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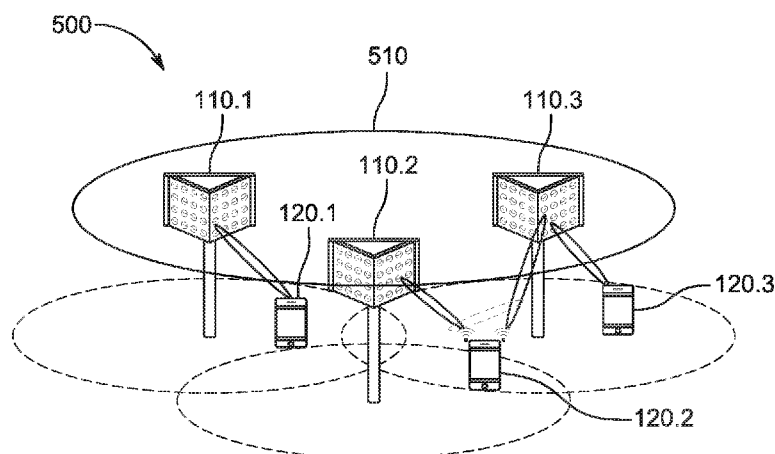


FIG. 5

(57) Abstract: Embodiments of initial access and handover in 5G networks generally described herein. In some embodiments, a UE (user equipment) decodes a plurality of channels including one or more signal quality measurements of a plurality of reference signals belonging to a plurality of nodes transmitting synchronization signals with a same cell identifier, at least a first reference signal from among the plurality of reference signals being associated with different PDSCH (physical downlink shared channel) and different control channels from at least a second reference signal from among the plurality of reference signals. The UE derives a measurement quality from the one or more signal quality measurements associated with the cell identifier. The UE computes reporting conditions based on the derived measurement quality and associated with the cell identifier and based on a plurality of measurements of the plurality of reference signals.



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INITIAL ACCESS AND HANDOVER

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PRIORITY CLAIM

[0001] This application claims priority under 35 U.S.C. § 119 to United States Provisional Patent Application Serial No. 62/372,683, filed August 9, 2016, and titled, "NR INITIAL ACCESS PROCEDURE AND HANDOVER," which is incorporated herein by reference in its entirety.

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TECHNICAL FIELD

[0002] Embodiments pertain to wireless communications. Some embodiments pertain to systems and methods for initial access and handover in New Radio (NR) or Fifth Generation (5G) networks.

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BACKGROUND

[0003] A user equipment (UE) may perform initial access or handover to connect to a cell. As the foregoing illustrates, systems and methods for initial access and handover in New Radio (NR) or Fifth Generation (5G) networks may be desirable.

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BRIEF DESCRIPTION OF THE DRAWINGS

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[0004] FIG. 1 illustrates an example system in which Transmission and Reception Point (TRP) based initial access and handover may be implemented, in accordance with some embodiments.

[0005] FIG. 2 is a graph illustrating an example beam validity time versus radius for a User Equipment (UE) traveling at 300 kilometers per hour (kmph), in accordance with some embodiments.

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[0006] FIG. 3 is a graph illustrating an example beam validity time versus radius for a User Equipment (UE) traveling at 120 kilometers per hour (kmph), in accordance with some embodiments.

5 [0007] FIG. 4 is a graph illustrating an example beam validity time versus radius for a User Equipment (UE) traveling at 30 kilometers per hour (kmph), in accordance with some embodiments.

[0008] FIG. 5 illustrates an example system in which overlaid cell based initial access and handover may be implemented, in accordance with some embodiments.

10 [0009] FIG. 6 is a functional diagram of a wireless network, in accordance with some embodiments.

[0010] FIG. 7 illustrates components of a communication device, in accordance with some embodiments.

15 [0011] FIG. 8 illustrates a block diagram of a communication device, in accordance with some embodiments.

[0012] FIG. 9 illustrates another block diagram of a communication device, in accordance with some embodiments.

DETAILED DESCRIPTION

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[0013] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

25 [0014] FIG. 1 illustrates an example system 100 in which Transmission and Reception Point (TRP) based initial access and handover may be implemented, in accordance with some embodiments. The system 100 include
30 TRPs 110.1, 110.2, and 110.3 and User Equipment (UE) 120.1, 120.2, and 120.3. FIG. 1 illustrates the concept of individual TRP based initial access and handover. For some cases identified below, the UE 120 tries to attach to the TRP 110 based on an initial access procedure in which the UE may not be able to

acquire system information. In these cases, the UE 110 may try to perform handover across each TRP 120, resulting in higher layer signaling overhead.

[0015] In the system 100, both system information acquisition and data communication are based on the TRP level. Cell search (NR (New Radio) PSS (Primary Synchronization Signal)/ SSS (Secondary Synchronization Signal)/ PBCH (Physical Broadcast Channel)/ SIB1 (System Information Block 1)) is mobility based on each TRP.

[0016] New Radio (NR) technology targets deployment scenarios of up to 100 GHz (gigahertz) carrier frequency. Due to the large propagation loss in higher carrier frequencies, beamforming technology might be used to compensate. In some cases, an evolved NodeB (eNB) (which may correspond to a TRP 110) may apply beam sweeping operation in initial access or handover measurement so that the UE 120 can detect the preferred beam(s), which may be used at a later stage to receive downlink (DL) channels. If there is reciprocity between the eNB and the UE 120, this information can be further used as prior information for later communication steps. In high mobility UEs 120 which are moving perpendicularly to the beam direction (in particular when the UE 120 is close to the eNB), the detected beam may not be valid any more.

[0017] As used herein, an eNB may include a gNB (Fifth Generation NodeB). The terms eNB and gNB may be used interchangeably throughout this document.

[0018] Beamforming and beam-sweeping may be used for initial access and for handover measurement for NR technology operating in high carrier frequency. In some cases, the initial access procedure and handover can be based on each TRP 110. However, this may not operate well in the case of a high mobility UE 120 (e.g., a UE 120 that is moving by car or train), bad blockage, and the like. Some aspects of the subject technology address these problems.

[0019] In NR, the initial access and handover may be based on an overlaid cell level (which includes one or more TRPs). The specific time/frequency regions may be configured based on potential different characteristics of the channels with other TRP-level transmissions or receptions.

[0020] FIG. 2 is a graph 200 illustrating an example beam validity time versus radius for a UE traveling at 300 kilometers per hour (kmph), in

accordance with some embodiments. FIG. 3 is a graph 300 illustrating an example beam validity time versus radius for a UE traveling at 120 kmph, in accordance with some embodiments. FIG. 4 is a graph 400 illustrating an example beam validity time versus radius for a UE traveling at 30 kmph, in accordance with some embodiments.

Table 1. Example beam validity time t, ms (UE speed = 300 kmph)

	NTX=8	NTX=16	NTX=24	NTX=32
r=10 m	13.29	6.65	4.43	3.32
r=20 m	26.58	13.29	8.86	6.65
r=100 m	132.90	66.45	44.30	33.23

Table 2. Example beam validity time t, ms (UE speed = 120 kmph)

	NTX=8	NTX=16	NTX=24	NTX=32
r=10 m	33.23	16.61	11.08	8.31
r=20 m	66.45	33.23	22.15	16.61
r=100 m	332.25	166.13	110.75	83.06

Table 3. Example beam validity time t, ms (UE speed = 30 kmph)

	NTX=8	NTX=16	NTX=24	NTX=32
r=10 m				
	132.90	66.45	44.30	33.23
r=20 m				
	265.80	132.90	88.60	66.45
r=100 m				
	1329.00	664.50	443.00	332.25

[0021] Tables 1-3 and FIGS. 2-4 show examples of the analyses on the duration of beam validity time due to UE mobility. The beam validity time is the time for maintaining the link budget up to 3dB lower than the main (peak) lobe of a beam towards the UE location. NTX stands for the number of transmit (Tx) beams for the analysis, where a larger number of NTX represents a narrower beam with higher beam gain. The beam validity time may be shorter for the case of higher UE speed and closer location to eNB. When the detected beam does not correspond to the peak (main) lobe (e.g. 1dB lower than peak lobe), the beam

validity time becomes shorter. This may result in less accurate beam tracking and sometimes the tracking/ detection might not work. This harms the initial access and handover measurement, which requires uniform coverage for all UEs. In this case, the UE may not be attached to the cell in initial access, where this procedure is the earliest step for any data communications (i.e., it can be a bottleneck for overall data communication).

[0022] Even assuming perfect beam acquisition, in the mobile UE scenario, the UE may move across different TRPs frequently (e.g., if the TRP is based on a small cell). Some handover failure happens during handover in small cells due to mobility causing a lot of higher signaling overhead during the handover procedure. In addition, taking into account the beam sweeping/ tracking operation, the frequencies of handover failure may increase further.

[0023] Aspects of the subject technology relate to overlaid cell based initial access and handover techniques. A cell may include a unit for mobility, which includes one or more TRPs.

[0024] FIG. 5 illustrates an example system 500 in which overlaid cell based initial access and handover may be implemented, in accordance with some embodiments. The system 500 includes the TRPs 110.1, 110.2, and 110.3, and the UEs 120.1, 120.2, and 120.3 of FIG. 1. In addition, an overlaid cell 510 includes the TRPs 110.1, 110.2, and 110.3.

[0025] The overlaid cell 510 is a cell that is composed of multiple nodes that transmit synchronization signals with the same cell identifier (ID). In some cases, the overlaid cell 510 may include a plurality of underlaid cells and a plurality of TRPs 110.

[0026] In the system 500, the cell identifier (ID) and the TRP ID are decoupled. The cell search (NR PSS/ SSS/ PBCH/ SIB1) and mobility are based on the overlaid cell 510. Basic system information acquisition is based on the overlaid cell 510. Data communication is based on the TRP 110.

[0027] FIG. 5 illustrates the concept of the overlaid cell 510. The overlaid cell 510 includes one or more TRPs 110. The UE 120 performs initial access to find the overlaid cell 510, rather than the TRP 110, to acquire basic system information, such as NR PSS/ SSS/ PBCH/ SIBx (where x is a number). The TRP 110 can be further identified or detected in parallel based on certain

reference signals. The amount of basic system information can be minimized and the later system information can be provided to the UE 120 in a TRP-specific or UE-specific manner. In sending the basic system information, all TRPs 110 may send identical information data (i.e., identical physical signal; in this case, an overlaid cell-specific scrambling may be applied to cope against inter-overlaid cell interferences which might carry the different system information across the overlaid cell) so that SFN (Single Frequency Network) gain can be obtained within the overlaid cell 510.

[0028] To facilitate SFN, either beamformed or non-beamformed (e.g., omni-directional Tx, quasi-omni-directional Tx, wider beam Tx, etc.) can be used from each TRP 110. In other words, a single antenna port in a given instance (e.g., OFDM (Orthogonal Frequency Division Multiplexed) symbol level, subframe level, slot level, and the like; in other words, a unit of time scaling) may be assumed to exist at the UEs 120 to safely process such combined signals. A time/ frequency region can be configured for such transmission for NR PSS/ SSS/ PBCH/ SIBx, where the single antenna port assumption in the given instance can be applied for all the concerned signals/ channels together or individually. For transmitting NR PBCH/NR SIBx, a reference signal can be defined to support demodulating. In some cases, an additional reference signal can be defined in order to support transmit diversity schemes or spatial multiplexing in the given beam. A shared data channel (e.g., NR PDSCH) can be also sent and received in such region to exploit wider beam/ SFN in case when a fall-back scheme is required for non-reliable beam information or a high speed case which can be triggered by L1/L2 control signaling, MAC (Medium Access Control) CE (Channel Element), or RRC (Radio Resource Control) signaling.

[0029] A separate reference signal for the measurement (for overlaid RSRP (Reference Signal Received Power)/ RSRQ (Reference Signal Received Quality)/ RSSI (Received Signal Strength Indicator) in the overlaid cell level) can be defined. The configuration of the separate reference signal can be provided by higher layers via NR MIB (Master Information Block) or NR SIBx across the overlaid cell. Further, the generation of the separate reference signal may be defined as a function of the overlaid cell. The new RS (Reference Signal)

can be shared with the RS for demodulating NR PBCH, SIBx, or potentially fall-backed PDSCH (Physical Downlink Shared Channel).

[0030] In some cases, the overlaid cell boundary may experience low SINR (Signal to Interference plus Noise Ratio). Due to reduced SFN gain, a hybrid approach can be used. For instance, the UE may be configured/ triggered to use either/ both overlaid cell-based RSRP/ RSRQ/ RSSI and/or TRP-based RSRP/ RSRQ/ RSSI for measurement reporting triggering. Table 4 illustrates a comparison of an example of the overlaid cell-based concept (of FIG. 5) with an example of the TRP-based concept (of FIG. 1).

Table 4. Comparison of an example of the overlaid cell-based concept with an example of the TRP-based concept.

	TRP-based	Overlaid cell-based
TRP based Tx	All channels/signals	All others than PSS/SSS/MIB/SIBx
Overlaid Cell based Tx	N/A	PSS/SSS/MIB/SIBx, (potential) fall-back mode/schemes
Handover	TRP based	Overlaid Cell based
Signaling overhead for measurement/HO in high speed	Larger (i.e. signaling stream)	Smaller
HO frequencies in small cell	More often	Less often
SFN gain	Not applicable	Applicable
TRPRS for beam detection	Yes	Yes
TRP ID acquisition	Via NR SSS	Via TRPRS possibly with assistant information from PBCH/SIBx
UE Rx BF support on PSS/SSS/	Yes	Depending on UE implementation (e.g. multiple panel)
RSRP/RSRQ for mobility	On PSS/SSS/TRPRS	On PSS/SSS/Overlaid-CRS

[0031] In some aspects, a UE stores, in a memory, reporting conditions based on an overlaid cell. The reporting conditions may be based on a plurality of reference signals of the overlaid cell. The UE determines that the reporting conditions based on the overlaid cell or the reporting conditions based on the plurality of reference signals are met. The UE encodes for transmission, to an eNB (evolved NodeB), of one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator) measurements in response to determining that the reporting conditions based on the overlaid cell or the reporting conditions based on the plurality of reference signals are met.

[0032] In some cases, the reporting conditions based on the overlaid cell are stored, in the memory of the UE. The reporting conditions based on the overlaid cell may be stored, in the memory of the UE, in response to one or more of the following events: Event A1 (Serving becomes better than threshold), Event A2 (Serving becomes worse than threshold), Event A3 (Neighbor becomes offset better than PCell/ PSCell), Event A4 (Neighbor becomes better than threshold), Event A5 (PCell/ PSCell becomes worse than threshold1 and neighbor becomes better than threshold2), and Event A6 (Neighbor becomes offset better than SCell). In some cases, the reporting conditions based on the overlaid cell may be stored, in the memory of the UE, by the eNB, in response to other event(s) that are not listed here.

[0033] The plurality of reference signals may include any time indexed reference signals. For example, the plurality of reference signals may be distinguishable by TRP ID. The time index could be, for example, an OFDM symbol level index, a slot number, a subframe number, a radio frame number, or combination(s) of those. If the transmission of xS-SCH (Fifth Generation Secondary Synchronization Channel) is predetermined, the time index counter can be used. The UE may report one or multiple detected (or decoded) time indexes. In one implementation, the eNB may autonomously chose the relationship between the time index and the beamforming index, and the UE may report the detected time index(es). The used beamforming instructions may be transparent to the UE.

[0034] In some aspects, a UE decodes a plurality of reference signals for a plurality of cells. The UE computes, based on the received plurality of reference signals, one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator) measurements for the plurality of cells. The UE determines, for each cell in the plurality of cells, a cell-level quantity for the cell based on the computed one or more of RSRP measurements, RSRQ measurements, and RSSI measurements stored in a memory. The UE selects, based on the cell-level quantities, one of the plurality of cell for the UE to join. The UE joins the selected cell to communicate with an eNB (evolved NodeB) of the selected cell.

[0035] In some aspects, an eNB stores, in a memory, basic system information of an overlaid cell including the eNB, the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System Information Block number). The eNB applies an overlaid cell specific scrambling to the basic system information to generate a scrambled signal. The eNB encodes for transmission of the scrambled signal to a UE (user equipment), the scrambled signal indicating a cell for the UE to join.

[0036] Throughout this application, the terms evolved NodeB (eNB) and next generation NodeB (gNB) may be used interchangeably. The terms Evolved Universal Terrestrial Radio Access (E-UTRA) New Radio (NR) may be used interchangeably. The terms Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Next Generation Radio Access Network (NG-RAN) may be used interchangeably. The terms Long Term Evolution (LTE) and Fifth Generation (5G) may be used interchangeably, as the subject technology may be implemented in either a LTE or a 5G system. The terms Evolved Packet Core (EPC) and Next Generation Core Network (NGCN) may be used interchangeably.

[0037] FIG. 6 shows an example of a portion of an end-to-end network architecture of a Long Term Evolution (LTE) network with various components of the network in accordance with some embodiments. As used herein, an LTE network refers to both LTE and LTE Advanced (LTE-A) networks as well as

other versions of LTE networks to be developed. The network 600 may comprise a radio access network (RAN) (e.g., as depicted, the E-UTRAN or evolved universal terrestrial radio access network) 601 and core network 620 (e.g., shown as an evolved packet core (EPC)) coupled together through an S1 interface 615. For convenience and brevity, only a portion of the core network 620, as well as the RAN 601, is shown in the example.

[0038] The subject technology may be implemented in NR or LTE, as described below. In NR, a 5G NodeB (gNB) corresponds to a LTE eNB. In NR, the Xn interface corresponds to the X2 interface of LTE. In NR, TRP corresponds to LPN of LTE. In conjunction with FIGS. 6-9, various implementations are discussed in conjunction with LTE. However, the subject technology may also be implemented in a NR environment or any other cellular environment.

[0039] The core network 620 may include a mobility management entity (MME) 622, serving gateway (serving GW) 624, and packet data network gateway (PDN GW) 626. The RAN 601 may include evolved NodeBs (eNBs) 604 (which may operate as base stations) for communicating with user equipment (UE) 602. The eNBs 604 may include macro eNBs 604a and low power (LP) eNBs 604b. The UEs 602 may correspond to any of the UEs 120A, 125A, and 130B of FIGS. 1A-1B.

[0040] The MME 622 may be similar in function to the control plane of legacy Serving GPRS Support Nodes (SGSN). The MME 622 may manage mobility aspects in access such as gateway selection and tracking area list management. The serving GW 624 may terminate the interface toward the RAN 601, and route data packets between the RAN 601 and the core network 620. In addition, the serving GW 624 may be a local mobility anchor point for inter-eNB handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement. The serving GW 624 and the MME 622 may be implemented in one physical node or separate physical nodes.

[0041] The PDN GW 626 may terminate a SGi interface toward the packet data network (PDN). The PDN GW 626 may route data packets between the EPC 620 and the external PDN, and may perform policy enforcement and

charging data collection. The PDN GW 626 may also provide an anchor point for mobility devices with non-LTE access. The external PDN can be any kind of IP network, as well as an IP Multimedia Subsystem (IMS) domain. The PDN GW 626 and the serving GW 624 may be implemented in a single physical node or separate physical nodes.

[0042] The eNBs 604 (macro and micro) may terminate the air interface protocol and may be the first point of contact for a UE 602. In some embodiments, an eNB 604 may fulfill various logical functions for the RAN 601 including, but not limited to, RNC (radio network controller functions) such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In accordance with embodiments, UEs 602 may be configured to communicate orthogonal frequency division multiplexed (OFDM) communication signals with an eNB 604 over a multicarrier communication channel in accordance with an OFDMA communication technique. The OFDM signals may comprise a plurality of orthogonal subcarriers.

[0043] The S1 interface 615 may be the interface that separates the RAN 601 and the EPC 620. It may be split into two parts: the S1-U, which may carry traffic data between the eNBs 604 and the serving GW 624, and the S1-MME, which may be a signaling interface between the eNBs 604 and the MME 622. The X2 interface may be the interface between eNBs 604. The X2 interface may comprise two parts, the X2-C and X2-U. The X2-C may be the control plane interface between the eNBs 604, while the X2-U may be the user plane interface between the eNBs 604.

[0044] With cellular networks, LP cells 604b may be typically used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with dense usage. In particular, it may be desirable to enhance the coverage of a wireless communication system using cells of different sizes, macrocells, microcells, picocells, and femtocells, to boost system performance. The cells of different sizes may operate on the same frequency band, or may operate on different frequency bands with each cell operating in a different frequency band or only cells of different sizes operating on different frequency bands. As used herein, the term LP eNB refers to any suitable

relatively LP eNB for implementing a smaller cell (smaller than a macro cell) such as a femtocell, a picocell, or a microcell. Femtocell eNBs may be typically provided by a mobile network operator to its residential or enterprise customers. A femtocell may be typically the size of a residential gateway or smaller and
5 generally connect to a broadband line. The femtocell may connect to the mobile operator's mobile network and provide extra coverage in a range of typically 30 to 60 meters. Thus, a LP eNB 604b might be a femtocell eNB since it is coupled through the PDN GW 626. Similarly, a picocell may be a wireless communication system typically covering a small area, such as in-building
10 (offices, shopping malls, train stations, etc.), or more recently in-aircraft. A picocell eNB may generally connect through the X2 link to another eNB such as a macro eNB through its base station controller (BSC) functionality. Thus, LP eNB may be implemented with a picocell eNB since it may be coupled to a macro eNB 604a via an X2 interface. Picocell eNBs or other LP eNBs LP eNB
15 604b may incorporate some or all functionality of a macro eNB LP eNB 604a. In some cases, this may be referred to as an access point base station or enterprise femtocell.

[0045] In some embodiments, the UE 602 may communicate with an access point (AP) 604c. The AP 604c may use only the unlicensed spectrum
20 (e.g., WiFi bands) to communicate with the UE 602. The AP 604c may communicate with the macro eNB 604A (or LP eNB 604B) through an Xw interface. In some embodiments, the AP 604c may communicate with the UE 602 independent of communication between the UE 602 and the macro eNB 604A. In other embodiments, the AP 604c may be controlled by the macro eNB
25 604A and use LWA, as described in more detail below.

[0046] Communication over an LTE network may be split up into 8ms frames, each of which may contain ten 1ms subframes. Each subframe of the frame, in turn, may contain two slots of 0.5ms. Each subframe may be used for
uplink (UL) communications from the UE to the eNB or downlink (DL)
30 communications from the eNB to the UE. In one embodiment, the eNB may allocate a greater number of DL communications than UL communications in a particular frame. The eNB may schedule transmissions over a variety of frequency bands (f_1 and f_2). The allocation of resources in subframes used in one

frequency band and may differ from those in another frequency band. Each slot of the subframe may contain 7-7 OFDM symbols, depending on the system used. In one embodiment, the subframe may contain 12 subcarriers. A downlink resource grid may be used for downlink transmissions from an eNB to a UE, while an uplink resource grid may be used for uplink transmissions from a UE to an eNB or from a UE to another UE. The resource grid may be a time-frequency grid, which is the physical resource in the downlink in each slot. The smallest time-frequency unit in a resource grid may be denoted as a resource element (RE). Each column and each row of the resource grid may correspond to one OFDM symbol and one OFDM subcarrier, respectively. The resource grid may contain resource blocks (RBs) that describe the mapping of physical channels to resource elements and physical RBs (PRBs). A PRB may be the smallest unit of resources that can be allocated to a UE. A resource block may be 180 kHz wide in frequency and 1 slot long in time. In frequency, resource blocks may be either 12 x 15 kHz subcarriers or 24 x 8.5 kHz subcarriers wide. For most channels and signals, 12 subcarriers may be used per resource block, dependent on the system bandwidth. In Frequency Division Duplexed (FDD) mode, both the uplink and downlink frames may be 8ms and frequency (full-duplex) or time (half-duplex) separated. In Time Division Duplexed (TDD), the uplink and downlink subframes may be transmitted on the same frequency and are multiplexed in the time domain. The duration of the resource grid 400 in the time domain corresponds to one subframe or two resource blocks. Each resource grid may comprise 12 (subcarriers) * 14 (symbols) = 168 resource elements.

[0047] Each OFDM symbol may contain a cyclic prefix (CP) which may be used to effectively eliminate Inter Symbol Interference (ISI), and a Fast Fourier Transform (FFT) period. The duration of the CP may be determined by the highest anticipated degree of delay spread. Although distortion from the preceding OFDM symbol may exist within the CP, with a CP of sufficient duration, preceding OFDM symbols do not enter the FFT period. Once the FFT period signal is received and digitized, the receiver may ignore the signal in the CP.

[0048] There may be several different physical downlink channels that are conveyed using such resource blocks, including the physical downlink

control channel (PDCCH) and the physical downlink shared channel (PDSCH). Each subframe may be partitioned into the PDCCH and the PDSCH. The PDCCH may normally occupy the first two symbols of each subframe and carries, among other things, information about the transport format and resource allocations related to the PDSCH channel, as well as H-ARQ information related to the uplink shared channel. The PDSCH may carry user data and higher layer signaling to a UE and occupy the remainder of the subframe. Typically, downlink scheduling (assigning control and shared channel resource blocks to UEs within a cell) may be performed at the eNB based on channel quality information provided from the UEs to the eNB, and then the downlink resource assignment information may be sent to each UE on the PDCCH used for (assigned to) the UE. The PDCCH may contain downlink control information (DCI) in one of a number of formats that indicate to the UE how to find and decode data, transmitted on PDSCH in the same subframe, from the resource grid. The DCI format may provide details such as number of resource blocks, resource allocation type, modulation scheme, transport block, redundancy version, coding rate etc. Each DCI format may have a cyclic redundancy code (CRC) and be scrambled with a Radio Network Temporary Identifier (RNTI) that identifies the target UE for which the PDSCH is intended. Use of the UE-specific RNTI may limit decoding of the DCI format (and hence the corresponding PDSCH) to only the intended UE.

[0049] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. FIG. 7 illustrates components of a UE in accordance with some embodiments. At least some of the components shown may be used in an eNB. The UE 700 and other components may be configured to use the synchronization signals as described herein. The UE 700 may be one of the UEs 120 and may be a stationary, non-mobile device or may be a mobile device. In some embodiments, the UE 700 may include application circuitry 702, baseband circuitry 704, Radio Frequency (RF) circuitry 706, front-end module (FEM) circuitry 708 and one or more antennas 710, coupled together at least as shown. At least some of the baseband circuitry 704, RF circuitry 706, and FEM circuitry 708 may form a transceiver. In some embodiments, other network elements, such as the eNB may contain

some or all of the components shown in FIG. 7. Other of the network elements, such as the MME, may contain an interface, such as the S1 interface, to communicate with the eNB over a wired connection regarding the UE.

[0050] The application or processing circuitry 702 may include one or more application processors. For example, the application circuitry 702 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 and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0051] The baseband circuitry 704 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 704 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 706 and to generate baseband signals for a transmit signal path of the RF circuitry 706. Baseband processing circuitry 704 may interface with the application circuitry 702 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 706. For example, in some embodiments, the baseband circuitry 704 may include a second generation (2G) baseband processor 704a, third generation (3G) baseband processor 704b, fourth generation (4G) baseband processor 704c, and/or other baseband processor(s) 704d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 7G, etc.). The baseband circuitry 704 (e.g., one or more of baseband processors 704a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 706. 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 704 may include FFT, precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 704 may

include convolution, tail-biting convolution, turbo, Viterbi, and/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

5 embodiments.

[0052] In some embodiments, the baseband circuitry 704 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (E-UTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control
10 (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 704e of the baseband circuitry 704 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s)
15 (DSP) 704f. The audio DSP(s) 704f may be 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
20 all of the constituent components of the baseband circuitry 704 and the application circuitry 702 may be implemented together such as, for example, on a system on a chip (SOC).

[0053] In some embodiments, the baseband circuitry 704 may provide for communication compatible with one or more radio technologies. For
25 example, in some embodiments, the baseband circuitry 704 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/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 704 is configured to support radio
30 communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry. In some embodiments, the device can be configured to operate in accordance with communication standards or other protocols or standards, including Institute of Electrical and Electronic Engineers (IEEE)

602.16 wireless technology (WiMax), IEEE 602.11 wireless technology (WiFi) including IEEE 602.11 ad, which operates in the 70 GHz millimeter wave spectrum, various other wireless technologies such as global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE), GSM
5 EDGE radio access network (GERAN), universal mobile telecommunications system (UMTS), UMTS terrestrial radio access network (UTRAN), or other 2G, 3G, 4G, 6G, etc. technologies either already developed or to be developed.

[0054] RF circuitry 706 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid
10 medium. In various embodiments, the RF circuitry 706 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 706 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 708 and provide baseband signals to the baseband circuitry 704. RF circuitry 706 may also
15 include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 704 and provide RF output signals to the FEM circuitry 708 for transmission.

[0055] In some embodiments, the RF circuitry 706 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry
20 706 may include mixer circuitry 706a, amplifier circuitry 706b and filter circuitry 706c. The transmit signal path of the RF circuitry 706 may include filter circuitry 706c and mixer circuitry 706a. RF circuitry 706 may also include synthesizer circuitry 706d for synthesizing a frequency for use by the mixer circuitry 706a of the receive signal path and the transmit signal path. In some
25 embodiments, the mixer circuitry 706a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 708 based on the synthesized frequency provided by synthesizer circuitry 706d. The amplifier circuitry 706b may be configured to amplify the down-converted signals and the filter circuitry 706c may be a low-pass filter (LPF) or band-pass
30 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 704 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 706a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

5 [0056] In some embodiments, the mixer circuitry 706a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 706d to generate RF output signals for the FEM circuitry 708. The baseband signals may be provided by the baseband circuitry 704 and may be filtered by filter circuitry 706c. The filter circuitry 706c may include a low-pass filter (LPF), although the scope of
10 the embodiments is not limited in this respect.

[0057] In some embodiments, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 706a of the
15 receive signal path and the mixer circuitry 706a 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 706a of the receive signal path and the mixer circuitry 706a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments,
20 the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path may be configured for super-heterodyne operation.

[0058] 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
25 output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 706 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 704 may include a digital baseband interface to communicate with the RF circuitry 706.

30 [0059] 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.

[0060] In some embodiments, the synthesizer circuitry 706d 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 706d may be a
5 delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0061] The synthesizer circuitry 706d may be configured to synthesize an output frequency for use by the mixer circuitry 706a of the RF circuitry 706 based on a frequency input and a divider control input. In some embodiments,
10 the synthesizer circuitry 706d may be a fractional $N/N+1$ synthesizer.

[0062] 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 704 or the applications processor 702 depending on the desired output frequency. In some
15 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 702.

[0063] Synthesizer circuitry 706d of the RF circuitry 706 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
20 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
25 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.

[0064] In some embodiments, synthesizer circuitry 706d may be
30 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 (f_{LO}). In some embodiments, the RF circuitry 706 may include an IQ/polar converter.

5 **[0065]** FEM circuitry 708 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 710, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 706 for further processing. FEM circuitry 708 may also include a transmit signal path which may include circuitry
10 configured to amplify signals for transmission provided by the RF circuitry 706 for transmission by one or more of the one or more antennas 710.

[0066] In some embodiments, the FEM circuitry 708 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.
15 The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 706). The transmit signal path of the FEM circuitry 708 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 706), and one or more filters to generate
20 RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 710).

[0067] In some embodiments, the UE 700 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface as described in more detail below. In some
25 embodiments, the UE 700 described herein may be part of a portable wireless communication device, such as a personal digital assistant (PDA), a laptop or portable computer with wireless communication capability, a web tablet, a wireless telephone, a smartphone, a wireless headset, a pager, an instant messaging device, a digital camera, an access point, a television, a medical
30 device (e.g., a heart rate monitor, a blood pressure monitor, etc.), or other device that may receive and/or transmit information wirelessly. In some embodiments, the UE 700 may include one or more user interfaces designed to enable user interaction with the system and/or peripheral component interfaces designed to

enable peripheral component interaction with the system. For example, the UE 700 may include one or more of a keyboard, a keypad, a touchpad, a display, a sensor, a non-volatile memory port, a universal serial bus (USB) port, an audio jack, a power supply interface, one or more antennas, a graphics processor, an application processor, a speaker, a microphone, and other I/O components. The display may be an LCD or LED screen including a touch screen. The sensor may include a gyro sensor, an accelerometer, a proximity sensor, an ambient light sensor, and a positioning unit. The positioning unit may communicate with components of a positioning network, e.g., a global positioning system (GPS) satellite.

[0068] The antennas 710 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some multiple-input multiple-output (MIMO) embodiments, the antennas 710 may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result.

[0069] Although the UE 700 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements.

[0070] Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described herein. A computer-readable storage device may include any non-transitory

mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices and media. Some embodiments may include one or more processors and may be configured with instructions stored on a computer-readable storage device.

[0071] FIG. 8 is a block diagram of a communication device in accordance with some embodiments. The device may be a UE or eNB, for example, such as the UE 602 or eNB 604 shown in FIG. 6 that may be configured to track the UE as described herein. The physical layer circuitry 802 may perform various encoding and decoding functions that may include formation of baseband signals for transmission and decoding of received signals. The communication device 800 may also include medium access control layer (MAC) circuitry 804 for controlling access to the wireless medium. The communication device 800 may also include processing circuitry 806, such as one or more single-core or multi-core processors, and memory 808 arranged to perform the operations described herein. The physical layer circuitry 802, MAC circuitry 804 and processing circuitry 806 may handle various radio control functions that enable communication with one or more radio networks compatible with one or more radio technologies. The radio control functions may include signal modulation, encoding, decoding, radio frequency shifting, etc. For example, in some embodiments, communication may be enabled with one or more of a WMAN, a WLAN, and a WPAN. In some embodiments, the communication device 800 can be configured to operate in accordance with 3GPP standards or other protocols or standards, including WiMax, WiFi, WiGig, GSM, EDGE, GERAN, UMTS, UTRAN, or other 3G, 3G, 4G, 6G, etc. technologies either already developed or to be developed. The communication device 800 may include transceiver circuitry 812 to enable communication with other external devices wirelessly and interfaces 814 to enable wired communication with other external devices. As another example, the transceiver circuitry 812 may perform various transmission and reception functions such as conversion of signals between a baseband range and a Radio Frequency (RF) range.

[0072] The antennas 801 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some MIMO embodiments, the antennas 801 may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result.

[0073] Although the communication device 800 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including DSPs, and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, FPGAs, ASICs, RFICs and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements. Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described herein.

[0074] FIG. 9 illustrates another block diagram of a communication device 900 in accordance with some embodiments. In alternative embodiments, the communication device 900 may operate as a standalone device or may be connected (e.g., networked) to other communication devices. In a networked deployment, the communication device 900 may operate in the capacity of a server communication device, a client communication device, or both in server-client network environments. In an example, the communication device 900 may act as a peer communication device in peer-to-peer (P2P) (or other distributed) network environment. The communication device 900 may be a UE, eNB, PC, a tablet PC, a STB, a PDA, a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any communication device capable of executing instructions (sequential or otherwise) that specify actions to be taken by that communication device. Further, while only a single communication device is illustrated, the term "communication device" shall also be taken to

include any collection of communication devices that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

5 **[0075]** Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other
10 circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the
15 software may reside on a communication device readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0076] Accordingly, the term “module” is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically
20 configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose
25 hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

30 **[0077]** Communication device (e.g., computer system) 900 may include a hardware processor 902 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 904 and a static memory 906, some or all of which may

communicate with each other via an interlink (e.g., bus) 908. The communication device 900 may further include a display unit 910, an alphanumeric input device 912 (e.g., a keyboard), and a user interface (UI) navigation device 914 (e.g., a mouse). In an example, the display unit 910, input device 912 and UI navigation device 914 may be a touch screen display. The communication device 900 may additionally include a storage device (e.g., drive unit) 916, a signal generation device 918 (e.g., a speaker), a network interface device 920, and one or more sensors 921, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The communication device 900 may include an output controller 928, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0078] The storage device 916 may include a communication device readable medium 922 on which is stored one or more sets of data structures or instructions 924 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 924 may also reside, completely or at least partially, within the main memory 904, within static memory 906, or within the hardware processor 902 during execution thereof by the communication device 900. In an example, one or any combination of the hardware processor 902, the main memory 904, the static memory 906, or the storage device 916 may constitute communication device readable media.

[0079] While the communication device readable medium 922 is illustrated as a single medium, the term "communication device readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 924.

[0080] The term "communication device readable medium" may include any medium that is capable of storing, encoding, or carrying instructions for execution by the communication device 900 and that cause the communication device 900 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting communication device

readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of communication device readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, communication device readable media may include non-transitory communication device readable media. In some examples, communication device readable media may include communication device readable media that is not a transitory propagating signal.

[0081] The instructions 924 may further be transmitted or received over a communications network 926 using a transmission medium via the network interface device 920 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 602.11 family of standards known as Wi-Fi®, IEEE 602.16 family of standards known as WiMax®, IEEE 602.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 920 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 926. In an example, the network interface device 920 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), MIMO, or multiple-input single-output (MISO) techniques. In some examples, the network interface device 920 may wirelessly communicate using Multiple User MIMO techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying

instructions for execution by the communication device 900, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

5 [0082] The subject technology is described below in conjunction with various examples.

[0083] Example 1 is an apparatus of a UE (user equipment), the apparatus comprising: processing circuitry; and memory, the processing circuitry to: decode a plurality of channels including one or more signal quality measurements of a plurality of reference signals belonging to a plurality of
10 nodes transmitting synchronization signals with a same cell identifier, at least a first reference signal from among the plurality of reference signals being associated with different PDSCH (physical downlink shared channel) and different control channels from at least a second reference signal from among the plurality of reference signals; derive a measurement quality from the one or
15 more signal quality measurements associated with the cell identifier; compute reporting conditions based on the derived measurement quality and associated with the cell identifier and based on a plurality of measurements of the plurality of reference signals; if the reporting conditions are met: encode for transmission, to an eNB (evolved NodeB) from among the plurality of nodes, of the one or
20 more signal quality measurements in response to determining that the reporting conditions are met; and decode an indication, from the eNB, of a cell for the UE to join, the cell comprising one or more nodes from among the plurality of nodes; and trigger a measurement report for handover of the UE to the cell; and if the reporting conditions are not met: decode one or more additional signal
25 quality measurements.

[0084] Example 2 is the apparatus of Example 1, wherein the one or more signal quality measurements comprise one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator)
30 measurements.

[0085] Example 3 is the apparatus of any of Examples 1-2, wherein the cell comprises an overlaid cell.

[0086] Example 4 is the apparatus of any of Examples 1-2, the processing circuitry further to: store, in the memory, the decoded one or more signal quality measurements, the measurement quality, or the computed reporting conditions.

5 [0087] Example 5 is the apparatus of any of Examples 1-2, the processing circuitry further to: perform initial access to identify the cell; and decode, from the eNB, basic system information of the cell, the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System
10 Information Block number).

[0088] Example 6 is the apparatus of Example 5, wherein the basic system information comprises identical information received from each of a plurality of TRPs (transmission and reception points) in the cell.

[0089] Example 7 is the apparatus of any of Examples 1-2, wherein the
15 reporting conditions are based on the SFN (Single Frequency Network) gain.

[0090] Example 8 is the apparatus of any of Examples 1-2, wherein the processing circuitry comprises a baseband processor.

[0091] Example 9 is the apparatus of any of Examples 1-2, further comprising transceiver circuitry to: transmit, to the eNB, the one or more signal
20 quality measurements in response to determining that the reporting conditions are met.

[0092] Example 10 is the apparatus of Example 7, further comprising: an antenna coupled to the transceiver circuitry.

[0093] Example 11 is an apparatus of a UE (user equipment), the
25 apparatus comprising: processing circuitry; and memory, the processing circuitry to: decode a plurality of reference signals for a plurality of cells; compute, based on the received plurality of reference signals, one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator)
30 measurements for the plurality of cells; determine, for each cell in the plurality of cells, a cell-level quantity for the cell based on the computed one or more of RSRP measurements, RSRQ measurements, and RSSI measurements stored in the memory; select, based on the cell-level quantities, one of the plurality of cell

for the UE to join; and join the selected cell to communicate with an eNB (evolved NodeB) of the selected cell.

[0094] Example 12 is the apparatus of Example 11, further comprising transceiver circuitry to: receive the plurality of reference signals for the plurality
5 of cells; and communicate with the eNB of the selected cell.

[0095] Example 13 is an apparatus of an eNB (evolved NodeB), the apparatus comprising: processing circuitry; and memory, the processing circuitry to: store, in the memory, basic system information of an cell including the eNB, the basic system information comprising PSS (Primary Synchronization Signal),
10 SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System Information Block number); apply an cell specific scrambling to the basic system information to generate a scrambled signal; and encode for transmission of the scrambled signal to a UE (user equipment), the scrambled signal indicating a cell for the UE to join.

15 [0096] Example 14 is the apparatus of Example 13, wherein the cell specific scrambling causes SFN (Single Frequency Network) to be obtained within the cell.

[0097] Example 15 is the apparatus of Example 13, wherein the scrambled signal is encoded for transmission in a beamformed transmission.

20 [0098] Example 16 is the apparatus of Example 13, wherein the scrambled signal is encoded for transmission in a non-beamformed transmission.

[0099] Example 17 is a machine-readable medium storing instructions for execution by processing circuitry of a UE (user equipment), the instructions causing the processing circuitry to: decode a plurality of channels including one
25 or more signal quality measurements of a plurality of reference signals belonging to a plurality of nodes transmitting synchronization signals with a same cell identifier, at least a first reference signal from among the plurality of reference signals being associated with different PDSCH (physical downlink shared channel) and different control channels from at least a second reference
30 signal from among the plurality of reference signals; derive a measurement quality from the one or more signal quality measurements associated with the cell identifier; compute reporting conditions based on the derived measurement quality and associated with the cell identifier and based on a plurality of

measurements of the plurality of reference signals; if the reporting conditions are met: encode for transmission, to an eNB (evolved NodeB) from among the plurality of nodes, of the one or more signal quality measurements in response to determining that the reporting conditions are met; and decode an indication,
5 from the eNB, of a cell for the UE to join, the cell comprising one or more nodes from among the plurality of nodes; and trigger a measurement report for handover of the UE to the cell; and if the reporting conditions are not met: decode one or more additional signal quality measurements.

[00100] Example 18 is the machine-readable medium of Example 17,
10 wherein the one or more signal quality measurements comprise one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator) measurements.

[00101] Example 19 is the machine-readable medium of Example 17,
15 wherein the cell comprises an overlaid cell.

[00102] Example 20 is the machine-readable medium of Example 17, the instructions further causing the processing circuitry to: store, in a memory of the UE, the decoded one or more signal quality measurements, the measurement quality, or the computed reporting conditions.

20 [00103] Example 21 is the machine-readable medium of Example 17, the instructions further causing the processing circuitry to: perform initial access to identify the cell; and decode, from the eNB, basic system information of the cell, the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel),
25 or SIBx (System Information Block number).

[00104] Example 22 is an apparatus of a UE (user equipment), the apparatus comprising: means for decoding a plurality of channels including one or more signal quality measurements of a plurality of reference signals belonging to a plurality of nodes transmitting synchronization signals with a
30 same cell identifier, at least a first reference signal from among the plurality of reference signals being associated with different PDSCH (physical downlink shared channel) and different control channels from at least a second reference signal from among the plurality of reference signals; means for deriving a

measurement quality from the one or more signal quality measurements associated with the cell identifier; means for computing reporting conditions based on the derived measurement quality and associated with the cell identifier and based on a plurality of measurements of the plurality of reference signals; if
5 the reporting conditions are met: means for encoding for transmission, to an eNB (evolved NodeB) from among the plurality of nodes, of the one or more signal quality measurements in response to determining that the reporting conditions are met; and means for decoding an indication, from the eNB, of a cell for the UE to join, the cell comprising one or more nodes from among the plurality of
10 nodes; and means for triggering a measurement report for handover of the UE to the cell; and if the reporting conditions are not met: means for decoding one or more additional signal quality measurements.

[00105] Example 23 is the apparatus of Example 22, wherein the one or more signal quality measurements comprise one or more of RSRP (Reference
15 Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator) measurements.

[00106] Example 24 is the apparatus of Example 22, wherein the cell comprises an overlaid cell.

20 [00107] Example 25 is the apparatus of Example 22, further comprising: means for storing, in a memory of the UE, the decoded one or more signal quality measurements, the measurement quality, or the computed reporting conditions.

[00108] Example 26 is the apparatus of Example 22, further comprising:
25 means for performing initial access to identify the cell; and means for decoding, from the eNB, basic system information of the cell, the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System Information Block number).

30 [00109] Although an embodiment has been described with reference to specific example embodiments, it will be evident that various modifications and changes may be made to these embodiments. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. The

accompanying drawings that form a part hereof show, by way of illustration, and not of limitation, specific embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other
5 embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims
10 are entitled.

[00110] Such embodiments of the inventive subject matter may be referred to herein, individually and/or collectively, by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept if more than one is
15 in fact disclosed. Thus, although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other
20 embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

[00111] In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the
25 term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that
30 is, a system, UE, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the

terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

- [00112] The Abstract is provided to allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding
- 5 that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

What is claimed is:

1. An apparatus of a UE (user equipment), the apparatus
5 comprising:
 - processing circuitry; and memory, the processing circuitry to:
 - decode a plurality of channels including one or more signal quality
measurements of a plurality of reference signals belonging to a plurality of nodes
transmitting synchronization signals with a same cell identifier, at least a first
10 reference signal from among the plurality of reference signals being associated
with different PDSCH (physical downlink shared channel) and different control
channels from at least a second reference signal from among the plurality of
reference signals;
 - derive a measurement quality from the one or more signal quality
15 measurements associated with the cell identifier;
 - compute reporting conditions associated with the cell identifier based on
the derived measurement quality and based on a plurality of measurements of the
plurality of reference signals;
 - if the reporting conditions meet a predefined threshold:
 - 20 encode for transmission, to an eNB (evolved NodeB) from among
the plurality of nodes, of the one or more signal quality measurements;
 - and
 - decode an indication, from the eNB, of a cell for the UE to join,
the cell comprising one or more nodes from among the plurality of
25 nodes; and
 - trigger a measurement report for handover of the UE to the cell;
 - and
 - if the reporting conditions fail to meet the predefined threshold:
 - 30 decode one or more additional signal quality measurements.

2. The apparatus of claim 1, wherein the one or more signal quality measurements comprise one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator) measurements.

5

3. The apparatus of any of claims 1-2, wherein the cell comprises an overlaid cell.

4. The apparatus of any of claims 1-2, the processing circuitry
10 further to:
store, in the memory, the decoded one or more signal quality measurements, the measurement quality, or the computed reporting conditions.

5. The apparatus of any of claims 1-2, the processing circuitry
15 further to:
perform initial access to identify the cell; and
decode, from the eNB, basic system information of the cell, the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or
20 SIBx (System Information Block number).

6. The apparatus of claim 5, wherein the basic system information comprises identical information received from each of a plurality of TRPs (transmission and reception points) in the cell.

25

7. The apparatus of any of claims 1-2, wherein the reporting conditions are based on the SFN (Single Frequency Network) gain.

8. The apparatus of any of claims 1-2, wherein the processing
30 circuitry comprises a baseband processor.

9. The apparatus of any of claims 1-2, further comprising transceiver circuitry to:
transmit, to the eNB, the one or more signal quality measurements in response to determining that the reporting conditions are met.

5

10. The apparatus of claim 7, further comprising:
an antenna coupled to the transceiver circuitry.

11. An apparatus of a UE (user equipment), the apparatus
10 comprising:
processing circuitry; and memory, the processing circuitry to:
decode a plurality of reference signals for a plurality of cells;
compute, based on the received plurality of reference signals, one or
more of RSRP (Reference Signal Received Power) measurements, RSRQ
15 (Reference Signal Received Quality) measurements, and RSSI (Received Signal
Strength Indicator) measurements for the plurality of cells;
determine, for each cell in the plurality of cells, a cell-level quantity for
the cell based on the computed one or more of RSRP measurements, RSRQ
measurements, and RSSI measurements;
20 select, based on the cell-level quantities, one of the plurality of cell for
the UE to join; and
join the selected cell to communicate with an eNB (evolved NodeB) of
the selected cell.

25 12. The apparatus of claim 11, further comprising transceiver
circuitry to:
receive the plurality of reference signals for the plurality of cells; and
communicate with the eNB of the selected cell.

30

13. An apparatus of an eNB (evolved NodeB), the apparatus comprising:

processing circuitry; and memory, the processing circuitry to:

store, in the memory, basic system information of an cell including the
5 eNB, the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System Information Block number);

apply an cell specific scrambling to the basic system information to generate a scrambled signal; and

10 encode for transmission of the scrambled signal to a UE (user equipment), the scrambled signal indicating a cell for the UE to join.

14. The apparatus of claim 13, wherein the cell specific scrambling causes SFN (Single Frequency Network) to be obtained within the cell.

15

15. The apparatus of claim 13, wherein the scrambled signal is encoded for transmission in a beamformed transmission.

16. The apparatus of claim 13, wherein the scrambled signal is
20 encoded for transmission in a non-beamformed transmission.

17. A machine-readable medium storing instructions for execution by processing circuitry of a UE (user equipment), the instructions causing the processing circuitry to:

25 decode a plurality of channels including one or more signal quality measurements of a plurality of reference signals belonging to a plurality of nodes transmitting synchronization signals with a same cell identifier, at least a first reference signal from among the plurality of reference signals being associated with different PDSCH (physical downlink shared channel) and different control
30 channels from at least a second reference signal from among the plurality of reference signals;

derive a measurement quality from the one or more signal quality measurements associated with the cell identifier;

compute reporting conditions associated with the cell identifier based on the derived measurement quality and based on a plurality of measurements of the plurality of reference signals;

if the reporting conditions meet a predefined threshold:

5 encode for transmission, to an eNB (evolved NodeB) from among the plurality of nodes, of the one or more signal quality measurements; and

 decode an indication, from the eNB, of a cell for the UE to join, the cell comprising one or more nodes from among the plurality of
10 nodes; and

 trigger a measurement report for handover of the UE to the cell; and

if the reporting conditions fail to meet the predefined threshold:

 decode one or more additional signal quality measurements.
15

18. The machine-readable medium of claim 17, wherein the one or more signal quality measurements comprise one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator)
20 measurements.

19. The machine-readable medium of claim 17, wherein the cell comprises an overlaid cell.

25 20. The machine-readable medium of claim 17, the instructions further causing the processing circuitry to:
 store, in a memory of the UE, the decoded one or more signal quality measurements, the measurement quality, or the computed reporting conditions.

30

21. The machine-readable medium of claim 17, the instructions further causing the processing circuitry to:
perform initial access to identify the cell; and
decode, from the eNB, basic system information of the cell, the basic
5 system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System Information Block number).

22. An apparatus of a UE (user equipment), the apparatus
10 comprising:
means for decoding a plurality of channels including one or more signal quality measurements of a plurality of reference signals belonging to a plurality of nodes transmitting synchronization signals with a same cell identifier, at least a first reference signal from among the plurality of reference signals being
15 associated with different PDSCH (physical downlink shared channel) and different control channels from at least a second reference signal from among the plurality of reference signals;
means for deriving a measurement quality from the one or more signal quality measurements associated with the cell identifier;
20 means for computing reporting conditions associated with the cell identifier based on the derived measurement quality and based on a plurality of measurements of the plurality of reference signals;
if the reporting conditions meet a predefined threshold:
means for encoding for transmission, to an eNB (evolved NodeB)
25 from among the plurality of nodes, of the one or more signal quality measurements; and
means for decoding an indication, from the eNB, of a cell for the UE to join, the cell comprising one or more nodes from among the plurality of nodes; and
30 means for triggering a measurement report for handover of the UE to the cell; and
if the reporting conditions fail to meet the predefined threshold:

means for decoding one or more additional signal quality measurements.

23. The apparatus of claim 22, wherein the one or more signal quality
5 measurements comprise one or more of RSRP (Reference Signal Received Power) measurements, RSRQ (Reference Signal Received Quality) measurements, and RSSI (Received Signal Strength Indicator) measurements.

24. The apparatus of claim 22, wherein the cell comprises an overlaid
10 cell.

25. The apparatus of claim 22, further comprising:
means for storing, in a memory of the UE, the decoded one or more
signal quality measurements, the measurement quality, or the computed
15 reporting conditions.

26. The apparatus of claim 22, further comprising:
means for performing initial access to identify the cell; and
means for decoding, from the eNB, basic system information of the cell,
20 the basic system information comprising PSS (Primary Synchronization Signal), SSS (Secondary Synchronization Signal), PBCH (Physical Broadcast Channel), or SIBx (System Information Block number).

25

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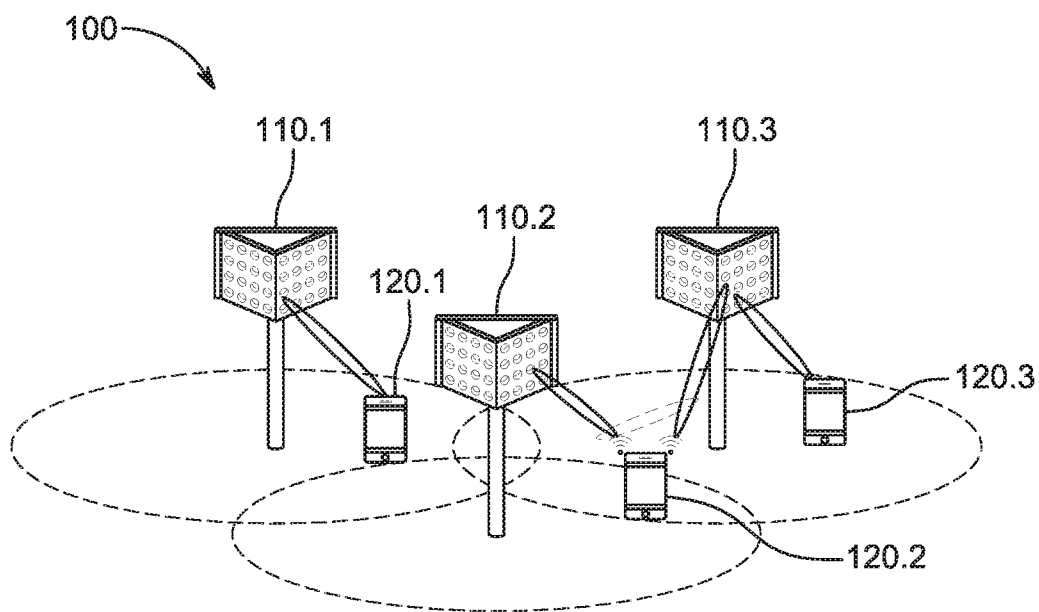


FIG. 1

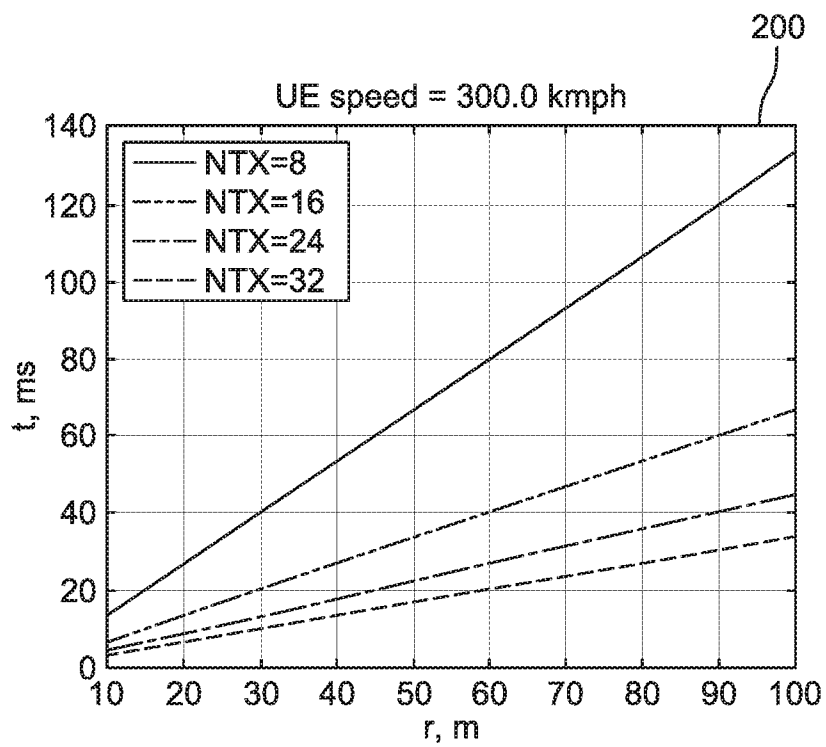


FIG. 2

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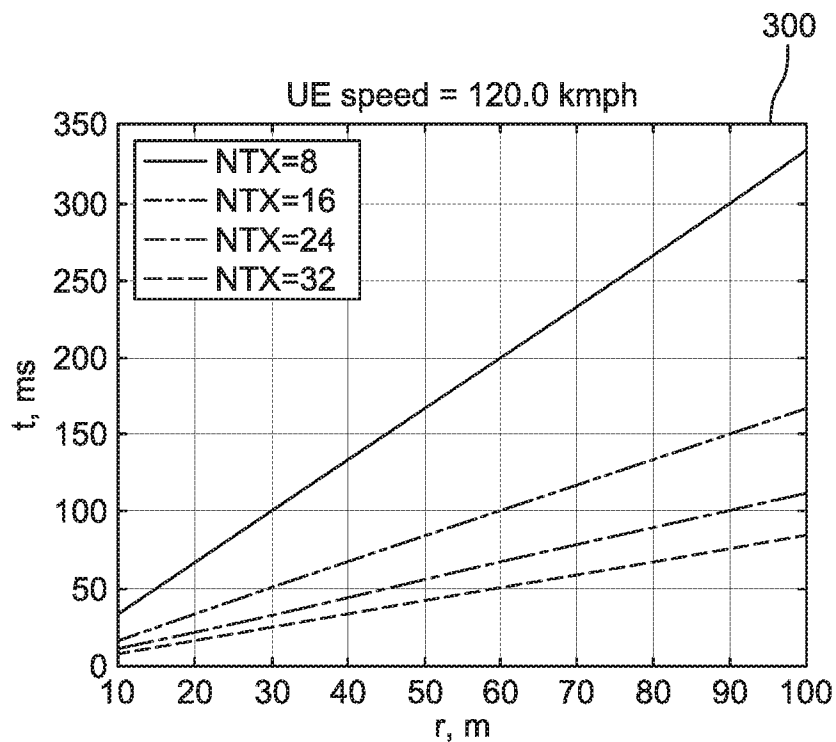


FIG. 3

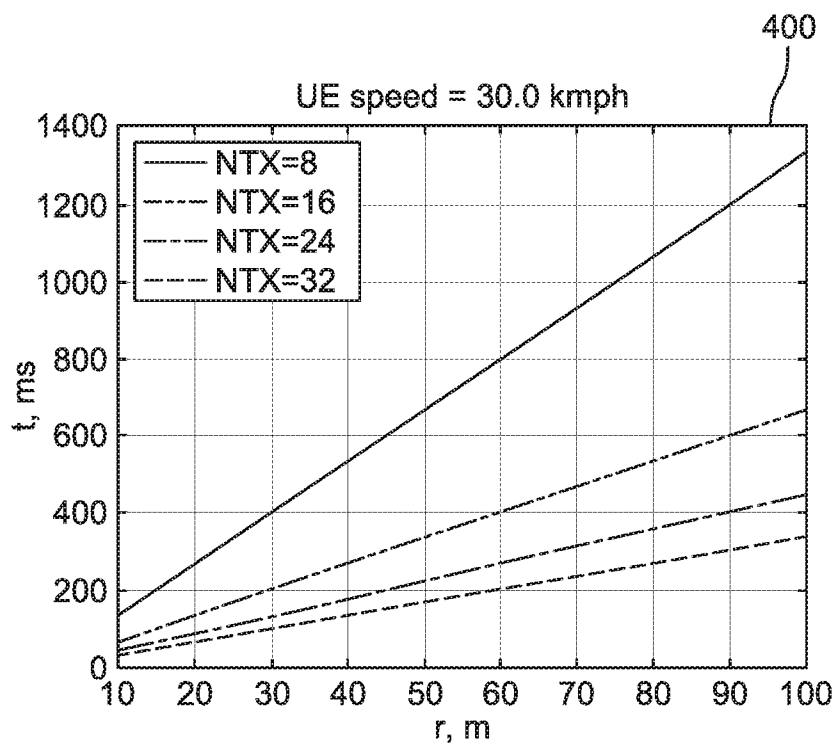


FIG. 4

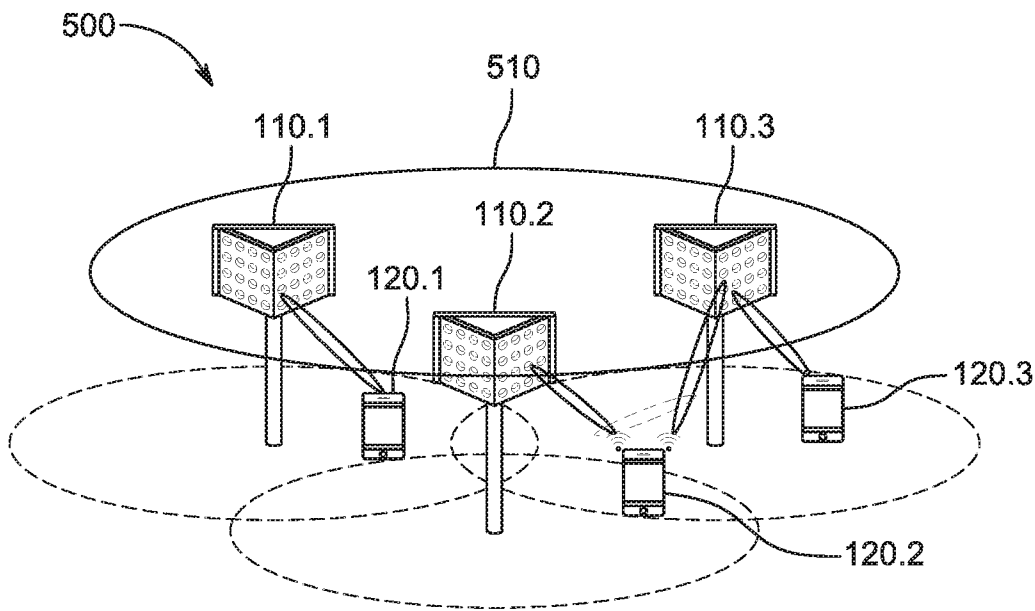


FIG. 5

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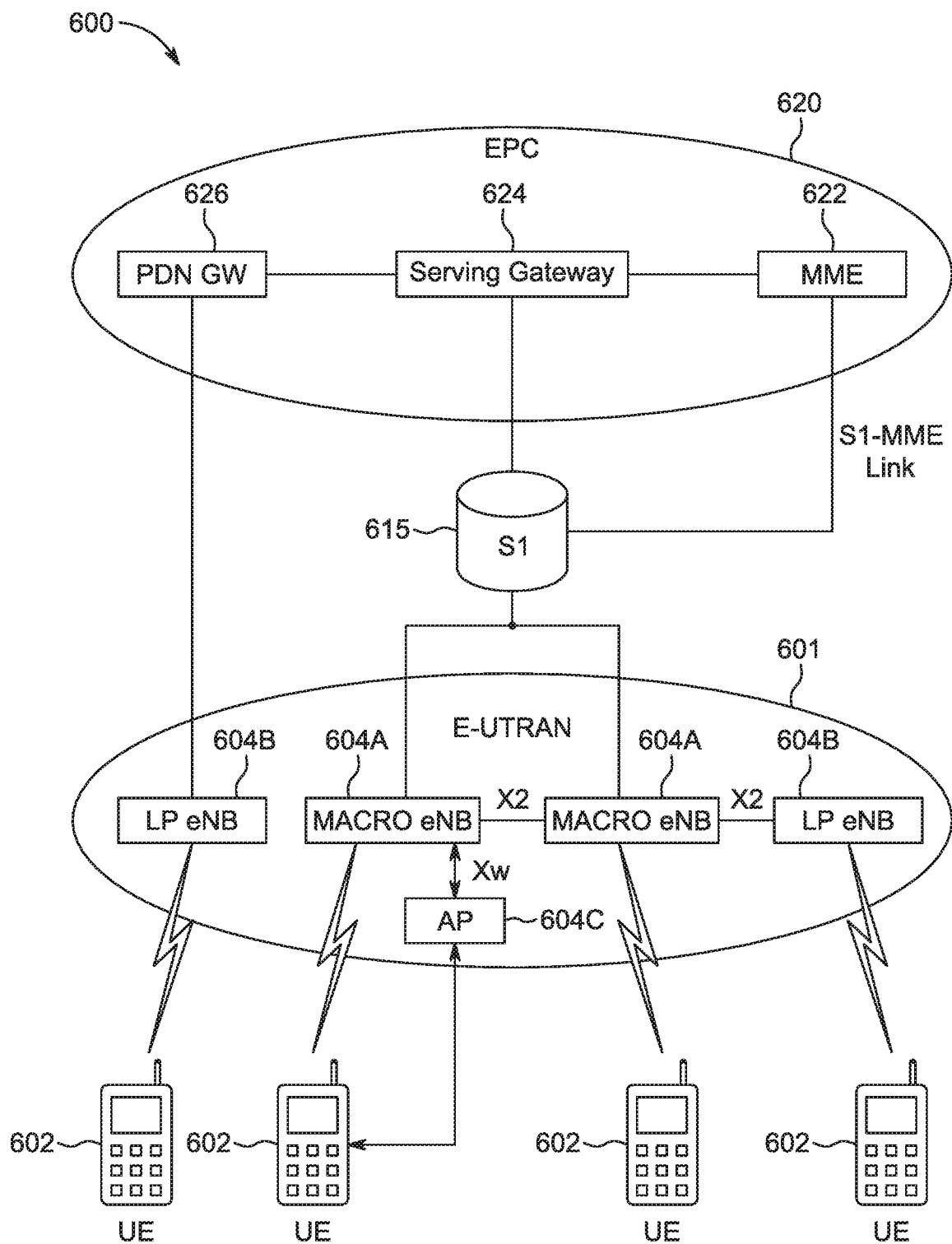


FIG. 6

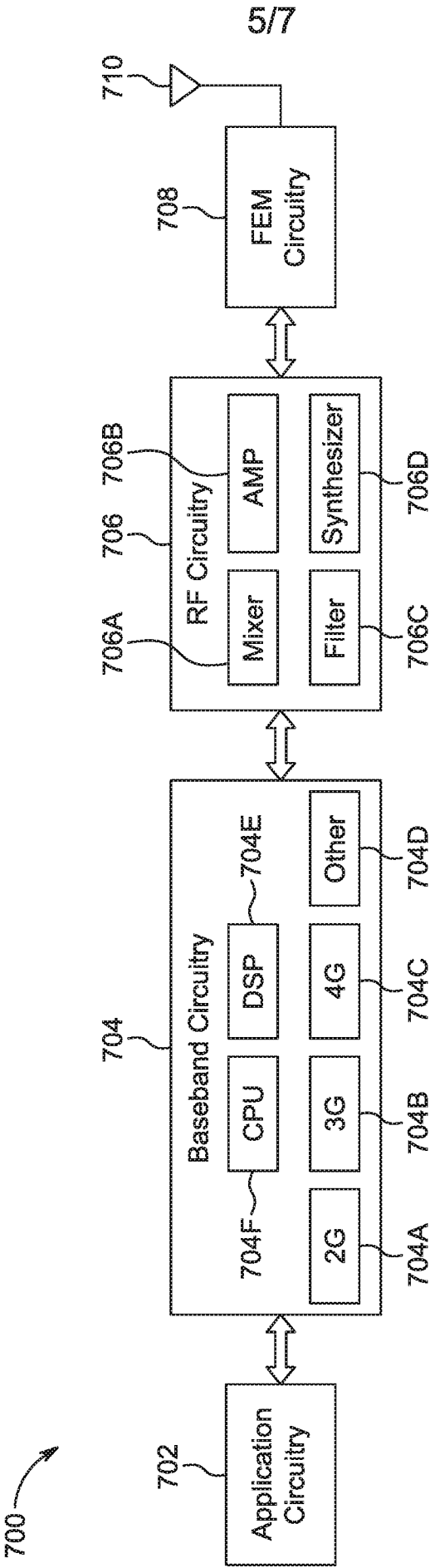


FIG. 7

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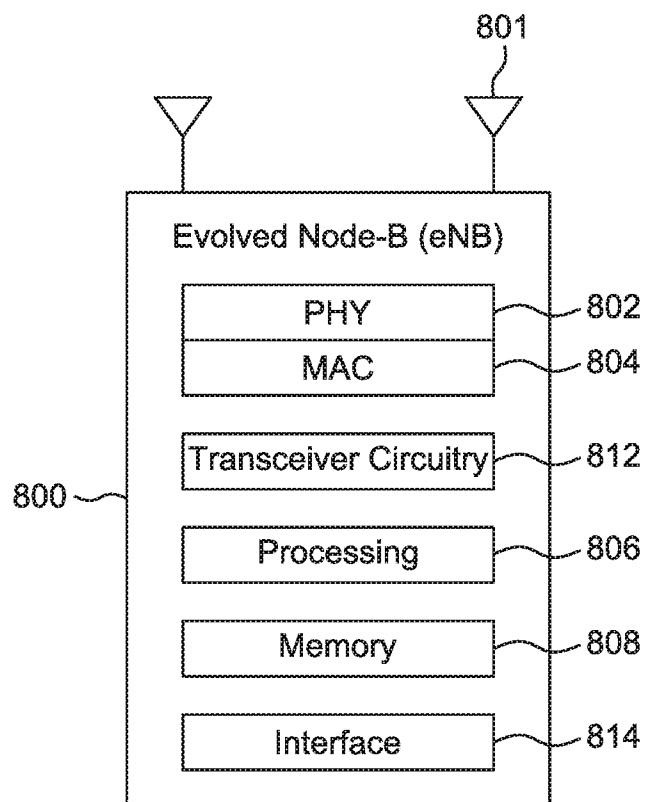


FIG. 8

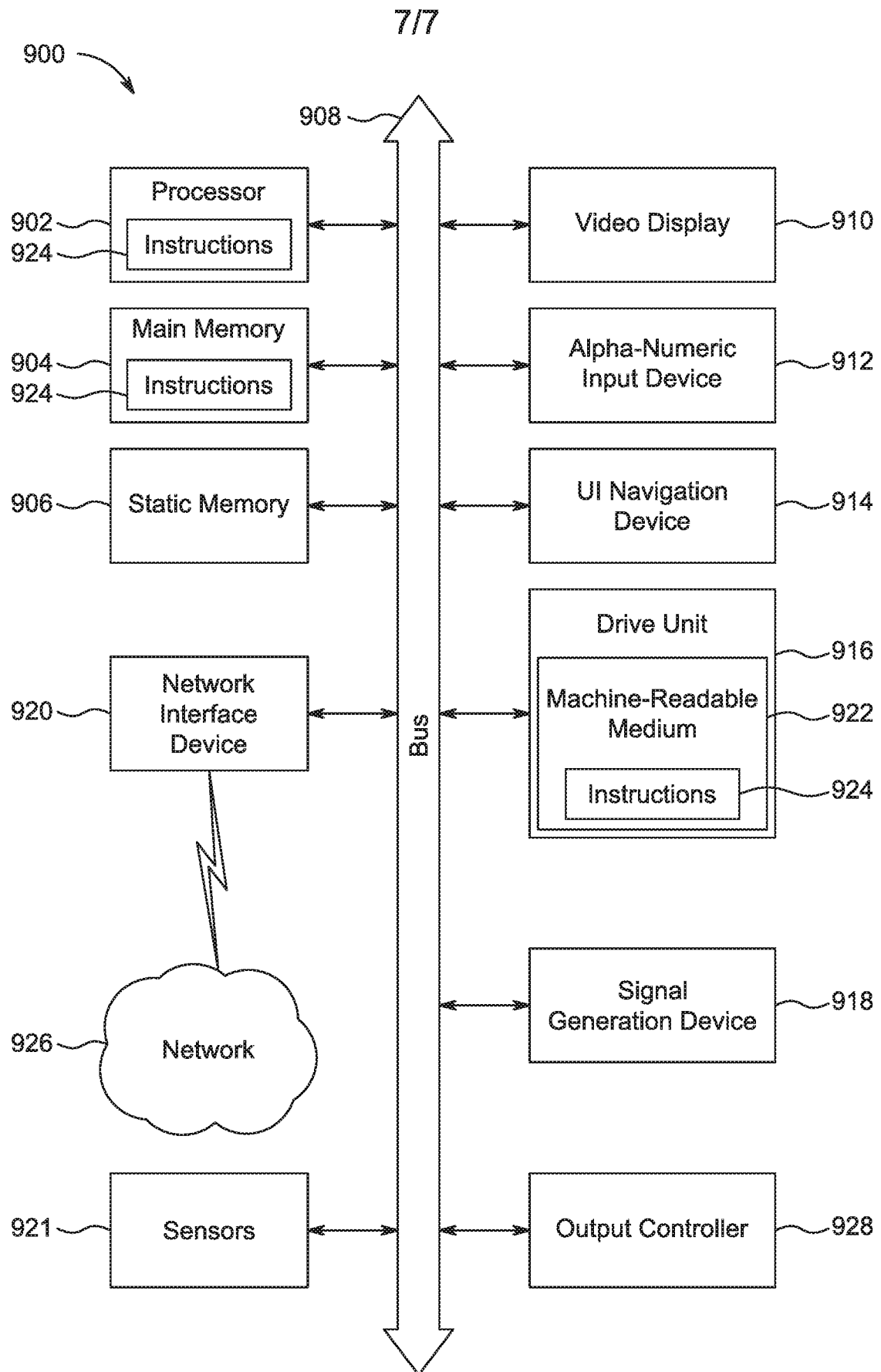


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/039695**A. CLASSIFICATION OF SUBJECT MATTER****H04W 24/10(2009.01)i, H04W 36/00(2009.01)i, H04W 36/30(2009.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W 24/10; H04Q 7/38; H04W 88/08; H04W 48/18; H04W 48/16; H04W 72/04; H04W 36/00; H04W 48/20; H04W 36/30

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: measurement, quality, report, select, and join

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2011-092636 A1 (NOKIA CORPORATION) 04 August 2011 See page 3, lines 5-14; page 7, line 10 - page 12, line 15; and claims 1-8.	1-26
Y	US 2012-0327904 A1 (MIN-KYOUNG PARK et al.) 27 December 2012 See paragraphs [0041]-[0047]; and claims 1-10.	1-10, 13-26
Y	US 2015-0005023 A1 (TELEFONAKTIEBOLAGET L M ERICSSON (PUBL)) 01 January 2015 See paragraphs [0033]-[0036], [0046], [0052], [0053]; and claim 1.	11, 12
A	WO 2007-106000 A1 (TELEFONAKTIEBOLAGET L M ERICSSON (PUBL)) 20 September 2007 See page 9, line 18 - page 11, line 11; and claims 1-11.	1-26
A	KR 10-1532152 B1 (NEC CORPORATION) 26 June 2015 See paragraphs [0009]-[0013]; and claims 1-9.	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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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

"&" document member of the same patent family

Date of the actual completion of the international search

19 October 2017 (19.10.2017)

Date of mailing of the international search report

19 October 2017 (19.10.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

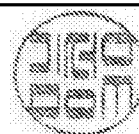


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/039695

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