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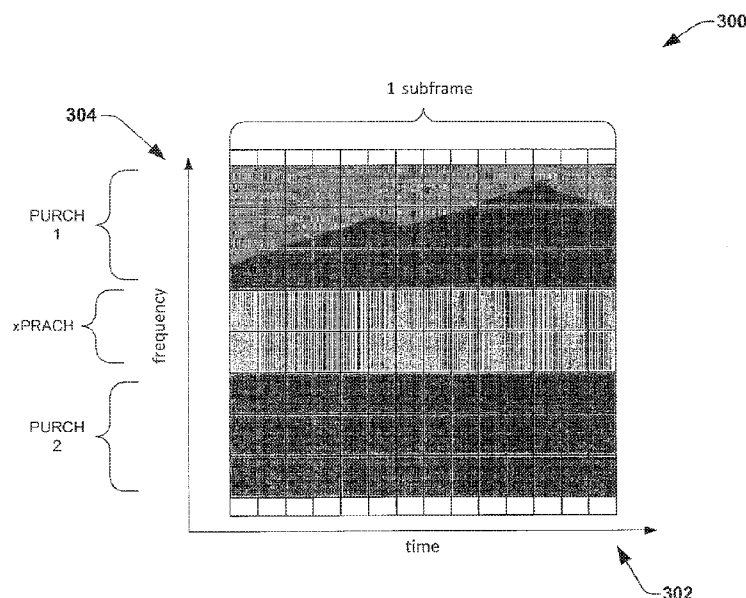


FIG. 3

(57) **Abstract:** An apparatus for use in a user equipment (UE) of a 5G communication network is disclosed. The apparatus comprises one or more processors configured to generate an uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith, and determine a physical uplink request channel (PURCH) comprising a set of PURCH orthogonal frequency division multiplexing (OFDM) symbols within a predefined PURCH subframe, to be utilized to map the UL request, wherein the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for PURCH, associated with a radio frame. The one or more processors is further configured to map the UL request to the set of PURCH OFDM symbols forming the PURCH, in order to subsequently provide the UL request to the gNodeB.



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SYSTEM AND METHOD FOR PHYSICAL UPLINK REQUEST CHANNEL DESIGN**REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of provisional Application No. PCT/CN2016/086150, filed June 17, 2016, entitled "PHYSICAL UPLINK REQUEST CHANNEL", and provisional Application No. PCT/CN2016/095901, filed August 18, 2016, entitled "SYSTEMS AND METHODS FOR BEAM AWARE UPLINK CONTROL CHANNEL DESIGN" the contents of which are herein incorporated by reference in their entirety

FIELD

[0002] The present disclosure relates to 5G communication systems, and in particular to an apparatus and a method for the design of a physical uplink request channel (PURCH) for a user equipment (UE) to send an uplink request information to a gNodeB so as to reduce the uplink latency.

BACKGROUND

[0003] Mobile communication has evolved significantly from early voice systems to today's highly sophisticated integrated communication platform. The next generation wireless communication system, 5G, will provide access to information and sharing of data anywhere, anytime by various users and applications. In the 5G systems, self-contained frame structure may be applied. Based on the self-contained frame structure, dynamic time division duplex (TDD) operation can be enabled, in which the subframe direction is not pre-defined but controlled by the control signaling in each subframe. Thus, the UE can be scheduled by a gNodeB associated therewith, to measure the CSI-RS or report the CSI or transmit some uplink data by uplink grant. However, in some case, the UE may need to send some uplink request to the gNodeB, such as scheduling request, beam refinement request and so on.

[0004] As a result of dynamic time division duplex (TDD) operation, in which the uplink transmission is scheduling based, UE needs to wait for the uplink grant from the gNodeB to send the uplink request information. In this case, the latency for UE sending uplink request could be high if it is always not scheduled by any uplink grant. Further, in massive MIMO systems, beamforming may be applied to both eNodeB and UE side. The eNodeB and UE can maintain a plurality of beams. Then how to decide the network (NW) beam to receive different UEs' uplink request also becomes a problem.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Some examples of circuits, apparatuses and/or methods will be described in the following by way of example only. In this context, reference will be made to the accompanying Figures.

[0006] Fig. 1 illustrates a simplified block diagram of a 5G communication network, according to one embodiment of the disclosure.

[0007] Fig. 2 illustrates an example circuit that implements the physical layer procedure that facilitates to provide a UL request from a UE to a gNodeB, according to one embodiment of the disclosure.

[0008] Fig. 3 illustrates an example physical uplink request channel (PURCH) subframe, according to one embodiment of the disclosure.

[0009] Fig. 4 illustrates a block diagram of an apparatus for use in a user equipment (UE) in a 5G communication network, according to the various embodiments described herein.

[0010] Fig. 5 illustrates a block diagram of an apparatus for use in an gNodeB in a 5G communication network, according to the various embodiments described herein.

[0011] Fig. 6 illustrates a flowchart of a method for a user equipment (UE) in a 5G communication network, according to one embodiment of the disclosure.

[0012] Fig. 7 illustrates a flowchart of a method for a gNodeB in a 5G communication network, according to one embodiment of the disclosure.

[0013] FIG. 8 illustrates example components of a device, in accordance with some embodiments.

DETAILED DESCRIPTION

[0014] In one embodiment of the disclosure, an apparatus for use in a user equipment (UE) of a 5G communication network is disclosed. The apparatus comprises one or more processors to generate an uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith. The one or more processors is further configured to determine a physical uplink request channel (PURCH) comprising a set of PURCH orthogonal frequency division multiplexing (OFDM) symbols within a predefined PURCH subframe, to be utilized to map the UL request. In some embodiments, the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, associated with a radio frame. In some embodiments, the one or more processors is further configured to map the UL request to the set of PURCH OFDM symbols forming the PURCH, in order to subsequently provide the UL request to the gNodeB.

[0015] In one embodiment of the disclosure, an apparatus for use in a user equipment (UE) of a 5G communication network is disclosed. The apparatus comprises one or more processors to generate a first uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith in a first instance and determine a first set of physical uplink request channel (PURCH) OFDM symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a first predefined PURCH subframe, to be utilized to map the first UL request, in order to provide the first UL request to the gNodeB. In some embodiments, a number of PURCH OFDM symbols in the first set of PURCH OFDM symbols is indicative of a first channel reciprocity comprising a channel quality between the UE and the gNodeB during the first instance. The one or more processors is further configured to generate a second, different uplink (UL) request comprising information

related to request from the UE to a gNodeB associated therewith in a second, different instance; and determine a second set of PURCH OFDM symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a second, different predefined PURCH subframe, to be utilized to map the second UL request, in order to provide the second UL request to the gNodeB. In some embodiments, a number of PURCH OFDM symbols in the second set of PURCH OFDM symbols is indicative of a second, different channel reciprocity comprising a channel quality between the UE and the gNodeB during the second instance.

[0016] In one embodiment of the disclosure, an apparatus for use in a gNodeB of a 5G communication network is disclosed. The apparatus comprises one or more processors to receive one or more uplink (UL) request signals, each comprising a UL request from a UE. In some embodiments, the UL request is mapped to one or more OFDM symbols respectively associated with the one or more UL request signals. In some embodiments, the one or more OFDM symbols is associated with a predefined physical uplink request channel (PURCH) subframe, wherein the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for mapping UL requests, within a radio frame. The one or more processors is further configured to process the one or more UL request signals, in order to decode the UL request on the one or more UL request signals; and selectively provide a UL resource signal for subsequent transmission to the UE, when the UL request is successfully decoded. In some embodiments, the UL resource signal comprises UL resources or information for the UE.

[0017] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” “circuit” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (e.g., mobile phone, etc.) with a

processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0018] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0019] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0020] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a

singular form. Furthermore, to the extent that the terms "including", "includes", "having", "has", "with", or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term "comprising."

[0021] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of various embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the various embodiments may be practiced in other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the various embodiments with unnecessary detail.

[0022] As indicated above, due to the dynamic TDD operation in 5G systems, in which the uplink transmission is scheduling based, a UE needs to wait for the uplink grant from a gNodeB associated therewith to send an uplink request, thereby increasing the uplink latency for the UE sending the uplink request. For example, if the UE needs to send a scheduling request, but the gNodeB does not know such information, the gNodeB may not schedule the uplink grant for the UE in time. In some embodiments, gNodeB refers to a RAN node or base station in 5G systems and is similar to the eNodeB in LTE networks. Further, in massive multiple input multiple output (MIMO) systems, beamforming may be applied to both gNodeB and UE side. For mid-band (carrier frequency between 6GHz and 30GHz) and high-band (carrier frequency beyond 30GHz), beamforming is one key technology to improve the signal quality and reduce the inter user interference by directing the narrow radiate beaming toward the target users. In beamforming systems, the gNodeB and UE can maintain a plurality of gNodeB beams. In current implementations, the uplink request, for example, a scheduling request (SR) is repeatedly transmitted by the UE to the gNodeB by utilizing time-frequency

resources associated with a plurality of gNodeB beams, thereby increasing the UE power. Further, in such embodiments, the gNodeB has to decode the SR on each of the plurality of gNodeB beams, in order to receive the SR, thereby increasing the SR overhead at the gNodeB.

[0023] In order to overcome the above disadvantages, a method for a UE to provide a UL request to a gNodeB using a predefined physical uplink request channel (PURCH) is proposed in this disclosure. In some embodiments, the PURCH comprises one or more time-frequency resources (e.g., orthogonal frequency domain multiplexing (OFDM) symbols) associated with a predefined PURCH subframe that can be utilized by the UE in order to send the UL request to the gNodeB. In some embodiments, the PURCH is an extension of the physical uplink control channel (PUCCH) or physical random access channel (PRACH) utilized in 5G physical layer and has similar configuration and features associated therewith. In some embodiments, the one or more time-frequency resources associated with the PURCH to be utilized by the UE to provide the UL request to the gNodeB is configured based on a channel quality between the UE and the gNodeB. In some embodiments, the proposed method of providing the UL request by the UE to the gNodeB utilizing the one or more time-frequency resources associated with the predefined PURCH subframe, enables to reduce the UE uplink latency, as the predefined PURCH subframe eliminates the need for the UE to wait for a UL grant from the gNodeB to send the UL request. Further, the proposed method enables to save UE power by avoiding the transmission of the UL request repeatedly on unwanted time-frequency resources.

[0024] Fig. 1 illustrates a simplified block diagram of a 5G communication network 100, according to one embodiment of the disclosure. The 5G communication network 100 comprises a user equipment (UE) 102 and a gNodeB 104. In some embodiments, the gNodeB 104 comprises a RAN node or base station (BS) in 5G systems and can be associated to an eNodeB in an evolved universal terrestrial radio access (E-UTRA) of a 3rd generation partnership project (3GPP) long-term evolution (LTE) network. In some embodiments, the UE 102 can comprise a mobile phone, a laptop, a tablet computer etc. and can be configured to communicate with the gNodeB 104. That is, in some

embodiments, the UE 102 can be configured to provide uplink (UL) data to the gNodeB 104, and further receive downlink (DL) data from the gNodeB 104.

[0025] In some embodiments, when the UE 102 has some uplink (UL) data to be transmitted to the gNodeB 104, the UE has to request the gNodeB 104 to grant some UL resources to transmit the UL data. Further, in some embodiments, for example, in beamforming systems, beam switching may happen as a result of UE movement, rotation and blockage. In such embodiments, the UE 102 may need to request the gNodeB 104 to transmit a beam refinement reference signal (BRRS) or request the gNodeB 104 to schedule a Beam Reference Signal Receiving Power (BRS-RP) report to tell the eNodeB that a better network (NW) beam or gNodeB is founded or the receiving power for the NW beam changed a lot. Furthermore, in some embodiments, the UE 102 may find that the downlink channel quality changed substantially and may need to request the gNodeB 104 to schedule the channel state information reference signal (CSI-RS) to reduce some channel quality indicator (CQI) mismatch.

[0026] In such embodiments, the UE 102 can be configured to generate a UL request comprising information on one or more requests from the UE 102 to the gNodeB 104. In some embodiments, the UL request may comprise a scheduling request (SR), by which the UE 102 could tell the gNodeB 104 that some uplink data needs to be transmitted and further request the gNodeB 104 to grant some uplink resource. In some embodiments, the UL request can comprise a buffer status report (BSR) or a short BSR that indicate the payload size of uplink data the UE 102 intends to transmit to the gNodeB 104. In some embodiments, the UE 102 may transmit a BSR directly instead of SR to reduce latency. In some embodiments, the BSR enables the gNodeB 104 to determine the UL resources to be granted (e.g., to judge whether the uplink data can be transmitted within one subframe) to the UE 102, for UL data transmission by the UE 102. Table 1 below illustrates one example for 3-bit short BSR, where N denotes the maximum transport block (TB) size within one resource block group (RBG) plus the TB (cyclic redundancy check) CRC sequence length. In one example, the RBG size can be equal to 4 resource

blocks (RBs). However, other ways of implementing the short BSR to the gNodeB 104 are contemplated to be within the scope of this disclosure.

Short BSR Index	Payload Size
0	BS=0
1	$0 < BS \leq 5N$
2	$5N < BS \leq 10N$
3	$10N < BS \leq 15N$
4	$20N < BS \leq 25N$
5	$BS > 25N$
6-7	reserved

Table 1: short BSR

[0027] In some embodiments, the UL request can comprise the BRS-RP report, the BRRS request or CSI-RS request. For example, in one example embodiment, the UL request can comprise a 2-bits BRS-RP report request in order to inform gNodeB 104 whether a full BRS-RP is reported or not, so that gNodeB 104 can decide whether to schedule a 5G physical uplink control channel (xPUCCH) resource or 5G physical uplink shared channel (xPUSCH) resource for BRS-RP report, e.g. “01” for requesting BRS-RP report based on xPUCCH resource, “10” for requesting BRS-RP report based on xPUSCH resource. Further, in some embodiments, the UL request can comprise a beam and CSI-RS report (BCR) to indicate the gNodeB 104 whether the UE 102 needs to trigger the BRS-RP report, BRRS request or CSI-RS request.

[0028] Table 2 below illustrates one example for the indication of a 2-bit BCR, where the first value may indicate no request on beam and CSI-RS, the second value may indicate the request of BRS-RP report scheduling, the third value may indicate the request of BRRS to refine UE beam and the fourth value may indicate

the request of CSI-RS. However, in another option, to enable simultaneous request, each request can be indicated by 1-bit. For example, in some embodiments, the BCR can comprise 1-bit to indicate BRS-RP report request, 1-bit for BRRS request and 1-bit for CSI-RS request. Then in such embodiments, the second value of each request may denote the request is enabled.

BCR Index	Indication
0	No request
1	Request BRS-RP report
2	Request BRRS
3	Request CSI-RS

Table 2: 2-bit BCR Indication

[0029] In some embodiments, a physical layer procedure for providing the UL request from a UE to a gNodeB associated therewith, for example, the gNodeB 104 comprises channel coding, scrambling, modulation, layer mapping, precoding and resource mapping, as illustrated in Fig. 2. In particular, Fig. 2 illustrates an example circuit 200 that implements the physical layer procedure and the various modules illustrated in Fig. 2 can be included within the UE 102 in Fig. 1. In some embodiments, the physical layer procedure illustrated in Fig. 2 is similar to the physical layer procedure defined in 3GPP technical specification (TS) 36.212. For example, a channel redundancy check (CRC) code may be applied to the UL request or to the data associated therewith, in the channel coding circuit 202 for error detection. Further, read-muller (RM) code, tailed bit convolutional coding (TBCC) or polar code may be applied to the data associated with the UL request in the channel coding circuit 202. Further, in some embodiments, a scramble sequence for scrambling the data associated with the UL request may be determined and applied at the scramble circuit 204. In some embodiments, the scrambling sequence is determined by the cell ID, virtual cell ID and/or C-RNTI, and/or scramble ID, and symbol/slot/subframe

index. Modulation schemes such as quadrature phase shift keying (QPSK) may be applied to the data associated with the UL request in modulation circuit 206. Transmit diversity, such as space frequency block coding (SFBC), can be applied in layer mapping and precoding circuit 208. Once the precoding is done, in some embodiments, the UL request is mapped into resources associated with a physical channel comprising a time-frequency grid within a radio frame, as defined in LTE, in the resource mapping circuit 210, in order to provide the UL request from the UE 102 to the gNodeB 104.

[0030] In some embodiments, the UE 102 can be configured to provide the UL request to the gNodeB 104, based on mapping the UL request or the data associated therewith to a physical uplink request channel (PURCH) comprising time-frequency resources associated with a predefined PURCH subframe. In some embodiments, utilizing the predefined PURCH subframe for providing the UL request to the gNodeB 104 enables to reduce the uplink latency associated with the UE 102. In some embodiments, the predefined PURCH subframe used for the transmission of the UL request can be configured by higher layers or by the gNodeB 104. In some embodiments, the PURCH is an extension of the physical uplink control channel (PUCCH) or physical random-access channel (PRACH) utilized in 5G physical layer and has similar configuration and features associated therewith. In some embodiments, the gNodeB 104 is configured to provide a PURCH signal 105 comprising information on resource configuration of one or more predefined PURCH subframes to the UE 102, in order to enable the UE 102 to provide the UL request to the gNodeB 104 using the predefined subframes. In some embodiments, PURCH signal 105 is provided to the UE 102 in a cell specific or UE specific manner from the gNodeB 104. For instance, in some embodiments, the PURCH signal 105 can be provided to the UE 102 from the gNodeB 104 by 5G master information block (xMIB), 5G system information block (xSIB), when configuring the PURCH subframes in a cell specific manner. Similarly, in other embodiments, the PURCH signal 105 can be provided to the UE 102 from the gNodeB 104 by radio resource control (RRC) signaling, when configuring the PURCH subframes in a UE specific manner. In some embodiments, the PURCH signal 105 comprises information on a periodicity associated with the PURCH subframe and a PURCH

subframe offset, thereby providing information on the one or more predefined PURCH subframes. In some embodiments, the PURCH signal 105 can further comprise information on one or more of a time domain resource, e.g. subframe offset, OFDM symbol index, the occupied OFDM symbols; the frequency domain resource, e. g. resource block (RB) or resource block group (RBG) index; and code domain resource, e.g. cyclic shift, associated with the PURCH subframe. Further, in some embodiments, the PURCH signal 105 can comprise one or more PURCH signals, for example, a first PURCH signal comprising information on a first predefined PURCH subframe and a second, different PURCH signal comprising a second, different PURCH subframe. In one example, the PURCH transmission instances or subframes are the subframes satisfying:

$$(10 \times n_f + \lfloor n_s/2 \rfloor - N_{\text{OFFSET,PURCH}}) \bmod \text{PURCH}_{\text{PERIODICITY}} = 0 \quad (1)$$

Where n_f indicates a frame index, n_s indicates a slot index, $N_{\text{OFFSET,PURCH}}$ indicates the PURCH subframe offset and $\text{PURCH}_{\text{PERIODICITY}}$ indicates the periodicity associated with the PURCH subframe. However, other possible ways of determining the PURCH subframe are also contemplated to be within the scope of this disclosure.

[0031] In some embodiments, the predefined PURCH subframe comprises a subframe having one or more predefined PURCH OFDM symbols (i.e., time resources), each PURCH OFDM symbol having a plurality of subcarriers (i.e., frequency resources) reserved for mapping UL requests associated with a UE (e.g., the UE 102), within a radio frame associated with the long-term evolution (LTE) physical layer or 5G systems. Fig. 3 illustrates an example PURCH subframe 300, according to one embodiment of the disclosure. The time axis 302 indicates the OFDM symbols (i.e., the time resources) associated with the PURCH subframe 300 and the frequency axis 304 indicates the subcarriers (i.e., the frequency resources) associated with the PURCH subframe 300. In the PURCH subframe 300, PURCH 1 and PURCH 2 comprises frequency resources or subcarriers that can be utilized for PURCH (i.e., for mapping UL requests associated with a UE). Further in the PURCH subframe 300, all the OFDM symbols are configured to be utilized for PURCH, forming the PURCH OFDM symbols. However, in other embodiments, only part of the OFDM symbols associated with the

PURCH subframe 300 may be configured to be utilized for PURCH. In this embodiment, the PURCH and 5G random access channel (xPRACH) are multiplexed (i.e., frequency division multiplexing) in the same subframe. However, in other embodiments, the resources for PURCH within the PURCH subframe can be configured differently.

[0032] Once information on the predefined PURCH subframe is available at the UE 102, in some embodiments, the UE 102 is further configured to determine a resource configuration of the PURCH comprising a set of PURCH OFDM symbols of the one or more predefined PURCH OFDM symbols within the predefined PURCH subframe (e.g., the PURCH subframe 200), to be utilized to map the UL request, in order to provide the UL request to the gNodeB 104. In some embodiments, a number of OFDM symbols within the set of PURCH OFDM symbols is indicative of a channel reciprocity comprising a channel quality between the gNodeB 104 and the UE 102.

[0033] In some embodiments, the set of PURCH OFDM symbols forming the PURCH is determined at the UE 102 based on measurements at the UE 102. In some embodiments, the UE 102 is configured to determine a number of PURCH OFDM symbols within the PURCH subframe to be utilized for providing the UL request to the gNodeB, based on information of a channel reciprocity between the UE 102 and the gNodeB 104, in order to determine the set of PURCH OFDM symbols that forms the PURCH. In some embodiments, the number of OFDM symbols in the set of PURCH OFDM symbols forming the PURCH is indicative of the channel reciprocity comprising a channel quality between the UE 102 and the gNodeB 104. For example, in one embodiment, the set of PURCH OFDM symbols can comprise a single PURCH OFDM symbol associated with the predefined PURCH subframe, when the channel reciprocity comprises a full channel reciprocity indicative of an ideal channel quality, and the set of PURCH OFDM symbols can comprise a plurality of PURCH OFDM symbols associated with the predefined PURCH subframe, when the channel quality between the UE and gNodeB comprises a partial reciprocity indicative of a non-ideal channel quality. In some embodiments, the UE 102 is configured to determine the channel reciprocity based on measurements at the UE 102. However, in other embodiments, the UE 102 is configured to determine the channel reciprocity based on information of the channel reciprocity received from the gNodeB 104.

[0034] In one example embodiment, the number of PURCH OFDM symbols to be utilized for providing the UL request to the gNodeB 104 is determined at the UE 102 based on defining a reciprocity offset $I_{reciprocity}$, which is used to indicate the offset between partial reciprocity indicative of a non-ideal channel quality and full reciprocity indicative of an ideal channel quality. In some embodiments, the reciprocity offset $I_{reciprocity}$ is indicative of the channel reciprocity. Further, the gNodeB 104 is configured to configure thresholds so as to allow UE 102 to derive the number of OFDM symbols L for the transmission of the UL request. In this example embodiment, three levels of thresholds are configured by higher layers or the gNodeB 104 in a cell specific manner via 5G master information block (xMIB), 5G system information block (xSIB), or RRC signalling, i.e., $Threshold_0$, $Threshold_1$, $Threshold_2$. In this case, UE may derive the number of OFDM symbols forming the PURCH based on the following equation:

$$\begin{cases} L = 1, I_{reciprocity} \leq Threshold_0 \\ L = 2, Threshold_0 < I_{reciprocity} \leq Threshold_1 \\ L = 3, Threshold_1 < I_{reciprocity} \leq Threshold_2 \\ L = 4, I_{reciprocity} > Threshold_2 \end{cases} \quad (2)$$

Where L indicates the number of PURCH OFDM symbols within the predefined subframe to be utilized for mapping the UL request. For example, when $L = 1$, the UL request is provided to the gNodeB 104 from the UE 102 only once, based on mapping the UL request to a single PURCH OFDM symbol associated with the predefined PURCH subframe. Similarly, when $L = 4$, the UL request is repeatedly provided to the gNodeB 104 from the UE 102 four times, based on mapping the UL request to a four different PURCH OFDM symbols associated with the predefined PURCH subframe. Equation (2) above is one possible way of determining the number of PURCH OFDM symbols to be utilized to map the UL request. However, in other embodiments, other methods/equations for determining the number of PURCH OFDM symbols could be utilized.

[0035] Upon determining the number of OFDM symbols L , in some embodiments, the UE 102 is further configured to identify the set of PURCH OFDM symbols (e.g., determine the symbol indexes of the set of PURCH OFDM symbols) within the PURCH

subframe to be utilized for providing the UL control request to the gNodeB, corresponding to the determined number of OFDM symbols, based on downlink measurements of gNodeB beams associated with the PURCH OFDM symbols in the predefined PURCH subframe. For example, in some embodiments, UE 102 is configured to determine beam reference signal (BRS) receive powers associated with the OFDM symbols of the predefined PURCH subframe, in order to identify the set of PURCH OFDM symbols forming the PURCH within the predefined PURCH subframe. In some embodiments, the UE 102 is further configured to determine the subcarrier indexes or resource block indexes associated with the set of OFDM symbols.

[0036] Alternately, in other embodiments, the resource configuration comprising the set of PURCH OFDM symbols associated with the PURCH is determined at the UE 102 based on information of the set of PURCH OFDM symbols provided by higher level signaling. In some embodiments, the information on the set of PURCH OFDM symbols to be utilized for mapping the UL request is received at the UE 102 from the gNodeB 104. In some embodiments, the information on the set of PURCH OFDM symbols received at the UE 102 by higher level signaling or from the gNodeB 104 can comprise information on one or more of a number of OFDM symbols within the PURCH subframe to be utilized to map the UL request, symbol indexes (i.e., identifiers) of the PURCH OFDM symbols to be used for mapping the UL request, subcarrier indexes, resource block indexes and beam indexes that identify a set of gNodeB beams respectively associated with the set of PURCH OFDM symbols. In some embodiments, the beam index for the OFDM symbols associated with a subframe (e.g., the PURCH subframe) is predefined. In such embodiments, the gNodeB 104 can be configured to generate and provide a PURCH information signal 107 comprising information on the set of PURCH OFDM symbols forming the PURCH to the UE 102. In some embodiments, the PURCH information signal 107 can be provided using 5G master information block (xMIB), 5G system information block (xSIB) or RRC signaling. In one example embodiment, the PURCH information signal 107 comprises a single resource index I_{PURCH} . In such embodiments, UE may derive the frequency resource m and symbol index k for mapping the UL request as,

$$\begin{cases} k = \left\lfloor \frac{I_{PURCH}}{K_{PURCH}} \right\rfloor, & k = 0, 1, \dots, K_{PURCH} - 1 \\ m = I_{PURCH} \bmod K_{PURCH} \end{cases} \quad (3)$$

Where k is the OFDM symbol index and m is the frequency resource for mapping the UL request.

[0037] In some embodiments, the PURCH information signal 107 can be part of the PURCH signal 105. In such embodiments, the PURCH signal 105 can provide information of the predefined PURCH subframe as well as the set of PURCH OFDM symbols forming the PURCH within the predefined PURCH subframe to be utilized by the UE 102 for mapping the UL request. In some embodiments, the gNodeB 104 can be configured to determine the set of PURCH OFDM symbols to be utilized for mapping the UL request by implementing equation (2) as explained above and also based on downlink measurements (e.g., BRS receive powers) of the predefined PURCH subframe. However, in other embodiments, the set of PURCH OFDM symbols can be determined at the gNodeB 104 differently.

[0038] In some embodiments, when the channel reciprocity comprises full reciprocity and when an information of a best gNodeB beam (e.g., a maintained Tx/Rx beam pair) associated with the predefined PURCH subframe is available at the UE 102, the UE 102 may be configured to map the UL request to an OFDM symbol associated with the best gNodeB beam, in order to provide the UL request to the gNodeB 104. Similarly, when the channel reciprocity comprises full reciprocity and when information of a best gNodeB beam associated with the predefined PURCH subframe is available at the gNodeB 104, the gNodeB 104 may provide at least one of a symbol index, a frequency resource index (e.g., subcarrier index) or a beam index associated with the best gNodeB beam to the UE 102, in order to map the UL request.

[0039] Upon determining the set of PURCH OFDM symbols forming the PURCH, the UE 102 is configured to map the UL request to the PURCH, thereby generating a set of mapped PURCH OFDM symbols, in order to provide the UL request to the gNodeB 104. In some embodiments, the UL request is provided to the gNodeB from the UE 102 based on generating a set of UL request signals 106 respectively

associated with set of mapped PURCH OFDM symbols in the PURCH. In such embodiments, the UE 102 is configured to generate the set of UL request signals 106 from the set of mapped PURCH OFDM symbols associated with the PURCH. In such embodiments, each of the UL request signal in the set of UL request signals 106 comprises the UL request. In some embodiments, when the set of PURCH OFDM symbols or the PURCH comprise a single PURCH OFDM symbol (e.g., in full reciprocity scenario), the set of UL request signals 106 comprises a single UL request signal respectively associated with the single PURCH OFDM symbol. Similarly, when the set of PURCH OFDM symbols forming the PURCH comprise a plurality of PURCH OFDM symbols (e.g., in the partial reciprocity scenario), the set of UL request signals 106 comprises a plurality of UL request signals respectively associated with the plurality of PURCH OFDM symbols. Once the set of UL request signals 106 are generated at the UE 102, the UE 102 is further configured to provide the set of UL request signals 106 to the gNodeB 104.

[0040] Once the UE 102 provides the set of UL request signals 106 comprising the UL request to the gNodeB 104, the gNodeB 104 is configured to receive the set of UL request signals 106 and process the set of UL request signals 106, in order to decode the UL request. Upon successfully decoding the UL request, in some embodiments, the gNodeB 104 is configured to provide an UL resource signal 108 comprising one or more UL resources/information/reference signals for the UE 102. In some embodiments, the one or more UL resources comprises resources that the UE 102 can utilize to provide UL data associated with the UE 102 to the gNodeB 104. In some embodiments, if the UL request is not successfully decoded, the gNodeB 104 may not provide the UL resource signal 108 to the UE 102.

[0041] In some embodiments, the predefined PURCH subframe has a periodicity associated therewith (e.g., repeating at regular or predetermined time intervals) and can comprise a plurality of predefined PURCH subframes, each predefined PURCH subframe being associated with a respective time instance. In such embodiments, the UE 102 can configured to determine the set of PURCH OFDM symbols forming the PURCH on a dynamic basis for each of the plurality of the predefined PURCH subframes, based on information of a channel reciprocity at a respective time instance.

For example, in some embodiments, a first UL request associated with the UE 102 can be provided to the gNodeB 104 using a first predefined subframe of the plurality of predefined PURCH subframes during a first instance, and a second, different UL request associated with the UE 102 can be provided to the gNodeB 104 using a second predefined subframe of the plurality of predefined PURCH subframes during a second, different instance. In such embodiments, the UE 102 can be further configured to determine a first set of PURCH OFDM symbols within the first predefined PURCH subframe, in order to map the first UL request, based on a first channel reciprocity associated with the first instance.

[0042] Further, the UE 102 can be further configured to determine a second set of PURCH OFDM symbols within the second predefined PURCH subframe, in order to map the second UL request, based on a second channel reciprocity associated with the second instance. In some embodiments, a number of OFDM symbols in the first set of PURCH OFDM symbols and the second set of PURCH OFDM symbols can be different, based on the channel reciprocity at the respective time instances. In such embodiments, the PURCH signal 105 can comprise information on the first predefined PURCH subframe and the second predefined PURCH subframe. In some embodiments, the PURCH signal 105 can comprise a first PURCH signal comprising information of the first predefined PURCH subframe and a second, different PURCH signal comprising information on the second, different predefined PURCH subframe.

[0043] In some embodiments, the UE 102 is further configured to map the UL request to one or more time-frequency resources associated with 5G physical uplink control channel (xPUCCH) or 5G random access channel (xPRACH), when the PURCH subframe is not predefined or information of the predefined PURCH subframe is not available at the UE 102.

[0044] Fig. 4 illustrates a block diagram of an apparatus 400 for use in a user equipment (UE) in a 5G communication network, according to the various embodiments described herein. The UE can be described with reference to the UE 102 in Fig. 1 and the apparatus 400 can be included within the UE 102 in Fig. 1. The apparatus 400 includes a receiver circuit 420, a processing circuit 430, and a transmitter circuit 410.

Further, in some embodiments, the apparatus 400 comprises a memory circuit 440 coupled to the processing circuit 430. Each of the receiver circuit 420 and the transmitter circuit 410 are configured to be coupled to one or more antennas, which can be the same or different antenna(s). In some embodiments, the receiver circuit 420 and transmitter circuit 410 can have one or more components in common, and both can be included within a transceiver circuit, while in other aspects they are not. In various embodiments, the apparatus 400 can be included within a UE, for example, with apparatus 400 (or portions thereof) within a receiver and transmitter or a transceiver circuit of a UE. In some embodiments, the processing circuit 430 can be mapped to the baseband circuitry 804 in Fig. 8 below, and the receiver circuit 420 and the transmitter circuit 410 can be mapped to the RF circuitry 410 in Fig. 8 below.

[0045] In some embodiments, the processing circuit 430 is configured to generate an UL request comprising one or more bits of information to be provided to a gNodeB (e.g., the gNodeB 104 in Fig. 1). In some embodiments, the UL request can comprise an SR, a BRS-RP report, a BRRS request, a CSI-RS request etc. as explained above with respect to Fig. 1. Upon generating the UL request, the processing circuit 430 is further configured to map the UL request to time-frequency resources (e.g., a set of orthogonal frequency division multiplexing (OFDM) symbols) within a predefined physical uplink request channel (PURCH) subframe, in order to provide the UL request to the gNodeB. In some embodiments, the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for PURCH, associated with a radio frame, as explained above with respect to Fig. 1.

[0046] In some embodiments, the processing circuit 430 is further configured to receive a PURCH signal (e.g., the PURCH signal 105 in Fig. 1) comprising information on a resource configuration of the predefined PURCH subframe, via the receive circuit 420, from the gNodeB, prior to mapping the UL request to the resources associated with the predefined PURCH subframe. In some embodiments, the PURCH signal can comprise information on one or more predefined PURCH subframes for the UE. In some embodiments, the memory circuit 440 is configured to store the information on the one or more predefined PURCH subframes. In some embodiments, the processing

circuit 430 is further configured to process the UL request based on the physical layer procedure 200 explained above in Fig. 2 (e.g., channel coding, scrambling, modulation, layer mapping and precoding), prior to mapping the UL request to the time-frequency resources associated with the predefined PURCH subframe. In some embodiments, the processing circuit 430 is further configured to determine a PURCH comprising a set of PURCH OFDM symbols from the one or more predefined PURCH OFDM symbols within the predefined PURCH subframe, in order to map the UL request. In some embodiments, the PURCH is determined at the processing circuit 430 based on determining a number of PURCH OFDM symbols to be utilized to map the UL request and symbol indexes associated with the PURCH OFDM symbols within the PURCH subframe, as explained above with respect to Fig. 1.

[0047] In some embodiments, the number of OFDM symbols forming the PURCH are determined at the processing circuit 430 based on implementing equation (2) above. Further, in some embodiments, the symbol indexes associated with the PURCH OFDM symbols within the PURCH subframe is determined based on downlink measurements associated with the PURCH subframe at the processing circuit 430. For example, in some embodiments, the processing circuit 430 is configured to determine beam reference signal (BRS) receive powers associated with the predefined PURCH OFDM symbols within the predefined PURCH subframe, in order to determine the symbol indexes of the set of PURCH OFDM symbols forming the PURCH. In some embodiments, the number of OFDM symbols forming the PURCH comprises a single PURCH OFDM symbol, when the channel reciprocity between the UE (e.g., the UE 102 in Fig.1) and the gNodeB (e.g., the gNodeB 104 in Fig. 1) comprises a full reciprocity. Similarly, in some embodiments, the number of OFDM symbols forming the PURCH comprises a plurality of PURCH OFDM symbols, when the channel reciprocity between the UE and the gNodeB comprises a partial reciprocity. In some embodiments, the processing circuit 430 is configured to utilize an OFDM symbol associated with a best gNodeB beam (e.g., of a maintained Rx/Tx beam pair) associated with the predefined PURCH subframe, in order to map the UL request, when the channel reciprocity comprises a full reciprocity.

[0048] Alternately, in other embodiments, the PURCH is determined at the processing circuit 430 based on receiving information on the PURCH from a gNodeB associated therewith (e.g., the gNodeB 104 in Fig. 1). In such embodiments, the processing circuit 430 is configured to receive a PURCH information signal (e.g., the PURCH information signal 107 in Fig. 1) comprising information on the PURCH from the gNodeB, via the receive circuit 420. In some embodiments, the PURCH information signal can comprise information on the number of PURCH OFDM symbols within the predefined PURCH subframe to be utilized to map the UL request or the symbol indexes associated with the PURCH OFDM symbols within the predefined PURCH subframe to be utilized to map the UL request or both. Upon mapping the UL request to the PURCH, the processing circuit 430 is further configured to generate a set of mapped PURCH OFDM symbols.

[0049] Further, the processing circuit 430 is configured to generate a set of UL request signals (e.g., the set of UL request signals 106 in Fig. 1) respectively from the set of mapped PURCH OFDM symbols associated with the PURCH. In such embodiments, each UL request signal within the set of UL request signals comprises the UL request. Upon generating the set of UL request signals, the processing circuit 430 is further configured to transmit the set of UL request signals to the gNodeB, via the transmitter circuit 410. In some embodiments, the processing circuit 430 is further configured to receive a UL resource signal 108 comprising one or more UL resources/information/reference signals for the UE, from the gNodeB, via the receive circuit 420, in response to providing the set of UL request signals to the gNodeB. In some embodiments, the processing circuit 430 can utilize the UL resources within the UL resource signal 108, in order to provide UL data associated with the UE to the gNodeB. In some embodiments, the processing circuit 430 is further configured to map the UL request to one or more time-frequency resources associated with 5G physical uplink control channel (xPUCCH) or 5G random access channel (xPRACH), when the PURCH subframe is not predefined or information of the predefined PURCH subframe is not available at the processing circuit 430.

[0050] Fig. 5 illustrates a block diagram of an apparatus 500 for use in an gNodeB in a 5G communication network, according to the various embodiments described herein.

The gNodeB is described herein with reference to the gNodeB 104 in Fig. 1. The apparatus 500 includes a receiver circuit 520, a processing circuit 530, and a transmitter circuit 510. Further, in some embodiments, the apparatus 500 comprises a memory circuit 540 coupled to the processing circuit 530. Each of the receiver circuit 520 and the transmitter circuit 510 are configured to be coupled to one or more antennas, which can be the same or different antenna(s). Further, in some embodiments, the apparatus comprises a memory circuit 540 coupled to the processing circuit 530. In some embodiments, the receiver circuit 520 and the transmitter circuit 510 can have one or more components in common, and both can be included within a transceiver circuit, while in other aspects they are not. In various embodiments, the apparatus 500 can be included within an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (Evolved NodeB, eNodeB, or eNB) or a gNB or gNodeB associated with 5G communication networks. In some embodiments, the processing circuit 530 can be mapped to the baseband circuitry 804 in Fig. 8 below, and the receiver circuit 520 and the transmitter circuit 510 can be mapped to the RF circuitry 410 in Fig. 8 below.

[0051] When a UE (e.g., the UE 102 in Fig. 1) has an uplink (UL) data or some other request to be provided to a gNodeB (e.g., the gNodeB 104 in Fig.1), the UE 102 is configured to provide an UL request to the gNodeB that comprises a request to the gNodeB, for example, a scheduling request (SR) to grant UL resources for the transmission of UL data from the UE to the gNodeB. In such embodiments, the processing circuit 530 is configured to receive a set of UL request signals (e.g., the set of UL request signals 106 in Fig. 1) comprising the UL request from the UE, via the receive circuit 520. In some embodiments, each of the UL request signal of the set of UL request signals comprises the UL request. In some embodiments, the set of UL request signals is respectively associated with a set of PURCH OFDM symbols associated with a predefined physical uplink request channel (PURCH) subframe, as explained above with respect to Fig. 1. In some embodiments, the UL request from the UE is mapped onto the set of predefined PURCH OFDM symbols within the predefined PURCH subframe, that forms the PURCH.

[0052] Upon receiving the set of UL request signals from the UE, the processing circuit 530 is configured to process the set of UL request signals, in order to decode the

UL request from the UE. Upon decoding the UL request, the processing circuit 530 is configured to generate a UL resource signal (e.g., the UL resource signal 108 in Fig. 1) comprising one or more UL resources/information/reference signals for the UE and transmit the UL resource signal to the UE, via the transmit circuit 510. In some embodiments, the set of UL request signals from the UE comprises one or more UL request signals, based on a channel reciprocity between the UE and the gNodeB.

[0053] In some embodiments, the processing circuit 530 is further configured to determine a resource configuration of the predefined PURCH subframe and provide a PURCH signal (e.g., the PURCH signal 105 in Fig. 1) comprising information on the resource configuration of the predefined PURCH subframe to the UE, via the transmit circuit 510, prior to receiving the set of UL request signals from the UE. In some embodiments, the processing circuit 530 is further configured to generate the PURCH signal, prior to providing the PURCH signal to the UE. In some embodiments, the resource configuration of the predefined PURCH subframe is stored within the memory circuit 540. In some embodiments, the processing circuit 530 is further configured to determine the set of PURCH OFDM symbols of one or more predefined PURCH OFDM symbols within the predefined PURCH subframe, forming a PURCH, to be utilized by the UE to map the UL request. In some embodiments, the processing circuit 530 is configured to provide information on the set of PURCH OFDM symbols within the predefined PURCH subframe forming the PURCH to be utilized to map the UL request from the UE, as part of the PURCH signal to the UE. However, in other embodiments, the processing circuit 530 is further configured to generate a PURCH information signal (e.g., the PURCH information signal 107 in Fig. 1) comprising information on the set of PURCH OFDM symbols within the predefined PURCH subframe to be utilized to map the UL request from the UE, and transmit the PURCH information signal, via the transmit circuit 510, to the UE, prior to receiving the set of UL request signals from the UE.

[0054] In some embodiments, determining the set of PURCH OFDM symbols forming the PURCH to be utilized to map the UL request at the processing circuit 530 comprises determining a number of OFDM symbols within the set of PURCH OFDM symbols or determining symbol indexes associated with the set of PURCH OFDM

symbols within the predefined PURCH subframe or both. In some embodiments, the number of OFDM symbols within the set of PURCH OFDM symbols is determined at the processing circuit 530, based on an information of the channel reciprocity between the UE and the gNodeB. For example, in one example embodiment, when the channel reciprocity comprises a full reciprocity indicative of an ideal channel quality, the set of PURCH OFDM symbols within the predefined PURCH subframe forming the PURCH comprises a single OFDM symbol and when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality, the set of PURCH OFDM symbols within the predefined PURCH subframe forming the PURCH comprises a plurality of OFDM symbols. However, the number of OFDM symbols within the set of PURCH OFDM symbols can be chosen differently than above, based on the channel reciprocity, in other embodiments.

[0055] In some embodiments, the processing circuit 530 can be configured to implement the equation (2) above, in order to determine the number of OFDM symbols within the set of PURCH OFDM symbols. In some embodiments, one or more reciprocity thresholds are predefined at the processing circuit 530, in order to determine the number of OFDM symbols in the PURCH. In some embodiments, the channel reciprocity is compared with the one or more reciprocity thresholds, in order to determine the number of OFDM symbols forming the PURCH. However, other methods of determining the number of OFDM symbols forming the PURCH are also contemplated to be within the scope of this disclosure. In some embodiments, the processing circuit 530 is configured to determine the symbol indexes associated with the PURCH OFDM symbols within the predefined PURCH subframe forming the PURCH, to be utilized to map the UL request, based on measurements of gNodeB beams (or BRS receive powers) associated with the predefined PURCH subframe. For example, in some embodiments, PURCH OFDM symbols having highest BRS receive powers within the predefined PURCH subframe are chosen for mapping the UL request.

[0056] Fig. 6 illustrates a flowchart of a method 600 for a user equipment (UE) in a 5G communication network, according to one embodiment of the disclosure. The method 600 is explained herein with reference to the apparatus 400 in Fig. 4 and the UE 102 in the 5G communication network 100 in Fig. 1. At 602, a physical uplink

request channel (PURCH) signal (e.g., the PURCH signal 105 in Fig. 1) comprising information on a predefined PURCH subframe to be utilized to map a UL request associated with a UE (e.g., the UE 012 in Fig. 1), in order to provide the UL request to a gNodeB associated therewith (e.g., the gNodeB 104 in Fig. 1), is received at the processing circuit 430, via the receiver circuit 420. In some embodiments, the predefined PURCH subframe comprises a subframe comprising one or more predefined time-frequency resources (e.g., predefined PURCH OFDM symbols), reserved for mapping the UL request, associated with a radio frame. At 604, a UL request comprising information to be send from the UE to the gNodeB associated therewith, is generated at the processing circuit 430. At 606, a PURCH comprising a set of PURCH orthogonal frequency division multiplexing (OFDM) symbols from the one or more predefined PURCH OFDM symbols within the predefined PURCH subframe, to be utilized to map the UL request, is determined at the processing circuit 430.

[0057] In some embodiments, a number of OFDM symbols in the set of PURCH OFDM symbols is indicative of a channel reciprocity between the UE and the gNodeB. In some embodiments, the set of PURCH OFDM symbols forming the PURCH is determined at the processing circuit 430 based on measurements at the processing circuit 430. However, in other embodiments, the set of PURCH OFDM symbols forming the PURCH is determined at the processing circuit 430 based on information related to the set of PURCH OFDM symbols received at the processing circuit 430 from the gNodeB. In such embodiments, a PURCH information signal (e.g., the PURCH information signal 107 in Fig. 1) comprising information related to the set of URCH OFDM symbols forming the PURCH is received at the processing circuit 430, prior to determining the PURCH at 606 above. At 608, the UL request is mapped to each OFDM symbol of set of PURCH OFDM symbols forming the PURCH, at the processing circuit 430, thereby forming a set of mapped OFDM symbols. At 610, a set of UL request signals comprising the UL request is respectively generated from the set of mapped PURCH OFDM symbols, at the processing circuit 430. At 612, the set of UL request signals comprising the UL request is provided to the gNodeB, via the transmitter circuit 410.

[0058] Fig. 7 illustrates a flowchart of a method 700 for a gNodeB in a 5G communication network, according to one embodiment of the disclosure. The method 700 is explained herein with reference to the apparatus 500 in Fig. 5 and the gNodeB 104 in the 5G communication network 100 in Fig. 1. At 702, a physical uplink request channel (PURCH) signal (e.g., the PURCH signal 105 in Fig. 1) comprising information on one or more predefined PURCH subframes to be utilized to map a UL request from a UE (e.g., the UE 102 in Fig. 1) associated therewith, is generated at the processing circuit 530, and the PURCH signal is provided to the UE, via the transmitter circuit 510. At 704, a set of uplink (UL) request signals, each comprising the UL request from the UE, is received at the processing circuit 530, via the receiver circuit 520. In some embodiments, the set of UL request signals is respectively associated with a set of PURCH OFDM symbols in the predefined PURCH subframe and the UL request is mapped to each PURCH OFDM symbol of the set of PURCH OFDM symbols.

[0059] In some embodiments, the set of PURCH OFDM symbols within the predefined PURCH subframe to be utilized to map the UL request from the UE is determined at the processing circuit 530. In such embodiments, a PURCH information signal (e.g., the PURCH information signal 107 in Fig. 1) comprising information on the set of PURCH OFDM symbols within the predefined PURCH subframe to be utilized to map the UL request, is generated at the processing circuit 530 and provided to the UE, via the transmitter circuit 510, prior to receiving the set of UL signals from the UE at 704 above. At 706, the set of UL request signals, is processed at the processing circuit 530, in order to decode the UL request on the set of UL request signals. At 708, a UL resource signal (e.g., the UL resource signal 108) is selectively generated at the processing circuit 530 and provided to the UE, via the transmitter circuit 510, when the UL request is successfully decoded. In some embodiments, the UL resource signal comprises one or more information for the UE.

[0060] While the methods are illustrated, and described above as a series of acts or events, it will be appreciated that the illustrated ordering of such acts or events are not to be interpreted in a limiting sense. For example, some acts may occur in different orders and/or concurrently with other acts or events apart from those illustrated and/or described herein. In addition, not all illustrated acts may be required to implement one

or more aspects or embodiments of the disclosure herein. Also, one or more of the acts depicted herein may be carried out in one or more separate acts and/or phases.

[0061] Fig. 8 illustrates example components of a device 800 in accordance with some embodiments. In some embodiments, the device 800 may include application circuitry 802, baseband circuitry 804, Radio Frequency (RF) circuitry 806, front-end module (FEM) circuitry 808, one or more antennas 810, and power management circuitry (PMC) 812 coupled together at least as shown. The components of the illustrated device 800 may be included in a UE (e.g., the UE 102 in Fig. 1) or a RAN node (e.g., the gNodeB 104 in Fig. 1). In some embodiments, the device 800 may include less elements (e.g., a RAN node may not utilize application circuitry 802, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 800 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[0062] The application circuitry 802 may include one or more application processors. For example, the application circuitry 802 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 800. In some embodiments, processors of application circuitry 802 may process IP data packets received from an EPC.

[0063] The baseband circuitry 804 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 804 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 806 and to generate baseband signals for a transmit signal path of the RF circuitry 806. Baseband processing circuitry

804 may interface with the application circuitry 802 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 806. For example, in some embodiments, the baseband circuitry 804 may include a third generation (3G) baseband processor 804A, a fourth generation (4G) baseband processor 804B, a fifth generation (5G) baseband processor 804C, or other baseband processor(s) 804D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 804 (e.g., one or more of baseband processors 804A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 806. In other embodiments, some or all of the functionality of baseband processors 804A-D may be included in modules stored in the memory 804G and executed via a Central Processing Unit (CPU) 804E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 804 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 804 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0064] In some embodiments, the baseband circuitry 804 may include one or more audio digital signal processor(s) (DSP) 804F. The audio DSP(s) 804F may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 804 and the application circuitry 802 may be implemented together such as, for example, on a system on a chip (SOC).

[0065] In some embodiments, the baseband circuitry 804 may provide for communication compatible with one or more radio technologies. For example, in some

embodiments, the baseband circuitry 804 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0066] RF circuitry 806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 806 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 806 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 808 and provide baseband signals to the baseband circuitry 804. RF circuitry 806 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 804 and provide RF output signals to the FEM circuitry 808 for transmission.

[0067] In some embodiments, the receive signal path of the RF circuitry 806 may include mixer circuitry 806a, amplifier circuitry 806b and filter circuitry 806c. In some embodiments, the transmit signal path of the RF circuitry 806 may include filter circuitry 806c and mixer circuitry 806a. RF circuitry 806 may also include synthesizer circuitry 806d for synthesizing a frequency for use by the mixer circuitry 806a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 806a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 808 based on the synthesized frequency provided by synthesizer circuitry 806d. The amplifier circuitry 806b may be configured to amplify the down-converted signals and the filter circuitry 806c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 804 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 806a of the receive signal

path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0068] In some embodiments, the mixer circuitry 806a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 806d to generate RF output signals for the FEM circuitry 808. The baseband signals may be provided by the baseband circuitry 804 and may be filtered by filter circuitry 806c.

[0069] In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may be configured for super-heterodyne operation.

[0070] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 806 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 804 may include a digital baseband interface, for example, an RF interface, to communicate with the RF circuitry 806.

[0071] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0072] In some embodiments, the synthesizer circuitry 806d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 806d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0073] The synthesizer circuitry 806d may be configured to synthesize an output frequency for use by the mixer circuitry 806a of the RF circuitry 806 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 806d may be a fractional $N/N+1$ synthesizer.

[0074] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 804 or the applications processor 802 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 802.

[0075] Synthesizer circuitry 806d of the RF circuitry 806 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0076] In some embodiments, synthesizer circuitry 806d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature

generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 806 may include an IQ/polar converter.

[0077] FEM circuitry 808 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 810, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 806 for further processing. FEM circuitry 808 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 806 for transmission by one or more of the one or more antennas 810. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 806, solely in the FEM 808, or in both the RF circuitry 806 and the FEM 808.

[0078] In some embodiments, the FEM circuitry 808 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 806). The transmit signal path of the FEM circuitry 808 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 806), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 810).

[0079] In some embodiments, the PMC 812 may manage power provided to the baseband circuitry 804. In particular, the PMC 812 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 812 may often be included when the device 800 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 812 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[0080] While FIG. 8 shows the PMC 812 coupled only with the baseband circuitry 804. However, in other embodiments, the PMC 812 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 802, RF circuitry 806, or FEM 808.

[0081] In some embodiments, the PMC 812 may control, or otherwise be part of, various power saving mechanisms of the device 800. For example, if the device 800 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 800 may power down for brief intervals of time and thus save power.

[0082] If there is no data traffic activity for an extended period of time, then the device 800 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 800 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 800 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

[0083] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[0084] Processors of the application circuitry 802 and processors of the baseband circuitry 804 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 804, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 804 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As

referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[0085] While the apparatus has been illustrated, and described with respect to one or more implementations, alterations and/or modifications may be made to the illustrated examples without departing from the spirit and scope of the appended claims. In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the invention.

[0086] In particular regard to the various functions performed by the above described components (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

[0087] Examples can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including instructions that, when performed by a machine cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using

multiple communication technologies according to embodiments and examples described herein.

[0088] Example 1 is an apparatus for use in a user equipment (UE) of a 5G communication network, comprising one or more processors configured to generate an uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith; determine a physical uplink request channel (PURCH) comprising a set of PURCH orthogonal frequency division multiplexing (OFDM) symbols within a predefined PURCH subframe, to be utilized to map the UL request, wherein the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for PURCH, associated with a radio frame; and map the UL request to the set of PURCH OFDM symbols forming the PURCH to generate a set of mapped PURCH OFDM symbols, in order to subsequently provide the UL request to the gNodeB.

[0089] Example 2 is an apparatus, including the subject matter of example 1, wherein the one or more processors is further configured to generate a set of UL request signals comprising the UL request, wherein the set of UL request signals are respectively generated from the set of mapped PURCH OFDM symbols, and provide, via a radio frequency (RF) interface associated therewith, the set of UL request signals to an RF circuitry, for subsequent transmission to the gNodeB.

[0090] Example 3 is an apparatus, including the subject matter of examples 1-2, including or omitting elements, wherein a number of OFDM symbols in the set of PURCH OFDM symbols forming the PURCH is indicative of a channel reciprocity comprising a channel quality between the UE and the gNodeB.

[0091] Example 4 is an apparatus, including the subject matter of examples 1-3, including or omitting elements, wherein the set of PURCH OFDM symbols forming the PURCH is determined at the one or more processors by determining, at the one or more processors, a number of OFDM symbols within the predefined PURCH subframe to be utilized for providing the UL request to the gNodeB, based on information of the channel reciprocity; or identifying, at the one or more processors, one or more PURCH OFDM symbols within the PURCH subframe to be utilized for providing the UL request

to the gNodeB, corresponding to the number of OFDM symbols, forming the set of PURCH OFDM symbols, based on downlink measurements of gNodeB beams associated with the one or more predefined PURCH OFDM symbols in the PURCH subframe, or both.

[0092] Example 5 is an apparatus, including the subject matter of examples 1-4, including or omitting elements, wherein the set of PURCH OFDM symbols forming the PURCH is determined at the one or more processors, based on receiving a PURCH information signal comprising information on the set of PURCH OFDM symbols, at the one or more processors, from the gNodeB.

[0093] Example 6 is an apparatus, including the subject matter of examples 1-5, including or omitting elements, wherein information on the set of PURCH OFDM symbols received from the gNodeB comprises at least one of a number of OFDM symbols forming the PURCH or symbol indexes that identify the set of PURCH OFDM symbols within the PURCH subframe or beam indexes that identify the set of gNodeB beams respectively associated with the set of PURCH OFDM symbols.

[0094] Example 7 is an apparatus, including the subject matter of examples 1-6, including or omitting elements, wherein the set of PURCH OFDM symbols forming the PURCH comprises a single PURCH OFDM symbol, when the channel reciprocity comprises a full channel reciprocity indicative of an ideal channel quality, and wherein the set of PURCH OFDM symbols forming the PURCH comprises a plurality of PURCH OFDM symbols, when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality.

[0095] Example 8 is an apparatus, including the subject matter of examples 1-7, including or omitting elements, wherein the set of UL request signals comprises a single UL request signal associated with the single PURCH OFDM symbol, when the channel reciprocity comprises the full reciprocity, and wherein the set of UL request signals comprises a plurality of UL request signals respectively associated with the plurality of PURCH OFDM symbols, when the channel reciprocity comprises the full reciprocity.

[0096] Example 9 is an apparatus, including the subject matter of examples 1-8, including or omitting elements, wherein the UL request comprises a scheduling request comprising a request to the gNodeB to grant uplink resources for sending uplink data or a buffer status report comprising an indication of a payload size of the uplink data to be transmitted to the gNodeB, or a beam and CSI-RS request (BCR) comprising a request to the gNodeB to provide one or more of a beam refinement reference signal (BRRS) or a beam reference signal receiving power (BRS-RP) report or channel state information reference signal (CSI-RS).

[0097] Example 10 is an apparatus, including the subject matter of examples 1-9, including or omitting elements, wherein the one or more processors is further configured to selectively map the UL request to one or more resources associated with 5G physical uplink control channel (xPUCCH) or 5G random access channel (xPRACH), when the PURCH subframe is not predefined.

[0098] Example 11 is an apparatus, including the subject matter of examples 1-10, including or omitting elements, wherein the one or more processors is further configured to receive a PURCH signal comprising information on a resource configuration associated with one or more predefined PURCH subframes to be utilized to map the UL request, from the gNodeB, prior to determining the PURCH.

[0099] Example 12 is an apparatus, including the subject matter of examples 1-11, including or omitting elements, wherein the one or more predefined PURCH subframes has a periodicity associated therewith.

[00100] Example 13 is an apparatus, including the subject matter of examples 1-12, including or omitting elements, wherein the resource configuration associated with the one or more predefined PURCH subframes comprises one or more of a PURCH subframe offset, OFDM symbol index, occupied OFDM symbol indexes, resource block (RB) index and resource block group (RBG) index.

[00101] Example 14 is an apparatus, including the subject matter of examples 1-13, including or omitting elements, wherein the PURCH signal is cell specific and the one or

more processors is configured to receive the PURCH signal using 5G master information block (xMIB), 5G system information block (xSIB).

[00102] Example 15 is an apparatus, including the subject matter of examples 1-14, including or omitting elements, wherein the PURCH signal is UE specific and the one or more processors is configured to receive the PURCH signal using radio resource control (RRC) signaling.

[00103] Example 16 is an apparatus, including the subject matter of examples 1-15, including or omitting elements, wherein the one or more processors is configured to determine the set of PURCH OFDM symbols forming the PURCH on a dynamic basis for the one or more predefined subframes, based on information of a channel reciprocity at a respective time instance.

[00104] Example 17 is an apparatus for use in a user equipment (UE) of a 5G communication network, comprising one or more processors configured to generate a first uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith in a first instance; determine a first set of physical uplink channel (PURCH) orthogonal frequency domain multiplexing (OFDM) symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a first predefined PURCH subframe, to be utilized to map the first UL request, in order to provide the first UL request to the gNodeB, wherein a number of OFDM symbols in the first set of PURCH OFDM symbols is indicative of a first channel reciprocity comprising a channel quality between the UE and the gNodeB during the first instance; generate a second, different uplink (UL) request comprising information related to request from the UE to a gNodeB associated therewith in a second, different instance; and determine a second set of PURCH OFDM symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a second, different predefined PURCH subframe, to be utilized to map the second UL request, in order to provide the second UL request to the gNodeB, wherein a number of OFDM symbols in the second set of PURCH OFDM symbols is indicative of a second, different channel reciprocity comprising a channel quality between the UE and the gNodeB during the second instance.

[00105] Example 18 is an apparatus, including the subject matter of example 17, wherein the one or more processors is further configured to map the first UL request to the first set of PURCH OFDM symbols to generate a first set of mapped PURCH OFDM symbols; and generate a first set of UL request signals comprising the UL request, wherein the first set of UL request signals are respectively generated from the first set of mapped PURCH OFDM symbols.

[00106] Example 19 is an apparatus, including the subject matter of examples 17-18, including or omitting elements, wherein the one or more processors is further configured to map the second UL request to the second set of PURCH OFDM symbols to generate a second set of mapped PURCH OFDM symbols; and generate a second set of UL request signals comprising the UL request, wherein the second set of UL request signals are respectively generated from the second set of mapped PURCH OFDM symbols.

[00107] Example 20 is an apparatus, including the subject matter of examples 17-19, including or omitting elements, further comprising a radio frequency (RF) interface configured to provide the first set of UL request signals and the second set of UL request signals to an RF circuitry, for subsequent transmission to the gNodeB.

[00108] Example 21 is an apparatus, including the subject matter of examples 17-20, including or omitting elements, wherein the one or more processors is further configured to receive a PURCH signal comprising information on the first predefined PURCH subframe and the second predefined PURCH subframe from the gNodeB associated therewith, prior to determining the first set of PURCH OFDM symbols and the second set of PURCH OFDM symbols.

[00109] Example 22 is an apparatus, including the subject matter of examples 17-21, including or omitting elements, wherein the number of OFDM symbols in the first set of PURCH OFDM symbols and the number of OFDM symbols in the second set of PURCH OFDM symbols are different.

[00110] Example 23 is an apparatus, including the subject matter of examples 17-22, including or omitting elements, wherein the PURCH signal comprises a first PURCH

signal comprising information of the first predefined PURCH subframe and a second, different PURCH signal comprising information on the second, different predefined PURCH subframe.

[00111] Example 24 is an apparatus for use in a gNodeB of a 5G communication network, comprising one or more processors configured to receive one or more uplink (UL) request signals, each comprising a UL request from a UE, wherein the UL request is mapped to one or more orthogonal frequency division multiplexing (OFDM) symbols respectively associated with the one or more UL request signals, and wherein the one or more OFDM symbols corresponds to one or more predefined physical uplink request channel (PURCH) OFDM symbols reserved for mapping UL requests from a UE, associated with a predefined PURCH subframe within a radio frame; and process the one or more UL request signals, in order to decode the UL request on the one or more UL request signals; and selectively generate a UL resource signal, when the UL request is successfully decoded, wherein the UL resource signal comprises one or more information for the UE.

[00112] Example 25 is an apparatus, including the subject matter of example 24, further comprising a radio frequency (RF) interface configured to provide the UL resource signal to an RF circuitry, for subsequent transmission to the UE.

[00113] Example 26 is an apparatus, including the subject matter of examples 24-25, including or omitting elements, wherein the one or more processors is further configured to determine a resource configuration of the predefined PURCH subframe comprising the predefined PURCH OFDM symbols reserved for mapping UL requests; and provide a PURCH signal comprising information on the resource configuration of the predefined PURCH subframe to the RF circuitry, via the RF interface, for subsequent transmission to the UE, prior to receiving the one or more UL request signals.

[00114] Example 27 is an apparatus, including the subject matter of examples 24-26, including or omitting elements, wherein the one or more processors is further configured to determine the one or more PURCH OFDM symbols within the predefined PURCH subframe that is utilized to map the UL request; and provide a PURCH information signal comprising information on the one or more PURCH OFDM symbols within the

predefined PURCH subframe to the RF circuitry, via the RF interface, for subsequent transmission to the UE, prior to receiving the one or more UL request signals.

[00115] Example 28 is an apparatus, including the subject matter of examples 24-27, including or omitting elements, wherein the one or more PURCH OFDM symbols is determined at the one or more processors, at least in part, based on a channel reciprocity comprising a channel quality between the UE and the gNodeB, and wherein the one or more PURCH OFDM symbols comprise a single PURCH OFDM symbol when the channel reciprocity comprises a full reciprocity indicative of an ideal channel quality.

[00116] Example 29 is an apparatus, including the subject matter of examples 24-28, including or omitting elements, wherein the one or more PURCH OFDM symbols comprise a plurality of PURCH OFDM symbols when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality.

[00117] Example 30 is an apparatus for use in a user equipment (UE) of a 5G communication network, comprising means for generating an uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith; means for determining a physical uplink request channel (PURCH) comprising a set of PURCH orthogonal frequency division multiplexing (OFDM) symbols within a predefined PURCH subframe, to be utilized to map the UL request, wherein the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for PURCH, associated with a radio frame; and means for mapping the UL request to the set of PURCH OFDM symbols forming the PURCH to generate a set of mapped PURCH OFDM symbols, in order to subsequently provide the UL request to the gNodeB.

[00118] Example 31 is an apparatus, including the subject matter of example 30, further comprising means for generating a set of UL request signals comprising the UL request, wherein the set of UL request signals are respectively generated from the set of mapped PURCH OFDM symbols, and means for providing, the set of UL request signals to the gNodeB.

[00119] Example 32 is an apparatus, including the subject matter of examples 30-31, including or omitting elements, wherein a number of OFDM symbols in the set of PURCH OFDM symbols forming the PURCH is indicative of a channel reciprocity comprising a channel quality between the UE and the gNodeB.

[00120] Example 33 is an apparatus, including the subject matter of examples 30-32, including or omitting elements, wherein determining the PURCH comprising the set of PURCH OFDM symbols comprises determining a number of OFDM symbols within the predefined PURCH subframe to be utilized for providing the UL request to the gNodeB, based on information of the channel reciprocity; or identifying one or more PURCH OFDM symbols within the PURCH subframe to be utilized for providing the UL request to the gNodeB, corresponding to the number of OFDM symbols, forming the set of PURCH OFDM symbols, based on downlink measurements of gNodeB beams associated with the one or more predefined PURCH OFDM symbols in the PURCH subframe, or both.

[00121] Example 34 is an apparatus, including the subject matter of examples 30-33, including or omitting elements, wherein the set of PURCH OFDM symbols forming the PURCH is determined based on receiving a PURCH information signal comprising information on the set of PURCH OFDM symbols, at the one or more processors, from the gNodeB.

[00122] Example 35 is an apparatus, including the subject matter of examples 30-34, including or omitting elements, wherein information on the set of PURCH OFDM symbols received from the gNodeB comprises at least one of a number of OFDM symbols forming the PURCH or symbol indexes that identify the set of PURCH OFDM symbols within the PURCH subframe or beam indexes that identify the set of gNodeB beams respectively associated with the set of PURCH OFDM symbols.

[00123] Example 36 is an apparatus, including the subject matter of examples 30-35, including or omitting elements, wherein the set of PURCH OFDM symbols forming the PURCH comprises a single PURCH OFDM symbol, when the channel reciprocity comprises a full channel reciprocity indicative of an ideal channel quality, and wherein the set of PURCH OFDM symbols forming the PURCH comprises a plurality of PURCH

OFDM symbols, when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality.

[00124] Example 37 is an apparatus, including the subject matter of examples 30-36, including or omitting elements, wherein the set of UL request signals comprises a single UL request signal associated with the single PURCH OFDM symbol, when the channel reciprocity comprises the full reciprocity, and wherein the set of UL request signals comprises a plurality of UL request signals respectively associated with the plurality of PURCH OFDM symbols, when the channel reciprocity comprises the full reciprocity.

[00125] Example 38 is an apparatus, including the subject matter of examples 30-37, including or omitting elements, wherein the UL request comprises a scheduling request comprising a request to the gNodeB to grant uplink resources for sending uplink data or a buffer status report comprising an indication of a payload size of the uplink data to be transmitted to the gNodeB, or a beam and CSI-RS request (BCR) comprising a request to the gNodeB to provide one or more of a beam refinement reference signal (BRRS) or a beam reference signal receiving power (BRS-RP) report or channel state information reference signal (CSI-RS).

[00126] Example 39 is an apparatus, including the subject matter of examples 30-38, including or omitting elements, further comprising means for selectively mapping the UL request to one or more resources associated with 5G physical uplink control channel (xPUCCH) or 5G random access channel (xPRACH), when the PURCH subframe is not predefined.

[00127] Example 40 is an apparatus, including the subject matter of examples 30-39, including or omitting elements, further comprising means for receiving a PURCH signal comprising information on a resource configuration associated with one or more predefined PURCH subframes to be utilized to map the UL request, from the gNodeB, prior to determining the PURCH.

[00128] Example 41 is an apparatus, including the subject matter of examples 30-40, including or omitting elements, wherein the one or more predefined PURCH subframes has a periodicity associated therewith.

[00129] Example 42 is an apparatus, including the subject matter of examples 30-41, including or omitting elements, wherein the resource configuration associated with the one or more predefined PURCH subframes comprises one or more of a PURCH subframe offset, OFDM symbol index, occupied OFDM symbol indexes, resource block (RB) index and resource block group (RBG) index.

[00130] Example 43 is an apparatus, including the subject matter of examples 30-42, including or omitting elements, wherein the PURCH signal is cell specific and the one or more processors is configured to receive the PURCH signal using 5G master information block (xMIB), 5G system information block (xSIB).

[00131] Example 44 is an apparatus, including the subject matter of examples 30-43, including or omitting elements, wherein the PURCH signal is UE specific and the one or more processors is configured to receive the PURCH signal using radio resource control (RRC) signaling.

[00132] Example 45 is an apparatus, including the subject matter of examples 30-44, including or omitting elements, wherein the set of PURCH OFDM symbols forming the PURCH is determined on a dynamic basis for the one or more predefined subframes, based on information of a channel reciprocity at a respective time instance.

[00133] Example 46 is an apparatus for use in a user equipment (UE) of a 5G communication network, comprising means for generating a first uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith in a first instance; means for determining a first set of physical uplink channel (PURCH) orthogonal frequency domain multiplexing (OFDM) symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a first predefined PURCH subframe, to be utilized to map the first UL request, in order to provide the first UL request to the gNodeB, wherein a number of OFDM symbols in the first set of PURCH OFDM symbols is indicative of a first channel reciprocity comprising a channel quality between the UE and the gNodeB during the first instance; means for generating a second, different uplink (UL) request comprising information related to request from the UE to a gNodeB associated therewith in a second, different instance; and means for determining a second set of PURCH OFDM

symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a second, different predefined PURCH subframe, to be utilized to map the second UL request, in order to provide the second UL request to the gNodeB, wherein a number of OFDM symbols in the second set of PURCH OFDM symbols is indicative of a second, different channel reciprocity comprising a channel quality between the UE and the gNodeB during the second instance.

[00134] Example 47 is an apparatus, including the subject matter of example 46, further comprising means for mapping the first UL request to the first set of PURCH OFDM symbols to generate a first set of mapped PURCH OFDM symbols; and means for generating a first set of UL request signals comprising the UL request, wherein the first set of UL request signals are respectively generated from the first set of mapped PURCH OFDM symbols.

[00135] Example 48 is an apparatus, including the subject matter of examples 46-47, including or omitting elements, further comprising means for mapping the second UL request to the second set of PURCH OFDM symbols to generate a second set of mapped PURCH OFDM symbols; and means for generating a second set of UL request signals comprising the UL request, wherein the second set of UL request signals are respectively generated from the second set of mapped PURCH OFDM symbols.

[00136] Example 49 is an apparatus, including the subject matter of examples 46-48, including or omitting elements, further comprising means for providing the first set of UL request signals and the second set of UL request signals to the gNodeB.

[00137] Example 50 is an apparatus, including the subject matter of examples 46-49, including or omitting elements, further comprising means for receiving a PURCH signal comprising information on the first predefined PURCH subframe and the second predefined PURCH subframe from the gNodeB associated therewith, prior to determining the first set of PURCH OFDM symbols and the second set of PURCH OFDM symbols.

[00138] Example 51 is an apparatus, including the subject matter of examples 46-50, including or omitting elements, wherein the number of OFDM symbols in the first set of

PURCH OFDM symbols and the number of OFDM symbols in the second set of PURCH OFDM symbols are different.

[00139] Example 52 is an apparatus, including the subject matter of examples 46-51, including or omitting elements, wherein the PURCH signal comprises a first PURCH signal comprising information of the first predefined PURCH subframe and a second, different PURCH signal comprising information on the second, different predefined PURCH subframe.

[00140] Example 53 is an apparatus for use in a gNodeB of a 5G communication network, comprising means for receiving one or more uplink (UL) request signals, each comprising a UL request from a UE, wherein the UL request is mapped to one or more orthogonal frequency division multiplexing (OFDM) symbols respectively associated with the one or more UL request signals, and wherein the one or more OFDM symbols corresponds to one or more predefined physical uplink request channel (PURCH) OFDM symbols reserved for mapping UL requests from a UE, associated with a predefined PURCH subframe within a radio frame; means for processing the one or more UL request signals, in order to decode the UL request on the one or more UL request signals; and means for selectively generating a UL resource signal, when the UL request is successfully decoded, wherein the UL resource signal comprises one or more information for the UE.

[00141] Example 54 is an apparatus, including the subject matter of example 53, further comprising means for providing the UL resource signal to the UE.

[00142] Example 55 is an apparatus, including the subject matter of examples 53-54, including or omitting elements, further comprising means for determining a resource configuration of the predefined PURCH subframe comprising the predefined PURCH OFDM symbols reserved for mapping UL requests; and means for providing a PURCH signal comprising information on the resource configuration of the predefined PURCH subframe to the UE, prior to receiving the one or more UL request signals.

[00143] Example 56 is an apparatus, including the subject matter of examples 53-55, including or omitting elements, further comprising means for determining the one or

more PURCH OFDM symbols within the predefined PURCH subframe that is utilized to map the UL request; and means for providing a PURCH information signal comprising information on the one or more PURCH OFDM symbols within the predefined PURCH subframe to the UE, prior to receiving the one or more UL request signals.

[00144] Example 57 is an apparatus, including the subject matter of examples 53-56, including or omitting elements, wherein the one or more PURCH OFDM symbols is determined, at least in part, based on a channel reciprocity comprising a channel quality between the UE and the gNodeB, and wherein the one or more PURCH OFDM symbols comprise a single PURCH OFDM symbol when the channel reciprocity comprises a full reciprocity indicative of an ideal channel quality.

[00145] Example 58 is an apparatus, including the subject matter of examples 53-57, including or omitting elements, wherein the one or more PURCH OFDM symbols comprise a plurality of PURCH OFDM symbols when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality.

[00146] Various illustrative logics, logical blocks, modules, and circuits described in connection with aspects disclosed herein can be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform functions described herein. A general-purpose processor can be a microprocessor, but, in the alternative, processor can be any conventional processor, controller, microcontroller, or state machine.

[00147] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00148] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00149] In particular regard to the various functions performed by the above described components (assemblies, devices, circuits, systems, *etc.*), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (*e.g.*, that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. An apparatus for use in a user equipment (UE) of a 5G communication network, comprising one or more processors configured to:
 - generate an uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith;
 - determine a physical uplink request channel (PURCH) comprising a set of PURCH orthogonal frequency division multiplexing (OFDM) symbols within a predefined PURCH subframe, to be utilized to map the UL request, wherein the predefined PURCH subframe comprises a subframe comprising one or more predefined PURCH OFDM symbols reserved for PURCH, associated with a radio frame; and
 - map the UL request to the set of PURCH OFDM symbols forming the PURCH to generate a set of mapped PURCH OFDM symbols, in order to subsequently provide the UL request to the gNodeB.
2. The apparatus of claim 1, wherein the one or more processors is further configured to:
 - generate a set of UL request signals comprising the UL request, wherein the set of UL request signals are respectively generated from the set of mapped PURCH OFDM symbols, and
 - provide, via a radio frequency (RF) interface associated therewith, the set of UL request signals to an RF circuitry, for subsequent transmission to the gNodeB.
3. The apparatus of any of the claims 1-2, wherein a number of OFDM symbols in the set of PURCH OFDM symbols forming the PURCH is indicative of a channel reciprocity comprising a channel quality between the UE and the gNodeB.
4. The apparatus of claim 3, wherein the set of PURCH OFDM symbols forming the PURCH is determined at the one or more processors by:

determining, at the one or more processors, a number of OFDM symbols within the predefined PURCH subframe to be utilized for providing the UL request to the gNodeB, based on information of the channel reciprocity; or

identifying, at the one or more processors, one or more PURCH OFDM symbols within the PURCH subframe to be utilized for providing the UL request to the gNodeB, corresponding to the number of OFDM symbols, forming the set of PURCH OFDM symbols, based on downlink measurements of gNodeB beams associated with the one or more predefined PURCH OFDM symbols in the PURCH subframe, or both.

5. The apparatus of claim 3, wherein the set of PURCH OFDM symbols forming the PURCH is determined at the one or more processors, based on receiving a PURCH information signal comprising information on the set of PURCH OFDM symbols, at the one or more processors, from the gNodeB.

6. The apparatus of any of the claims 3 or 5, wherein information on the set of PURCH OFDM symbols received from the gNodeB comprises at least one of a number of OFDM symbols forming the PURCH or symbol indexes that identify the set of PURCH OFDM symbols within the PURCH subframe or beam indexes that identify the set of gNodeB beams respectively associated with the set of PURCH OFDM symbols.

7. The apparatus of claim 3, wherein the set of PURCH OFDM symbols forming the PURCH comprises a single PURCH OFDM symbol, when the channel reciprocity comprises a full channel reciprocity indicative of an ideal channel quality, and wherein the set of PURCH OFDM symbols forming the PURCH comprises a plurality of PURCH OFDM symbols, when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality.

8. The apparatus of claim 7, wherein the set of UL request signals comprises a single UL request signal associated with the single PURCH OFDM symbol, when the channel reciprocity comprises the full reciprocity, and wherein the set of UL request signals comprises a plurality of UL request signals respectively associated with the

plurality of PURCH OFDM symbols, when the channel reciprocity comprises the full reciprocity.

9. The apparatus of any of the claims 1-2, wherein the UL request comprises a scheduling request comprising a request to the gNodeB to grant uplink resources for sending uplink data or a buffer status report comprising an indication of a payload size of the uplink data to be transmitted to the gNodeB, or a beam and CSI-RS request (BCR) comprising a request to the gNodeB to provide one or more of a beam refinement reference signal (BRRS) or a beam reference signal receiving power (BRS-RP) report or channel state information reference signal (CSI-RS).

10. The apparatus of any of the claims 1-2, wherein the one or more processors is further configured to selectively map the UL request to one or more resources associated with 5G physical uplink control channel (xPUCCH) or 5G random access channel (xPRACH), when the PURCH subframe is not predefined.

11. The apparatus of any of the claims 1-2, wherein the one or more processors is further configured to receive a PURCH signal comprising information on a resource configuration associated with one or more predefined PURCH subframes to be utilized to map the UL request, from the gNodeB, prior to determining the PURCH.

12. The apparatus of claim 11, wherein the one or more predefined PURCH subframes has a periodicity associated therewith.

13. The apparatus of claim 11, wherein the resource configuration associated with the one or more predefined PURCH subframes comprises one or more of a PURCH subframe offset, OFDM symbol index, occupied OFDM symbol indexes, resource block (RB) index and resource block group (RBG) index.

14. The apparatus of claim 11, wherein the PURCH signal is cell specific and the one or more processors is configured to receive the PURCH signal using 5G master information block (xMIB), 5G system information block (xSIB).

15. The apparatus of claim 11, wherein the PURCH signal is UE specific and the one or more processors is configured to receive the PURCH signal using radio resource control (RRC) signaling.

16. The apparatus of claim 11, wherein the one or more processors is configured to determine the set of PURCH OFDM symbols forming the PURCH on a dynamic basis for the one or more predefined subframes, based on information of a channel reciprocity at a respective time instance.

17. An apparatus for use in a user equipment (UE) of a 5G communication network, comprising one or more processors configured to:

- generate a first uplink (UL) request comprising information related to a request from the UE to a gNodeB associated therewith in a first instance;

- determine a first set of physical uplink channel (PURCH) orthogonal frequency domain multiplexing (OFDM) symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a first predefined PURCH subframe, to be utilized to map the first UL request, in order to provide the first UL request to the gNodeB, wherein a number of OFDM symbols in the first set of PURCH OFDM symbols is indicative of a first channel reciprocity comprising a channel quality between the UE and the gNodeB during the first instance;

- generate a second, different uplink (UL) request comprising information related to request from the UE to a gNodeB associated therewith in a second, different instance; and

- determine a second set of PURCH OFDM symbols from one or more predefined PURCH OFDM symbols reserved for UL requests associated with the UE, within a second, different predefined PURCH subframe, to be utilized to map the second UL request, in order to provide the second UL request to the gNodeB, wherein a number of OFDM symbols in the second set of PURCH OFDM symbols is indicative of a second, different channel reciprocity comprising a channel quality between the UE and the gNodeB during the second instance.

18. The apparatus of claim 17, wherein the one or more processors is further configured to receive a PURCH signal comprising information on the first predefined PURCH subframe and the second predefined PURCH subframe from the gNodeB associated therewith, prior to determining the first set of PURCH OFDM symbols and the second set of PURCH OFDM symbols.

19. The apparatus of any of the claims 17-18, wherein the number of OFDM symbols in the first set of PURCH OFDM symbols and the number of OFDM symbols in the second set of PURCH OFDM symbols are different.

20. The apparatus of claim 18, wherein the PURCH signal comprises a first PURCH signal comprising information of the first predefined PURCH subframe and a second, different PURCH signal comprising information on the second, different predefined PURCH subframe.

21. An apparatus for use in a gNodeB of a 5G communication network, comprising one or more processors configured to:

receive one or more uplink (UL) request signals, each comprising a UL request from a UE, wherein the UL request is mapped to one or more orthogonal frequency division multiplexing (OFDM) symbols respectively associated with the one or more UL request signals, and wherein the one or more OFDM symbols corresponds to one or more predefined physical uplink request channel (PURCH) OFDM symbols reserved for mapping UL requests from a UE, associated with a predefined PURCH subframe within a radio frame; and

process the one or more UL request signals, in order to decode the UL request on the one or more UL request signals; and

selectively generate a UL resource signal, when the UL request is successfully decoded, wherein the UL resource signal comprises one or more information for the UE.

22. The apparatus of claim 21, further comprising a radio frequency (RF) interface configured to provide the UL resource signal to an RF circuitry, for subsequent transmission to the UE.

23. The apparatus of claim 22, wherein the one or more processors is further configured to:

determine a resource configuration of the predefined PURCH subframe comprising the predefined PURCH OFDM symbols reserved for mapping UL requests; and

provide a PURCH signal comprising information on the resource configuration of the predefined PURCH subframe to the RF circuitry, via the RF interface, for subsequent transmission to the UE, prior to receiving the one or more UL request signals.

24. The apparatus of any of the claims 22-23, wherein the one or more processors is further configured to:

determine the one or more PURCH OFDM symbols within the predefined PURCH subframe that is utilized to map the UL request; and

provide a PURCH information signal comprising information on the one or more PURCH OFDM symbols within the predefined PURCH subframe to the RF circuitry, via the RF interface, for subsequent transmission to the UE, prior to receiving the one or more UL request signals.

25. The apparatus of claim 24, wherein the one or more PURCH OFDM symbols is determined at the one or more processors, at least in part, based on a channel reciprocity comprising a channel quality between the UE and the gNodeB, and wherein the one or more PURCH OFDM symbols comprise a single PURCH OFDM symbol when the channel reciprocity comprises a full reciprocity indicative of an ideal channel quality.

26. The apparatus of claim 25, wherein the one or more PURCH OFDM symbols comprise a plurality of PURCH OFDM symbols when the channel reciprocity comprises a partial reciprocity indicative of a non-ideal channel quality.

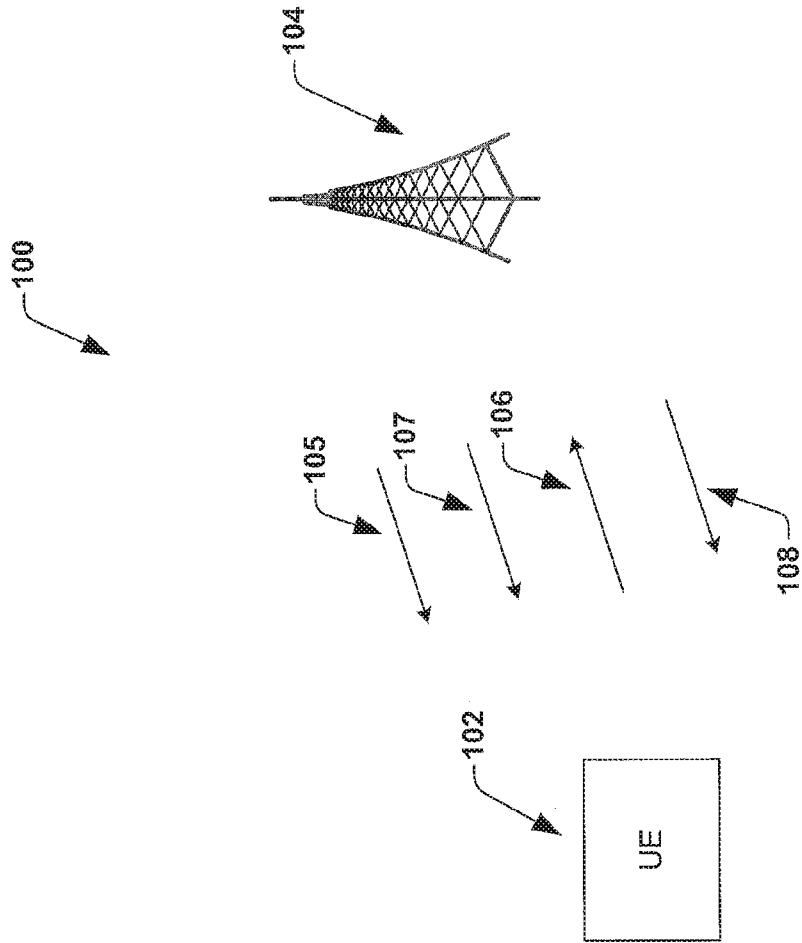


FIG. 1

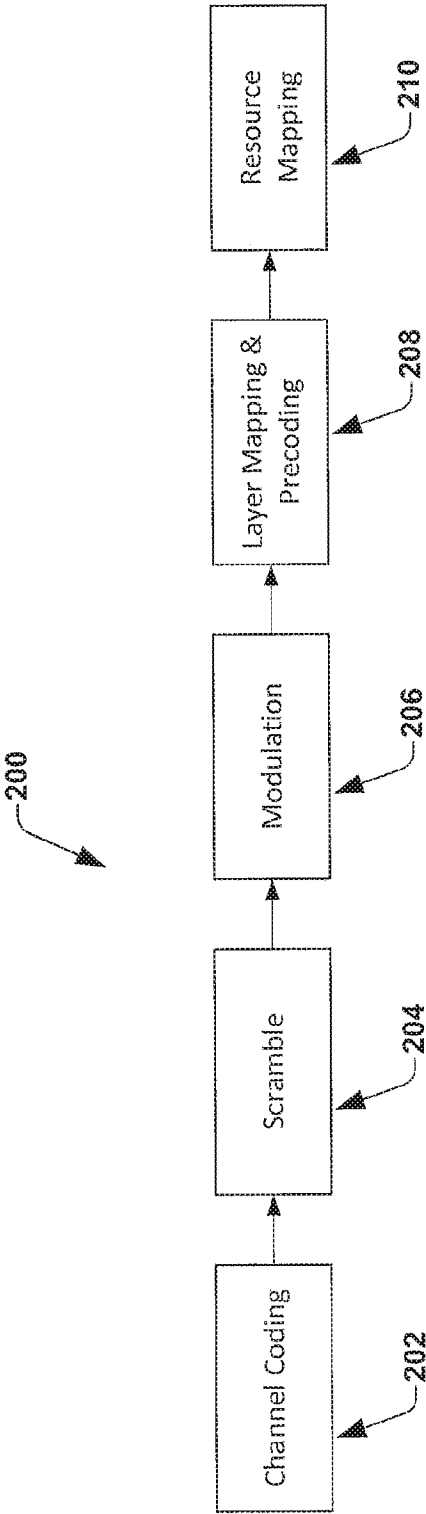


FIG. 2

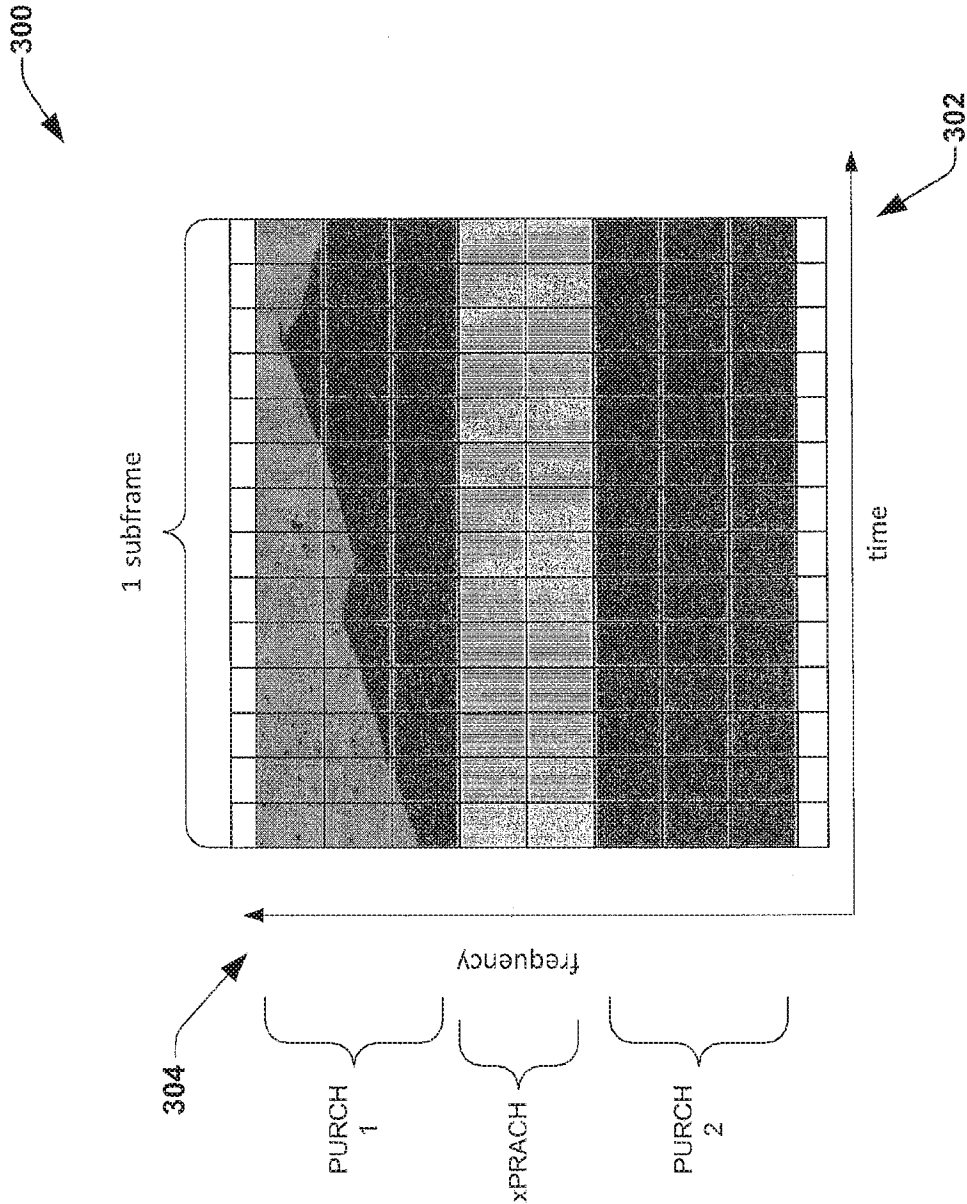


FIG. 3

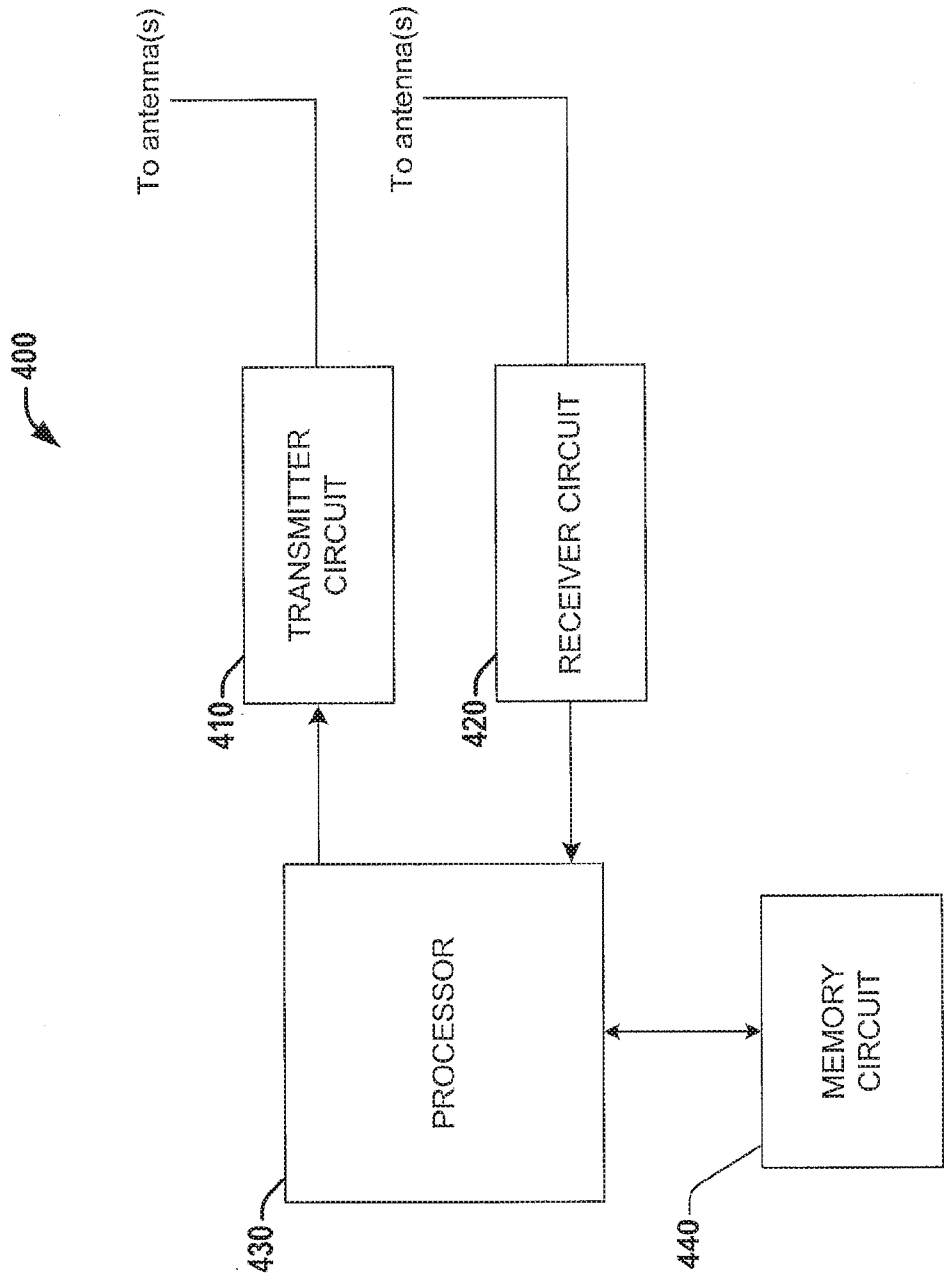


FIG. 4

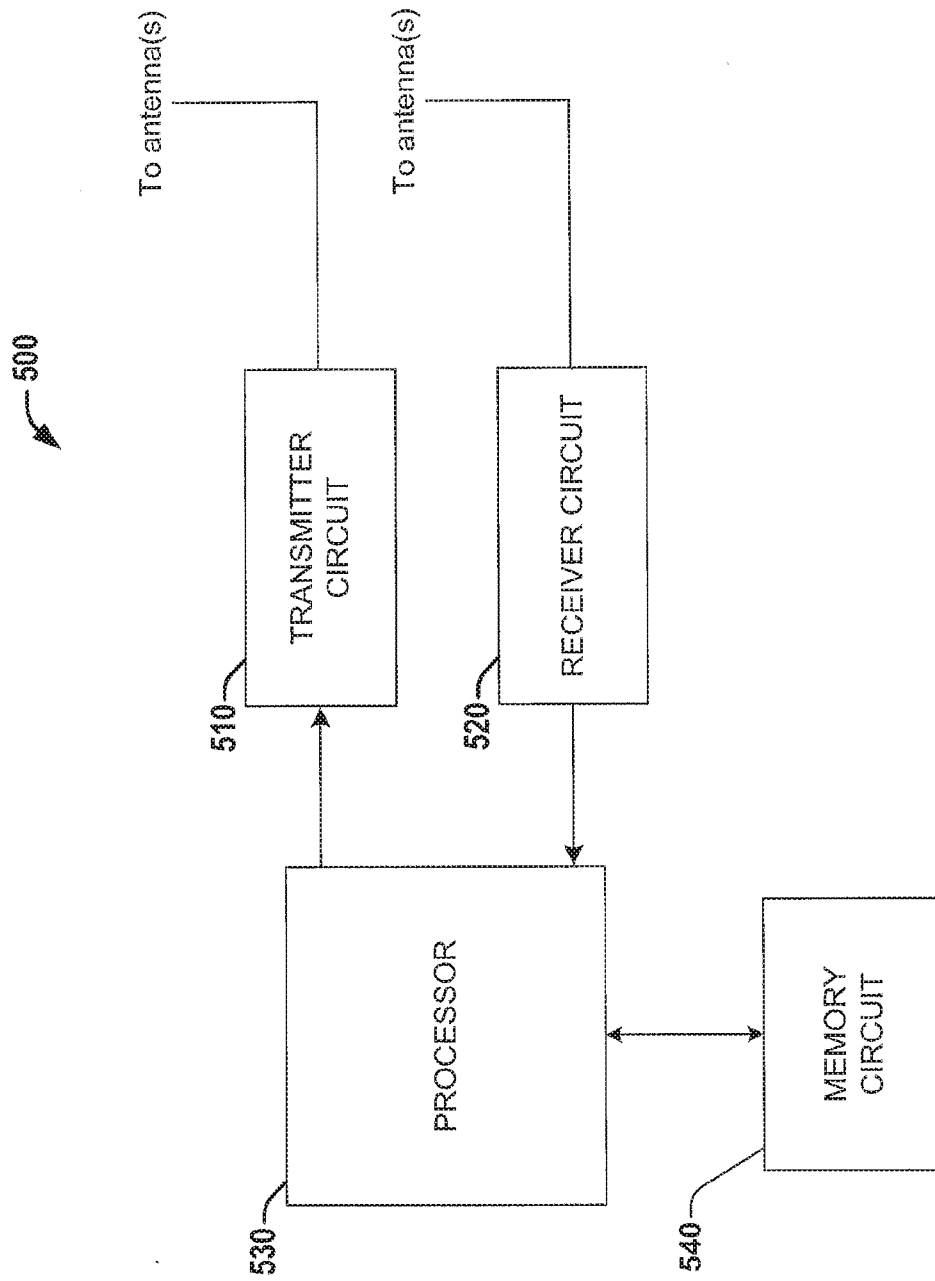


FIG. 5

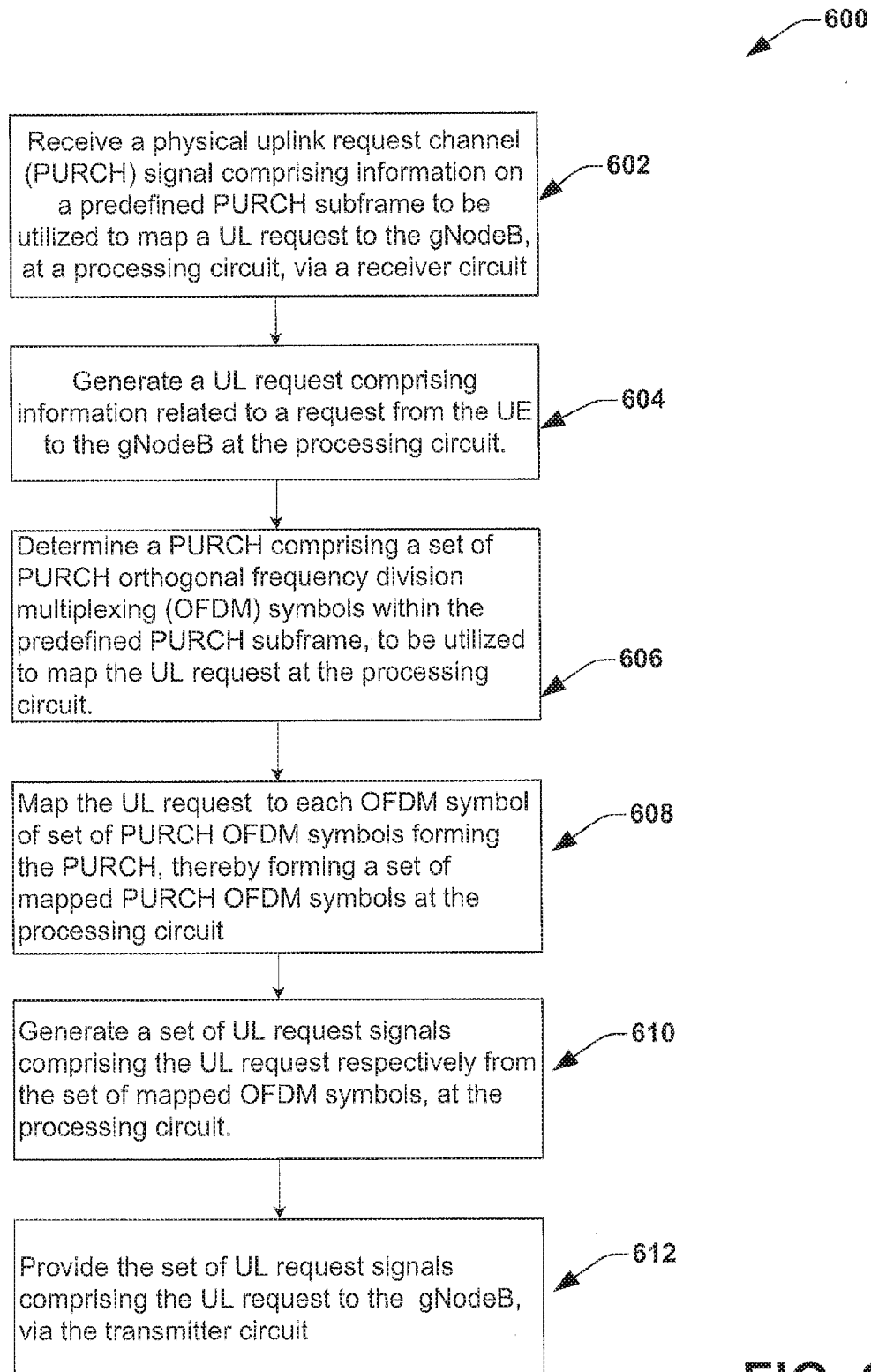


FIG. 6

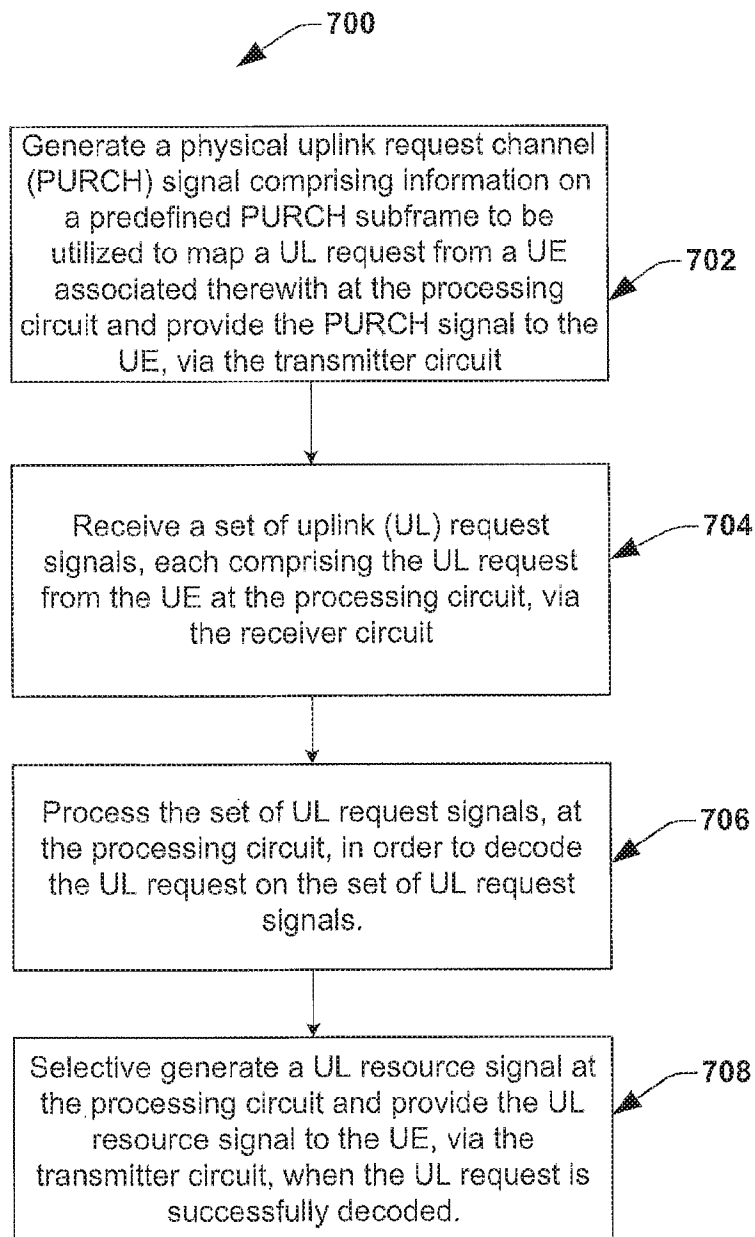


FIG. 7

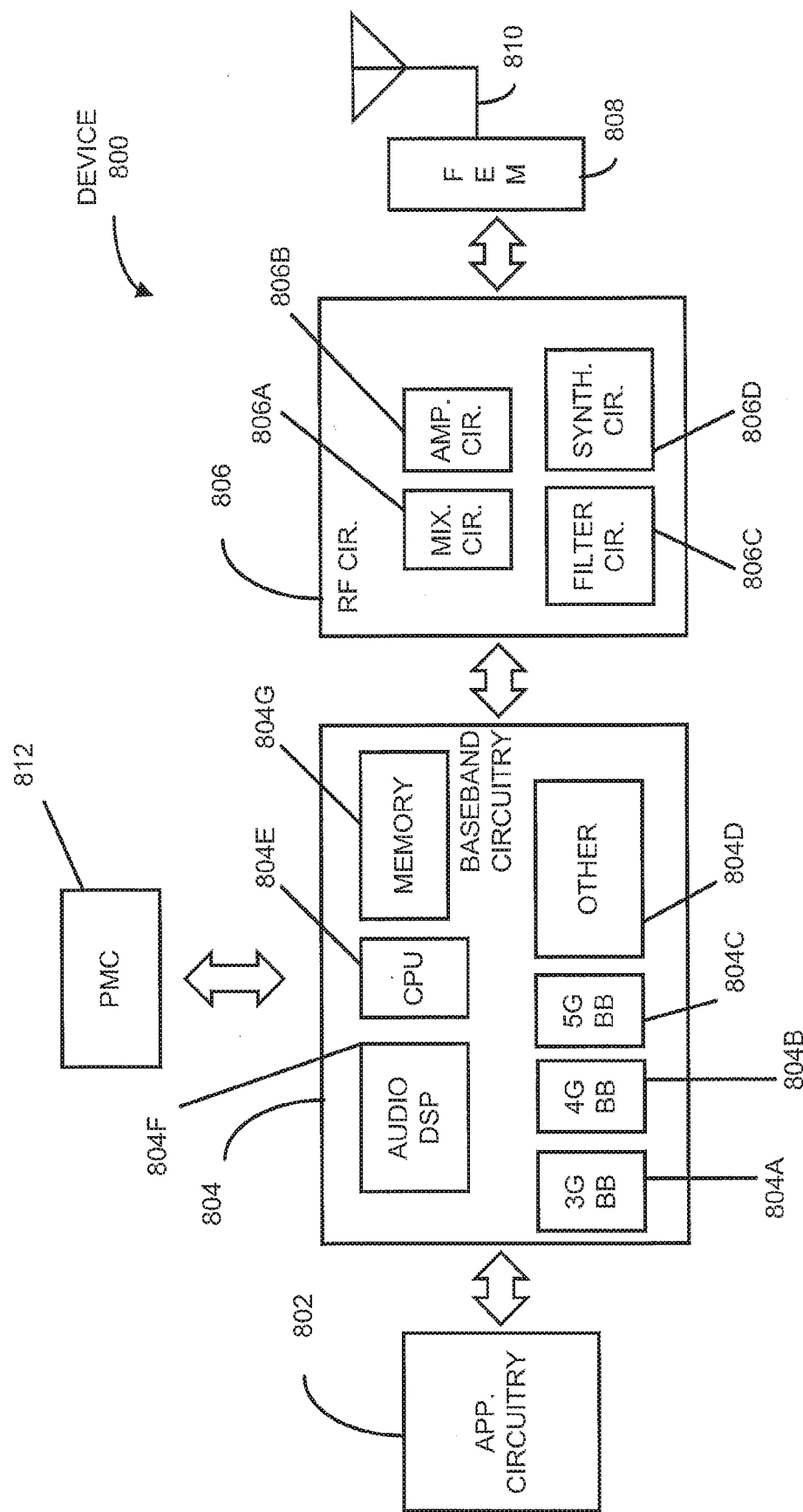


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/036513

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NOKIA ET AL: "Support for Beam Based Common Control Plane", 3GPP DRAFT; R1-165364, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE vol. RAN WG1, no. Nanjing, P.R. China; 20160523 - 20160527 13 May 2016 (2016-05-13), XP051096653, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_85/Docs/ [retrieved on 2016-05-13] page 2; figure 1 Section 2.2; page 3 - page 4 ----- -/--	1-26



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25 August 2017

Date of mailing of the international search report

06/09/2017

Name and mailing address of the ISA/

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Authorized officer

Fonseca dos Santos

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/036513

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	QUALCOMM INCORPORATED: "Candidate Frame Structures", 3GPP DRAFT; R1-164695 CANDIDATE FRAME STRUCTURES, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Nanjing, China; 20160523 - 20160527 14 May 2016 (2016-05-14), XP051089940, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_85/Docs/ [retrieved on 2016-05-14] page 4 -----	1-26