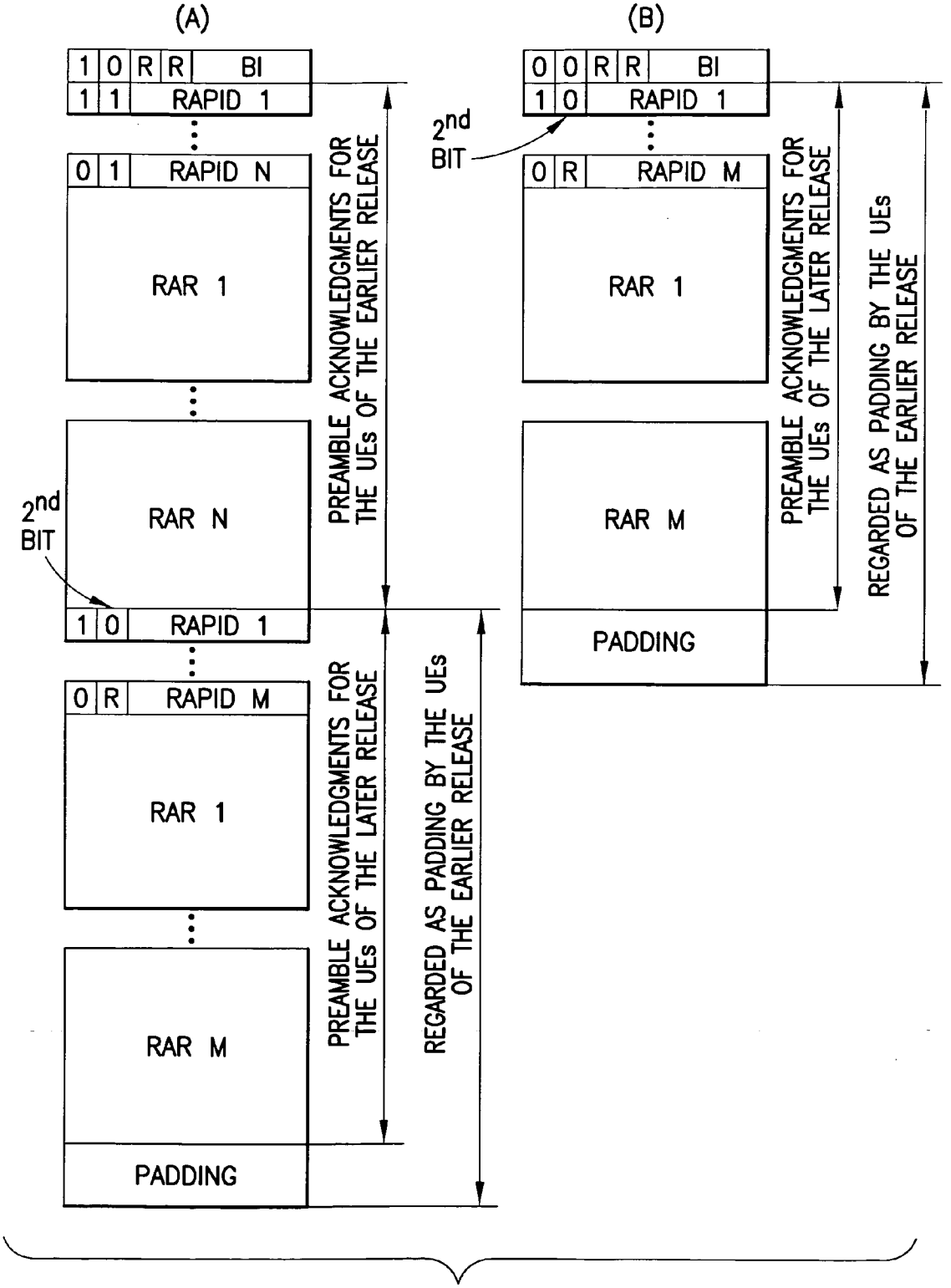
(A)
1 0 R R BI
1 1 RAPID 1
0 1 RAPID N
RAR 1
RAR N
2nd BIT
1 0 RAPID 1
0 R RAPID M
RAR 1
RAR M
PADDING
PREAMBLE ACKNOWLEDGMENTS FOR THE UEs OF THE EARLIER RELEASE
PREAMBLE ACKNOWLEDGMENTS FOR THE UEs OF THE LATER RELEASE
REGARDED AS PADDING BY THE UEs OF THE EARLIER RELEASE
(B)
0 0 R R BI
1 0 RAPID 1
2nd BIT
0 R RAPID M
RAR 1
RAR M
PADDING
PREAMBLE ACKNOWLEDGMENTS FOR THE UEs OF THE LATER RELEASE
REGARDED AS PADDING BY THE UEs OF THE EARLIER RELEASE

FIG.9

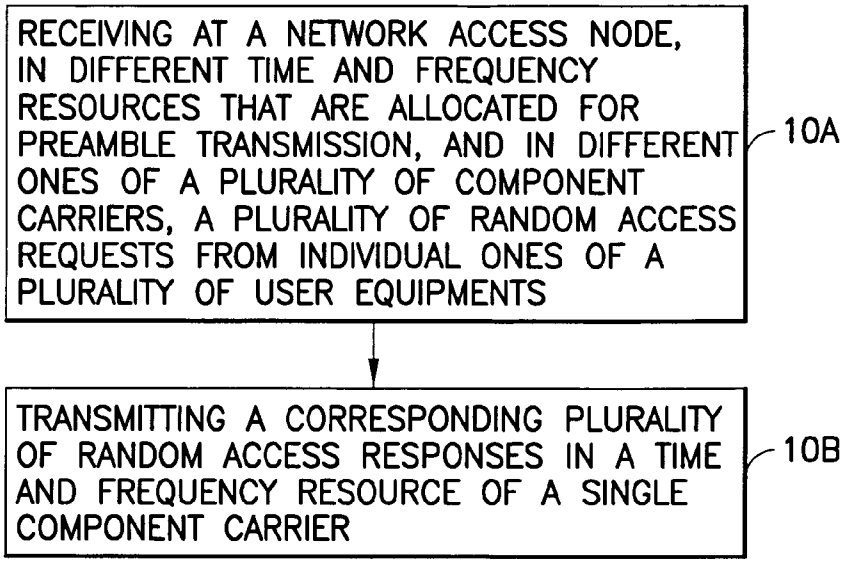

FIG.10

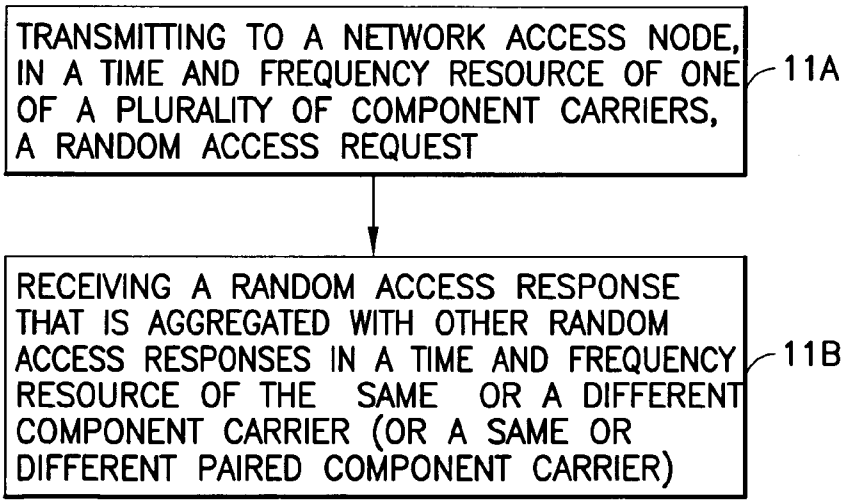

FIG.11

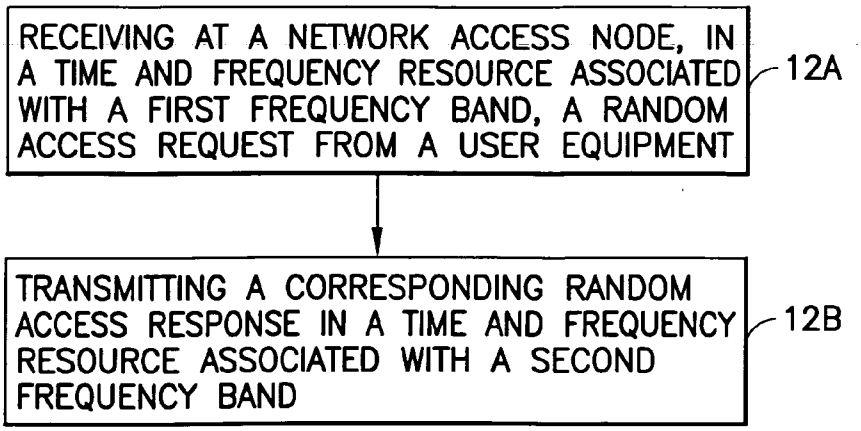

FIG.12

RANDOM ACCESS CHANNEL RESPONSE HANDLING WITH AGGREGATED COMPONENT CARRIERS

TECHNICAL FIELD

[0001] The exemplary and non-limiting embodiments of this invention relate generally to wireless communication systems, methods, devices and computer programs and, more specifically, relate to random access channel signaling techniques between a mobile node and a network access node.

BACKGROUND

[0002] This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

[0003] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

[0004] 3GPP third generation partnership project

[0005] DL downlink (eNB towards UE)

[0006] DwPTS downlink pilot time slot

[0007] eNB EUTRAN Node B (evolved Node B)

[0008] EPC evolved packet core

[0009] EUTRAN evolved UTRAN (LTE)

[0010] FDD frequency division duplex

[0011] FDMA frequency division multiple access

[0012] GP guard period

[0013] LTE long term evolution

[0014] MAC medium access control

[0015] MM/MME mobility management/mobility management entity

[0016] Node B base station

[0017] OFDMA orthogonal frequency division multiple access

[0018] O&M operations and maintenance

[0019] PDCP packet data convergence protocol

[0020] PDCCH physical downlink control channel

[0021] PDSCH physical downlink shared channel

[0022] PHY physical (layer **1**)

[0023] PRACH physical random access channel

[0024] RA-RNTI random access radio network temporary identity

[0025] RACH random access channel

[0026] RLC radio link control

[0027] RRC radio resource control

[0028] SGW serving gateway

[0029] SC-FDMA single carrier, frequency division multiple access

[0030] TDD time division duplex

[0031] T-CRNTI temporary cell random access radio network temporary identity

[0032] TTI transmission timing interval

[0033] UE user equipment

[0034] UL uplink (UE towards eNB)

[0035] UpPTS uplink pilot time slot

[0036] UTRAN universal terrestrial radio access network

[0037] The specification of a communication system known as evolved UTRAN (EUTRAN, also referred to as UTRANLTE or as EUTRA) is currently nearing completion within the 3GPP. As specified the DL access technique is OFDMA, and the UL access technique is SC-FDMA.

[0038] One specification of interest is 3GPP TS 36.300, V8.7.0 (2008-12), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (EUTRA) and Evolved Universal Terrestrial Access Network (EUTRAN); Overall description; Stage 2 (Release 8), incorporated by reference herein in its entirety. This system may be referred to for convenience as LTE Rel-8, or simply as Rel-8. In general, the set of specifications given generally as 3GPP TS 36.xyz (e.g., 36.211, 36.311, 36.312, etc.) may be seen as describing the entire Release 8 LTE system.

[0039] FIG. **1**A reproduces FIG. 4.1 of 3GPP TS 36.300, and shows the overall architecture of the EUTRAN system. The EUTRAN system includes eNBs, providing the EUTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of an X2 interface. The eNBs are also connected by means of an S1 interface to an EPC, more specifically to a MME (Mobility Management Entity) by means of a S1 MME interface and to a Serving Gateway (SGW) by means of a S1 interface. The S1 interface supports a many to many relationship between MMEs/Serving Gateways and eNBs.

[0040] The eNB hosts the following functions:

[0041] functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);

[0042] IP header compression and encryption of the user data stream;

[0043] selection of a MME at UE attachment;

[0044] routing of User Plane data towards Serving Gateway;

[0045] scheduling and transmission of paging messages (originated from the MME);

[0046] scheduling and transmission of broadcast information (originated from the MME or O&M); and

[0047] a measurement and a measurement reporting configuration for use in mobility and scheduling.

[0048] In the present LTE system preamble responses are sent utilizing both the PDCCH and the PDSCH. Each RACH resource (time and frequency resource reserved for preamble transmission) is associated with a RA-RNTI (random access radio network temporary identity). When the base station (eNB) observes a preamble, it transmits the preamble response on the PDSCH on a resource that is indicated by a PDCCH addressed with the RA-RNTI. More specifically, when a Random Access Response message is transmitted, the CRC word of the corresponding PDCCH is masked by RA-RNTI. When searching a preamble response the UE tries to find a RA-RNTI masking corresponding to the frequency and time resource that the UE had used when sending its preamble. In this manner the preamble response on the PDSCH is unambiguously associated with preambles transmitted on a certain time-frequency resource.

[0049] The system is flexible in the sense that the base station can acknowledge in the same PDSCH message several preambles that have been transmitted in the same RACH resource, but that carry different signatures (preamble sequences). In addition, the responses can be sent in a time window that is configurable up to a duration of 10 ms.

[0050] In the present LTE system the responses to a set of UEs that listen to the same RA-RNTI can be combined into the same message. However, responses corresponding to different RA-RNTI cannot be combined, and PDCCH and PDSCH messages must be sent separately for each RA-RNTI (i.e., each RACH time-frequency resource). Considering the limited PDCCH resources this is not an efficient procedure. Because the base station does not know the channel state of the UEs, a PDCCH entry for a preamble response must be heavily coded, which consumes significant PDCCH resources. This can lead to problems, especially in the TDD system of LTE where several PRACH resources can exist in one subframe, and where random access responses cannot be distributed in time as flexibly as in the FDD system. This is true at least for the reason that in the TDD system there are gaps in the PDCCH due to subframes reserved for UL.

[0051] One LTE specification of interest herein is 3GPP TS 36.211 V8.5.0 (2008-12) Technical Specification 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 8). As is stated in subclause 4.2, the frame structure type 2 is applicable to TDD.

[0052] The PRACH is described in subclause 5.7 of 3GPP TS 36.211 V8.5.0.

[0053] Another LTE specification of interest herein is 3GPP TS 36.321 V8.5.0 (2009-03) Technical Specification 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (EUTRA); Medium Access Control (MAC) protocol definition (Release 8). The specification describes in subclause 5.1 the overall Random Access procedure followed by the UE, in subclause 5.1.3 the Random Access Preamble transmission, and in subclause 5.1.4 the Random Access Response reception.

[0054] For example, as currently specified for Rel-8 in subclause 5.1.4 "Random Access Response reception", once the Random Access Preamble is transmitted and regardless of the possible occurrence of a measurement gap, the UE shall monitor the PDCCH for Random Access Response(s) identified by the RA-RNTI defined below, in the RA Response window which starts at the subframe that contains the end of the preamble transmission plus three subframes and has length ra-ResponseWindowSize subframes. The RA-RNTI associated with the PRACH in which the Random Access Preamble is transmitted, is computed as:

$$RA\text{-}RNTI = 1 + t_id + 10 * f_id,$$

where t_id is the index of the first subframe of the specified PRACH ($0 \leqq t_id < 10$), and f_id is the index of the specified PRACH within that subframe, in ascending order of frequency domain ($0 \leqq f_id < 6$). The UE may stop monitoring for Random Access Response(s) after successful reception of a Random Access Response containing Random Access Preamble identifiers that matches the transmitted Random Access Preamble.

[0055] It is further specified in subclause 5.1.4 that if a downlink assignment for this TTI has been received on the PDCCH for the RA-RNTI, and the received TB is successfully decoded, the UE shall regardless of the possible occurrence of a measurement gap: if the Random Access Response contains a Backoff Indicator subheader:

[0056] set the backoff parameter value in the UE as indicated by the BI field of the Backoff Indicator subheader and Table 7.2-1,

[0057] else, set the backoff parameter value in the UE to **0** ms.

[0058] If the Random Access Response contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble (see subclause 5.1.3), the UE shall consider this Random Access Response reception successful and process the received Timing Advance Command (see subclause 5.2) and indicate the preambleInitialReceivedTargetPower and the amount of power ramping applied to the latest preamble transmission to lower layers (i.e., (PREAMBLE_TRANSMISSION_COUNTER−1)*powerRampingStep); process the received UL grant value and indicate it to the lower layers; if ra-PreambleIndex was explicitly signaled and it was not 000000 (i.e., not selected by MAC) consider the Random Access procedure successfully completed.

[0059] If no Random Access Response is received within the RA Response window, or if none of all received Random Access Responses contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble, the Random Access Response reception is considered not successful and the UE shall, among other activities, if in this Random Access procedure the Random Access Preamble was selected by MAC: based on the backoff parameter in the UE, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value; delay the subsequent Random Access transmission by the backoff time; and proceed to the selection of a Random Access Resource (see subclause 5.1.2).

[0060] Of particular interest herein are the further releases of 3GPP LTE targeted towards future IMT-A systems, referred to herein for convenience simply as LTE-Advanced (LTE-A).

[0061] Reference can be made to 3GPP TR 36.913, V8.0.1 (2009-03), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Requirements for Further Advancements for E-UTRA (LTE-Advanced) (Release 8), incorporated by reference herein in its entirety. One element of the LTE-A system is the proposed use of the UHF band (698-960 MHz, referred to simply as 900 MHz) and a 2.3 GHz band (referred to simply as 2 GHz).

SUMMARY

[0062] The foregoing and other problems are overcome, and other advantages are realized, by the use of the exemplary embodiments of this invention.

[0063] In a first aspect thereof the exemplary embodiments of this invention provide a method that comprises receiving at a network access node, in different time and frequency resources that are allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments; and transmitting a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

[0064] In another aspect thereof the exemplary embodiments of this invention provide an apparatus that comprises a controller configured to operate with a wireless receiver and a wireless transmitter. The controller is further configured to respond to a reception in different time and frequency resources that are allocated for preamble transmission, and in

different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments and to transmit a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

[0065] In yet another aspect thereof the exemplary embodiments of this invention provide a method that comprises receiving at a network access node, in a time and frequency resource associated with a first frequency band, a random access request from a user equipment; and transmitting a corresponding random access response in a time and frequency resource associated with a second frequency band.

[0066] In yet another aspect thereof the exemplary embodiments of this invention provide a method that comprises transmitting to a network access node, in a time and frequency resource of one of a plurality of component carriers, a random access request; and receiving a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier.

[0067] In yet another aspect thereof the exemplary embodiments of this invention provide an apparatus that comprises a controller configured to operate with a wireless receiver and a wireless transmitter, where the controller is further configured to transmit to a network access node in a time and frequency resource allocated for preamble transmission, of one of a plurality of component carriers, a random access request, and to receive a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0068] In the attached Drawing Figures:

[0069] FIG. **1**A reproduces FIG. 4 of 3GPP TS 36.300 V 8.7.0, and shows the overall architecture of the EUTRAN system.

[0070] FIG. **1**B reproduces Table 4.2-2 of 3GPP TS 36.211 V8.5.0: Uplink-downlink configurations for the frame structure type 2.

[0071] FIG. **1**C reproduces FIG. 4.2-1 of 3GPP TS 36.211 V8.5.0, and shows the frame structure type 2.

[0072] FIGS. **1**D-**1**G reproduce FIGS. 6.1.5-1 through 6.1.5-4 of 3GPP TS 36.321 V8.5.0, and show the E/T/RAPID MAC subheader, the E/T/R/R/BI MAC subheader, the MAC RAR and an example of a MAC PDU containing a MAC header and MAC RARs, respectively.

[0073] FIG. **2**A shows a simplified block diagram of various electronic devices that are suitable for use in practicing the exemplary embodiments of this invention.

[0074] FIG. **2**B shows a more particularized block diagram of a UE such as that shown at FIG. **2**A.

[0075] FIG. **3** depicts a contiguous configuration of component carriers.

[0076] FIG. **4** shows an eNB operable with two UEs of different capability in a non-contiguous carrier aggregation network.

[0077] FIG. **5** shows an exemplary TDD CC configuration.

[0078] FIG. **6** shows one exemplary embodiment of a signaling scheme to provide additional information for those UEs **10** of a later release that is sent in a portion of a message that the UEs **10** of an earlier release regard as padding.

[0079] FIG. **7** shows an example of PRACH response for the non-contiguous carrier network.

[0080] FIG. **8** shows an example of PRACH response for the non-contiguous carrier network in accordance with the exemplary embodiments of this invention.

[0081] FIG. **9** depicts two exemplary embodiments (labeled A and B for convenience) of the merging of preamble responses for UEs of differing capabilities in accordance with the exemplary embodiments of this invention.

[0082] FIGS. **10**, **11** and **12** are each a logic flow diagram that illustrates the operation of methods, and a result of execution of computer program instructions embodied on a computer readable memory, in accordance with the exemplary embodiments of this invention.

DETAILED DESCRIPTION

[0083] References herein to a Rel-8 UE generally encompass those UEs that are compatible with the set of LTE Rel-8 specifications, including 3GPP TS 36.211 V8.5.0 and 3GPP TS 36.321 V8.5.0. References herein to a Rel-9 UE generally encompass those UEs that are generally compatible with the set of LTE Rel-8 specifications, including 3GPP TS 36.211 V8.5.0 and 3GPP TS 36.321 V8.5.0, but that may include additional functionality that is not expressly specified for Rel-8 operation. References herein to an LTE-A UE generally encompass those UEs that may be considered as beyond Rel-8 or Rel-9 UEs.

[0084] In LTE-A it is proposed that the total system bandwidth may have from two to five component carriers (CCs). These CCs can be contiguous as shown in FIG. **3**, where there are five CCs shown each having the Rel-8 bandwidth, or non-contiguous as shown in FIGS. **4** and **5** (note in FIGS. **4** and **5** that the CCs are from two separated bands, e.g., one bandwidth of 10 MHz is from 2 GHz and another bandwidth of 5 MHz is from 900 MHz and, in total, the bandwidth of the two CCs is 15 MHz, and are non-contiguous). At least in the case of non-contiguous carriers, the TDD UL/DL configurations may be different in the different carriers, as is shown more particularly in FIG. **5**. In FIGS. **4** and **5** "D" indicates a downlink subframe, "U" indicates an uplink subframe, and "S" indicates a special subframe (see, generally 3GPP TS 36.211 V8.5.0, subclause 4.2 "Frame structure type 2"). FIG. **1**B herein reproduces Table 4.2-2 of 3GPP TS 36.211 V8.5.0: Uplink-downlink configurations for the frame structure type 2. FIG. **1**C reproduces FIG. 4.2-1 3GPP TS 36.211 V8.5.0, and shows the frame structure type 2. The special subframe S has three fields: DwPTS, GP and UpPTS. The length of DwPTS and UpPTS is given by Table 4.2-1 of 3GPP TS 36.211 V8.5.0, subject to the total length of DwPTS, GP and UpPTS being equal to $30720 \cdot T_s = 1$ ms. Each subframe i is defined as two slots, 2i and 2i+1 of length $T_{slot} = 15360 \cdot T_s = 0.5$ ms in each subframe. Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported. In the case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe S exists in both half-frames. In the case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe S exists in the first half-frame only. Subframes **0** and **5** and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

[0085] In the first step of a Random Access (RA) procedure, the UE selects a CC and transmits a preamble sequence on that CC using a frequency and time resource reserved for preambles. The UE then searches for a preamble response

indicating that the base station has observed the preamble and that the UE is allowed to continue the RA procedure.

[0086] The exemplary embodiments of this invention provide an efficient technique for the signaling of the preamble responses over aggregated carriers.

[0087] A straightforward generalization of the RA procedure for LTE-A with more than one CC would be such that preambles, observed on different CCs, are acknowledged separately by the base station (e.g., by the eNB). That is, when a preamble is observed in the UL of a CC, the acknowledgment is sent in the DL of the same CC (for TDD) or in the DL CC paired with the UL CC (for FDD). While this may be the simplest approach, it does not provide a most efficient and flexible system for at least the following reasons.

[0088] Note first that in the FDD case there are pairs of UL and DL carriers, and the response is sent in the paired DL carrier. However, for LTE-A this is not necessarily the case, as there may be more or fewer UL carriers than DL carriers. Furthermore, even when there are an equal number of UL and DL carriers available, a specific UE maybe allocated only a part of those carriers (possibly a different number in UL and DL). For example, for LTE-A one of the DL component carriers could be considered as a primary component carrier and random access responses could be sent via this one component carrier only, whereas the random access request could be sent via any available UL component carrier.

[0089] As a first reason, PDCCH resources are not used efficiently since a PDCCH entry is needed per each carrier with an observed preamble.

[0090] Second, the use of this technique may result in a delay if the preamble response must be postponed by the eNB due to a lack of PDCCH resources.

[0091] Third, PDSCH resources are not utilized in the most efficient manner because many small response messages are sent instead of one larger message.

[0092] Furthermore, there is little or no flexibility in selecting a most suitable CC for sending the RA response. For example, the base station (eNB) may be forced to send the response in a CC having few DL sub-frames (it may be assumed that UL/DL configurations can be different at least in the case of non-contiguous CC configurations), or in a CC with a large PDCCH load due to a large number of UEs to schedule.

[0093] In addition, the foregoing approach does not support a system where all of the RA preambles would be acknowledged in a primary CC that all of the UEs would be listening to. That is, even if the preamble would be sent on another CC (in order to distribute the RA load) the UEs would never need to listen to more than one CC in the DL. The use of the conventional approach would assume having to resume listening to the CC paired with the UL carrier on which the preamble has been sent (when expecting a preamble response), or receiving from more than one CC.

[0094] An efficient and flexible system for carrying preamble responses is thus needed for with the use of multiple CCs, such as in LTE-A.

[0095] Before describing in further detail the exemplary embodiments of this invention, reference is made to FIG. **2**A for illustrating a simplified block diagram of various electronic devices and apparatus that are suitable for use in practicing the exemplary embodiments of this invention. In FIG. **2**A a wireless network **1** is adapted for communication over a wireless link **11** with an apparatus, such as a mobile communication device which may be referred to as a UE **10**, via a network access node, such as a Node B (base station), and more specifically an eNB **12**. The network **1** may include a network control element (NCE) **14** that may include the MME/SGW functionality shown in FIG. **1**A, and which provides connectivity with a network **1**, such as a telephone network and/or a data communications network (e.g., the internet). The UE **10** includes a controller, such as a computer or a data processor (DP) **10**A, a computer-readable memory medium embodied as a memory (MEM) **10**B that stores a program of computer instructions (PROG) **10**C, and a suitable radio frequency (RF) transceiver **10**D for bidirectional wireless communications with the eNB **12** via one or more antennas. The eNB **12** also includes a controller, such as a computer or a data processor (DP) **12**A, a computer-readable memory medium embodied as a memory (MEM) **12**B that stores a program of computer instructions (PROG) **12**C, and a suitable RF transceiver **12**D for communication with the UE **10** via one or more antennas. The eNB **12** is coupled via a data/control path **13** to the NCE **14**. The path **13** may be implemented as the S1 interface shown in FIG. **1**A. The eNB **12** may also be coupled to another eNB via data/control path **15**, which may be implemented as the X2 interface shown in FIG. **1**A.

[0096] At least one of the PROGs **10**C and **12**C is assumed to include program instructions that, when executed by the associated DP, enable the device to operate in accordance with the exemplary embodiments of this invention, as will be discussed below in greater detail.

[0097] That is, the exemplary embodiments of this invention maybe implemented at least in part by computer software executable by the DP **10**A of the UE **10** and/or by the DP **12**A of the eNB **12**, or by hardware, or by a combination of software and hardware (and firmware).

[0098] For the purposes of describing the exemplary embodiments of this invention the UE **10** may be assumed to also include a RACH function or module **10**E, and the eNB **12** also includes a corresponding RACH function or module **12**E, both of which are configured for operation in accordance with the exemplary embodiments of this invention.

[0099] The UE **10** may be a Rel-8 compatible UE, or a later than Rel-8 UE, such as a Rel-9 or an LTE-A compatible UE. In general, there will be some population of UEs **10** served by the eNB **12**, and the population may be mixed between UEs operating as Rel-8, Rel-9 and LTE-A UEs, as non-limiting examples.

[0100] In general, the various embodiments of the UE **10** can include, but are not limited to, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

[0101] The computer readable MEMs **10**B and **12**B may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The DPs **10**A and **12**A may be of any type suitable to the local technical environment, and may include one or

more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multi-core processor architectures, as non-limiting examples.

[0102] FIG. **2**B illustrates further detail of an exemplary UE **10** in both plan view (left) and sectional view (right), and the invention may be embodied in one or some combination of those more function-specific components. At FIG. **2**B the UE **10** has a graphical display interface **20** and a user interface **22** illustrated as a keypad but understood as also encompassing touchscreen technology at the graphical display interface **20** and voice recognition technology received at the microphone **24**. A power actuator **26** controls the device being turned on and off by the user. The exemplary UE **10** may have a camera **28** which is shown as being forward facing (e.g., for video calls) but may alternatively or additionally be rearward facing (e.g., for capturing images and video for local storage). The camera **28** is controlled by a shutter actuator **30** and optionally by a zoom actuator **30** which may alternatively function as a volume adjustment for the speaker(s) **34** when the camera **28** is not in an active mode.

[0103] Within the sectional view of FIG. **2**B are seen multiple transmit/receive antennas **36** that are typically used for cellular communication. The antennas **36** maybe multi-band for use with other radios in the UE. The operable ground plane for the antennas **36** is shown by shading as spanning the entire space enclosed by the UE housing though in some embodiments the ground plane may be limited to a smaller area, such as disposed on a printed wiring board on which the power chip **38** is formed. The power chip **38** controls power amplification on the channels being transmitted and/or across the antennas that transmit simultaneously where spatial diversity is used, and amplifies the received signals. The power chip **38** outputs the amplified received signal to the radio frequency (RF) chip **40** which demodulates and downconverts the signal for baseband processing. The baseband (BB) chip **42** detects the signal which is then converted to a bit stream and finally decoded. Similar processing occurs in reverse for signals generated in the apparatus **10** and transmitted from it.

[0104] Signals going to and from the camera **28** pass through an image/video processor **44** that encodes and decodes various image frames. A separate audio processor **46** may also be present controlling signals to and from the speakers **34** and the microphone **24**. The graphical display interface **20** is refreshed from a frame memory **48** as controlled by a user interface chip **50** which may process signals to and from the display interface **20** and/or additionally process user inputs from the keypad **22** and elsewhere.

[0105] Certain embodiments of the UE **10** may also include one or more secondary radios such as a wireless local area network radio WLAN **37** and a Bluetooth radio **39**, which may incorporate an antenna on-chip or be coupled to an off-chip antenna. Throughout the apparatus are various memories such as random access memory RAM **43**, read only memory ROM **45**, and in some embodiments removable memory such as the illustrated memory card **47** on which the various programs **10**C are stored. All of these components within the UE **10** are normally powered by a portable power supply such as a battery **49**.

[0106] The processors **38**, **40**, **42**, **44**, **46**, **50**, if embodied as separate entities in a UE **10** or eNB **12**, may operate in a slave relationship to the main processor **10**A, **12**A, which may then be in a master relationship to them. Embodiments of this invention may be localized, or they may be embodied across various chips and memories as shown, or disposed within another processor that combines some of the functions described above for FIG. **2**B. Any or all of these various processors of FIG. **2**B access one or more of the various memories, which may be on-chip with the processor or separate from the processor. Similar function-specific components that are directed toward communications over a network broader than a piconet (e.g., components **36**, **38**, **40**, **42**, **45** and **47**) may also be disposed in exemplary embodiments of the access node **12**, which may have an array of tower-mounted antennas rather than the two shown at FIG. **2**B.

[0107] Note that the various integrated circuits (e.g., chips **38**, **40**, **42**, etc.) that were described above may be combined into a fewer number than described and, in a most compact case, may all be embodied physically within a single chip.

[0108] Describing now in further detail the exemplary embodiments of this invention, there is provided a method, computer program and apparatus configured to enable bundling of RA preamble responses that are sent for preambles observed in different time and frequency resources and on different component carriers such that the bundled preamble response is sent on one component carrier. This minimizes the use of PDCCH resources, and may as well beneficially reduce the UE **10** receiver complexity and access procedure delay. As was noted above, a PDCCH resource may instead be needed either for each preamble or group of preambles sent on each carrier component. In accordance with the exemplary embodiments of this invention the eNB **12** is able to respond to RACH requests on different carrier components and combine the message **2** response on a DL resource of a single carrier. This enables the UE **10** RACH **10**E decoder operation to be simplified; for example only on one carrier frequency may be needed.

[0109] More specifically, after transmitting a preamble on a CC the UE **10** receives the Random Access response on a PDSCH of a CC. There are a number of ways to define which CC is used by the RACH function **12**E of the eNB **12** for sending the RA preamble response. Several non-limiting examples include:

[0110] A) The CC may be freely selected by the eNB **12** from the set of CCs which the UE **10** is monitoring. This gives full flexibility to the eNB **12**, but at the expense UE **10** receiver simplification, as the UE **10** should monitor all alternative DL slots within the specified time window until a matching preamble response is found.

[0111] B) A pre-defined rule known to both the eNB **12** and to at least some of the UEs **10** may be used to define the CC. To minimize the request-response delay, one exemplary rule uses the CC which has the first suitable DL slot (as the UE **10** is aware of the UL/DL configurations of all the CCs). For a case where the first suitable downlink slot occurs on multiple CCs at the same time, another rule (e.g., use the highest frequency subcarrier from the set of available subcarriers) is used to unambiguously specify which CC is being used for the preamble response.

[0112] C) Another technique is to use explicit signaling. This can be common signaling, e.g., in the form of system information (SI) which may be included in the same system information block (SIB) with the RACH parameters, to signal the preferred CC or CCs for RA preamble responses. Another approach to explicit signaling is for the UE **10** to specify in the UL request on which CC it expects to receive the response. While attractive at least for its simplicity from the UE **10** perspective, this approach may not be the most optimum at

least for the reason that the RACH resource space is limited, and the UE **10** has no information concerning the DL load situation of different CCs (in other words, it may be more preferable that the eNB **12** select the CC in which to respond).

[0113] Each response may include an indication of the CC on which the preamble was received, the sequence, frequency and subframe index, a timing advance (TA) command and the UL grant, and multiple ones of these responses are bundled in the same response message that is assigned with a RA-RNTI. The RA-RNTI can be, for example, any RA-RNTI reserved for assigning PDSCH resources for preamble responses. This is true at least for the reason that (for LTE-A UEs **10**) the PRACH resource (CC, frequency within the CC and subframe) of the observed preamble are given explicitly in the response, as opposed to being indicated by the RA-RNTI as in the case of Rel-8/9 UEs **10**).

[0114] Responses for Rel-8/9 UEs and LTE-A UEs can be bundled into the same message. In order to maintain backwards compatibility with Rel-8/9 UEs **10** the responses sent to the LTE-A UEs **10** may be inserted into that part of the response message that Rel-8/9 UEs expect to see as padding (and which they may simply just ignore). If there are only responses to LTE-A UEs **10** to be sent, a special RA-RNTI may be used for indicating this. Another exemplary embodiment inserts a byte of backoff (BO) control information (e.g., one with a BO value equal to 0, meaning no effect, and extension flag=0) in the beginning of the response message for indicating to Rel-8/9 UEs **10** that there are no responses for them.

[0115] Reference can be made to FIG. **6**, which shows one exemplary embodiment of a signaling scheme to provide additional information for those UEs **10** of a later release (e.g., LTE-A) that is sent in the portion of the message that the UEs **10** of an earlier release (e.g., Rel-8 or Rel-9) regard as padding. Note the use of a bit or byte to specify to the later release UEs that the padding does not begin at the indicated location, but instead that what is contained are one or more RA responses for later release UEs **10**.

[0116] In another exemplary embodiment of this invention the continuation of the message is indicated to the UEs **10** of the later release by utilizing one or more bits marked as reserved bits in the specification of the earlier release. For instance, there are two reserved bits, indicated with "R" in the E/T/R/R/BI header of the random access response MAC PDU (see FIG. 6.1.5-2 of 3GPP TS 36.321 V8.5.0). One of these bits, or a combination of bit values, may be used to indicate to a UE **10** of the later release that there may be a response for it in the message portion regarded as padding by the UEs **10** of the earlier release. Typically a UE **10** would not examine or consider any bit or bits indicated as being reserved in a message, and thus backwards compatibility with the earlier release UEs **10** is maintained. It should be noted that this embodiment does not require that the random access requests are sent on different component carriers, i.e., this embodiment can be applied also in the simple case where there is only one component carrier. Then the random access request (preamble) is sent in one of the resources allocated for RACH and the response is received as in Rel-8. But depending on the case the response message may contain either a) response(s) in Rel-8 format, or b) responses in both Rel-8 and LTE-A formats, or c) response(s) only in LTE-A format. For case a) nothing new is needed. For case b) the approach of FIG. **9**A can be used, and for case c) the approach of FIG. **9**B can be used.

[0117] The RAR for LTE-A may be different from Rel-8 due to several reasons. One reason is already mentioned: if responses for multiple RACH resources or component carriers are included, then the RAR needs to contain the RACH resource index and the component carrier index. Also, the resource allocation for the LTE-A UEs maybe different from the resource allocation for Rel-8/9 UEs, e.g., if the allocation is for a different component carrier than the one where the allocation is sent.

[0118] The foregoing description assumes that the eNB **12** has knowledge of the capability (release level) of the UE **10** that has sent a preamble. This implies that Rel-8/9 and LTE-A UEs use different parameters (e.g., one or more of sequences or frequency or time resources). If instead the same preamble resources are shared between Rel-8/9 and LTE-A UEs **10**, the exemplary embodiments of this invention may still be utilized for the bundling of responses to dedicated preambles since the eNB **12** knows the capability of a UE **10** when it orders the UE **10** to begin a non-contention based random access. In general, it may be the case that more than 50% of the RACH load may typically be the result of transmission of dedicated preambles for adjusting timing of RRC-connected UEs due to handovers and DL data arrivals.

[0119] A non-limiting example is now provided as to the operation of the exemplary embodiments of this invention for a TDD non-contiguous carrier system. In that it maybe assumed that the lower frequency band has better coverage than the higher frequency band (e.g., see FIG. **3**, FIG. **4**), one advantageous implementation uses more DL subframes in the lower frequency band. For example, assume that a particular UE **10** has 900 MHz and 2 GHz carrier components, and on the 900 MHz component the UE **10** uses U/D configuration 4, and on the 2 GHz component the UE **10** uses configuration 0 (see again FIG. **1**B, which shows the uplink-downlink configurations specified in 3GPP TS 36.211 V8.5.0). The UE **10** may select randomly on which CC to transmit the RACH transmission (or re-transmission) if the lower frequency carries a heavy RACH load. By assuming that at least one low frequency component carrier is common for all CCs of the UEs, the UE **10** monitoring all RACH responses of the CC and within the maximum time response window **10** ms of each UL/DL configuration of each CC, a RA-RNTI is reserved at the common or default component carrier for all UEs.

[0120] As previously considered the same preamble is assigned to each CC of the UE **10**, and at least one RA-RNTI is reserved for each CC. However, in accordance with the exemplary embodiments of this invention, only one RA-RNTI is used for all CCs. FIG. **7** illustrates a conventional approach in the response of the RA-RNTI to PRACHs in UpPTS or an UL subframe in a non-contiguous CC system, while FIG. **8** illustrates the operation of the exemplary embodiments of this invention

[0121] In a case where there are fewer DL subframes in the UL/DL frame configuration on one UE **10** CC, e.g., for configurations 0, 1, and 6 of Table 4.2-2 3GPP TS 36.211 V8.5.0 (see again FIG. **1**B herein), the responses are as show, for example, in FIG. **7**, using one PDCCH resource for up to 10 PRACHs in 10 ms on each CC. However, by using the bundled response approach in accordance with the exemplary embodiments of this invention over different CCs on message **2** in responses to PRACHs PDCCH resources are conserved, and response latencies are deduced, as shown in FIG. **8**.

[0122] On the UE side, when one preamble is sent on one CC of the UE **10** it automatically searches for the PDCCH within its response window, but on the lower frequency or the default component carrier. The response window is at most 10 ms long, and it begins 2 ms after the UL subframe in which the RA preamble was transmitted. The UE **10** searches for the response on the lower frequency carrier for the PDCCH and the corresponding response message on the PDSCH.

[0123] FIG. **9** shows the merging of the preamble responses for UEs **10** of different capability in accordance with exemplary aspects of this invention.

[0124] By way of clarification, reference may be made to 3GPP TS 36.321 V 8.5.0, subclause 6.1.5: MAC PDU (Random Access Response), and to FIGS. **1**D-**1**G, which reproduce FIGS. 6.1.5-1 through 6.1.5-4 of 3GPP TS 36.321 V 8.5.0. A MAC PDU is said to consist of a MAC header and one or more MAC Random Access Responses (MAC RAR) and optionally padding as described in FIG. **1**F. The MAC header is of variable size. A MAC PDU header consists of one or more MAC PDU subheaders; each subheader corresponding to a MAC RAR except for the Backoff Indicator subheader. If included, the Backoff Indicator subheader is only included once, and is the first subheader included within the MAC PDU header. A MAC PDU subheader consists of the three header fields E/T/RAPID (as described in FIG. **1**D), but for the Backoff Indicator subheader which consists of the five header field E/T/R/R/BI (as described in FIG. **1**E). A MAC RAR consists of the four fields R/Timing Advance Command/UL Grant/Temporary C-RNTI (as described in FIG. **1**F). Padding may occur after the last MAC RAR. The presence and length of the padding is implicit based on TB size, size of MAC header and number of RARs. FIG. **1**G depicts an example of a MAC PDU containing a MAC header and MAC RARs.

[0125] Returning to FIG. **9**, assume that both earlier release (e.g., Rel-8) and later release (e.g., LTE-A) UEs read the backoff indicator (BI) sent in the first byte. In the first example (A) the preamble acknowledgements are sent for the UEs of both the earlier and the later releases. The acknowledgements for the UEs of the later release are in that part of the message that the UEs **10** of the earlier release regard as padding (see again FIG. **6**). As an example, a value of 0 in the second bit of padding portion is used to indicate to the UEs of the later release that there may be preamble acknowledgements for them in the remainder of the message. In the example (B), preamble acknowledgements are sent only for the UEs of the later release (note again the value of 0 in the second bit of the padding).

[0126] There are a number of advantages and technical effects that may be realized by the use of the exemplary embodiments of this invention. For example, there can be realized a saving of PDCCH resources on different CCs, as well as reduction in the complexity of the UE **10** receiver operation during the reception of the RACH response. This implies that UE **10** receiver operation on 2-5 different RF carriers is not necessary. Further by example, there are reduced constraints on resource allocation, as well as potentially a reduced delay due to a high density of PRACH messages associated with limited PDCCH resources on some component carriers.

[0127] Note that later release UEs **10**, such as LTE-A UEs, may use a different preamble group set than earlier release, e.g., Rel-8/9, UEs to distinguish themselves to the eNB **12**.

[0128] The exemplary embodiments of this invention may also be used in the FDD system, when there are one or several PRACH time resources per 10 ms and per component carrier. Bundling of responses to preambles that have been observed at different CCs can save PDCCH resources without introducing any additional delay.

[0129] One specific and non-limiting advantage and technical effect that is gained by the use of these exemplary embodiments is an ability to bundle or aggregate in a single DL CC RA responses to RA preambles received from a population of UEs on a plurality of UL CCs.

[0130] Referring to FIG. **10**, based on the foregoing it should be apparent that the exemplary embodiments of this invention provide a method, and computer program instructions stored in a computer-readable medium, to perform steps and operations of (Block **10**A) receiving at a network access node, in different time and frequency resources that are allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments; and (Block **10**B) transmitting a message comprising a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

[0131] Note that the time and frequency resources that are allocated for preamble transmission may be considered to be those wherein the UE **10** is permitted or allowed to transmit the random access preamble. Note further, however, that at least in Rel-8 the eNB **12** may schedule a UE to transmit normal data using those time and frequency resources. Thus, while the time and frequency resources may be allocated for RACH, another (different) use may also be permitted.

[0132] The method and the computer program instructions as above, where the plurality of random access responses are transmitted on a physical downlink shared channel.

[0133] The method and the computer program instructions as above, where the single component carrier is selected freely by the network access node from a set of component carriers.

[0134] The method and the computer program instructions as above, where the single component carrier is selected by the network access node in accordance with at least one rule.

[0135] The method and the computer program instructions as above, where the at least one rule comprises selecting the single component carrier as being one having a first available downlink slot and, for a case where more than one of the component carriers each simultaneously contain an available downlink slot, selecting as the single component carrier the component carrier having the highest frequency subcarrier.

[0136] The method and the computer program instructions as above, where the single component carrier is specified by the use of explicit signaling.

[0137] The method and the computer program instructions as above, where the explicit signaling comprises use of system information transmitted from the network access node.

[0138] The method and the computer program instructions as above, where the corresponding plurality of random access responses are for a first type of user equipment and for a second type of user equipment, and where there is at least one random access response for one of the second type of user equipment that is placed in a message at a location that need not be read by the first type of user equipment.

[0139] The method and the computer program instructions as above, where the message comprises an indicator that is set

for indicating that the message contains the at least one random access response for one of the second type of user equipment.

[0140] The method and the computer program instructions as above, where the location that need not be read by the first type of user equipment is in a message padding portion, and where the indicator is also in the message padding portion.

[0141] The exemplary embodiments of this invention also pertain to an apparatus that comprises a controller configured to operate with a wireless receiver and a wireless transmitter, where the controller is further configured respond to a reception in different time and frequency resources allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments and to transmit a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

[0142] The exemplary embodiments of this invention also pertain to an apparatus that comprises means for receiving at a network access node, in different time and frequency resources allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments; and means for transmitting a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

[0143] Referring to FIG. **11**, based on the foregoing it should be apparent that the exemplary embodiments of this invention provide a method, and computer program instructions stored in a computer-readable medium, to perform steps and operations of (Block **11**A) transmitting to a network access node, in a time and frequency resource of one of a plurality of component carriers, a random access request; and (Block **11**B) receiving a message comprising a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier (or a same or different paired component carrier for the FDD case).

[0144] Referring to FIG. **12**, based on the foregoing it should be apparent that the exemplary embodiments of this invention also provide a method, and computer program instructions stored in a computer-readable medium, to perform steps and operations of (Block **12**A) receiving at a network access node, in a time and frequency resource associated with a first frequency band, a random access request from a user equipment; and (Block **12**B) transmitting a corresponding random access response in a time and frequency resource associated with a second frequency band.

[0145] The various blocks shown in FIGS. **10**, **11** and **12** may be viewed as method steps, and/or as operations that result from operation of computer program code, and/or as a plurality of coupled logic circuit elements constructed to carry out the associated function(s), such as the functions of the RACH module **12**E or RACH module **10**E, respectively, of FIG. **2**A.

[0146] The exemplary embodiments of this invention also pertain to an apparatus that comprises a controller configured to operate with a wireless receiver and a wireless transmitter, where the controller is further configured to transmit to a network access node, in a time and frequency resource reserved for preamble transmission, of one of a plurality of component carriers, a random access request, and to receive a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier.

[0147] The exemplary embodiments of this invention also pertain to an apparatus that comprises means for transmitting to a network access node, in a time and frequency resource of one of a plurality of component carriers, a random access request; and for receiving a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier, or in a paired component carrier.

[0148] The exemplary embodiments of this invention also pertain to an apparatus that comprises means for transmitting to a network access node, in a time and frequency resource of one of a plurality of component carriers, a random access request; and for receiving a random access response in a time and frequency resource of a different component carrier.

[0149] In general, the various exemplary embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the exemplary embodiments of this invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[0150] It should thus be appreciated that at least some aspects of the exemplary embodiments of the inventions may be practiced in various components such as integrated circuit chips and modules, and that the exemplary embodiments of this invention may be realized in an apparatus that is embodied as an integrated circuit. The integrated circuit, or circuits, may comprise circuitry (as well as possibly firmware) for embodying at least one or more of a data processor or data processors, a digital signal processor or processors, baseband circuitry and radio frequency circuitry that are configurable so as to operate in accordance with the exemplary embodiments of this invention.

[0151] Various modifications and adaptations to the foregoing exemplary embodiments of this invention may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings. However, any and all modifications will still fall within the scope of the non-limiting and exemplary embodiments of this invention.

[0152] It should be noted that the terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and/or printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio fre-

quency region, the microwave region and the optical (both visible and invisible) region, as several non-limiting and non-exhaustive examples.

[0153] Further, the various names used for the described parameters (e.g., RA-RNTI) are not intended to be limiting in any respect, as these parameters may be identified by any suitable names. Further, any formulas and expressions that use these various parameters may differ from those expressly disclosed herein. Further, the various names assigned to different channels (e.g., PRACH, PDCCH, PDSCH, etc.) are not intended to be limiting in any respect, as these various channels may be identified by any suitable names.

[0154] Furthermore, some of the features of the various non-limiting and exemplary embodiments of this invention may be used to advantage without the corresponding use of other features. As such, the foregoing description should be considered as merely illustrative of the principles, teachings and exemplary embodiments of this invention, and not in limitation thereof.

1. A method, comprising:

receiving at a network access node, in different time and frequency resources that are allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments; and

transmitting a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

2. The method of claim **1**, where the plurality of random access responses are transmitted on a physical downlink shared channel.

3. The method as in claim **1**, where the single component carrier is selected freely by the network access node from a set of component carriers.

4. The method as in claim **1**, where the single component carrier is selected by the network access node in accordance with at least one rule.

5. The method of claim **4**, where the at least one rule comprises selecting the single component carrier as being one having a first available downlink slot and, for a case where more than one of the component carriers each simultaneously contain an available downlink slot, selecting as the single component carrier the component carrier having the highest frequency subcarrier.

6. The method as in claim **1**, where the single component carrier is specified by the use of explicit signaling.

7. The method as in claim **6**, where the explicit signaling comprises use of system information transmitted from the network access node.

8. The method as in claim **1**, where the corresponding plurality of random access responses are for a first type of user equipment and for a second type of user equipment, and where there is at least one random access response for one of the second type of user equipment that is placed in a message at a location that need not be read by the first type of user equipment.

9. The method as in claim **8**, where the message comprises an indicator that is set for indicating that the message contains the at least one random access response for one of the second type of user equipment.

10. The method as in claim **9**, where the location that need not be read by the first type of user equipment is in a message padding portion of the first type of user equipment.

11. The method as in claim **10**, where the indicator is placed in a message padding portion, or is placed in one or more bits of the message that are considered by the first type of user equipment as being reserved.

12. The method as in claim **1**, that is performed as a result of the execution of program instructions stored in a computer readable medium.

13. An apparatus, comprising:

a controller configured to operate with a wireless receiver and a wireless transmitter, said controller further configured to respond to a reception in different time and frequency resources that are allocated for preamble transmission, and in different ones of a plurality of component carriers, a plurality of random access requests from individual ones of a plurality of user equipments and to transmit a corresponding plurality of random access responses in a time and frequency resource of a single component carrier.

14. The apparatus of claim **13**, where the plurality of random access responses are transmitted on a physical downlink shared channel.

15. The apparatus as in claim **13**, where the single component carrier is selected freely by the controller from a set of component carriers.

16. The apparatus as in claim **13**, where the single component carrier is selected by the controller in accordance with at least one rule, where the at least one rule causes the controller to select the single component carrier as being one having a first available downlink slot and, for a case where more than one of the component carriers each simultaneously contain an available downlink slot, to select as the single component carrier the component carrier having the highest frequency subcarrier.

17. The apparatus as in claim **13**, where the single component carrier is specified by the use of explicit signaling.

18. The apparatus as in claim **17**, where the explicit signaling comprises use of system information.

19. The apparatus as in claim **13**, where the corresponding plurality of random access responses are for a first type of user equipment and for a second type of user equipment, and where there is at least one random access response for one of the second type of user equipment that is placed in a message padding portion that need not be read by the first type of user equipment.

20. A method, comprising:

receiving at a network access node, in a time and frequency resource associated with a first frequency band, a random access request from a user equipment; and

transmitting a corresponding random access response in a time and frequency resource associated with a second frequency band.

21. The method of claim **20**, where transmitting comprises transmitting a plurality of aggregated random access responses for a corresponding plurality of user equipments in response to random access requests received in different time and frequency resources associated with the first frequency band, the second frequency band, or another frequency band.

22. A method, comprising:

transmitting to a network access node, in a time and frequency resource allocated for preamble transmission, of one of a plurality of component carriers, a random access request; and

receiving a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier.

23. The method of claim **22**, where the random access response is received on a physical downlink shared channel.

24. The method as in claim **22**, where the random access response is received in a component carrier that is selected freely by the network access node from the plurality of component carriers, or where the random access response is received in a component carrier selected by the network access node in accordance with at least one rule, or where the random access response is received in a component carrier specified by the use of explicit signaling.

25. The method of claim **24**, where the at least one rule comprises selecting the component carrier as being one having a first available downlink slot and, for a case where more than one of the component carriers each simultaneously contain an available downlink slot, selecting as the component carrier a component carrier having a highest frequency subcarrier.

26. The method as in claim **24**, where the explicit signaling comprises reception of system information transmitted from the network access node.

27. The method as in claim **22**, where the aggregated random access responses are for a first type of user equipment and for a second type of user equipment, where there is at least one random access response for one of the second type of user equipment that is placed in a message at a location that need not be read by the first type of user equipment, and where the message comprises an indicator that is set for indicating that the message contains the at least one random access response for one of the second type of user equipment.

28. The method as in claim **27**, where the location that need not be read by the first type of user equipment is in a message padding portion, and where the indicator is placed in the message padding portion or is placed in a bit or bits considered as reserved by the first type of user equipment.

29. The method as in claim **22**, performed as a result of execution of computer program instructions stored in a computer readable medium that comprises a part of a user equipment.

30. The method as in claim **22**, performed as a result of operation of a controller that comprises a part of a user equipment.

31. An apparatus, comprising:

a controller configured to operate with a wireless receiver and a wireless transmitter, where the controller is further configured to transmit to a network access node in a time and frequency resource allocated for preamble transmission, of one of a plurality of component carriers, a random access request, and to receive a random access response that is aggregated with other random access responses in a time and frequency resource of the same or a different component carrier.

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