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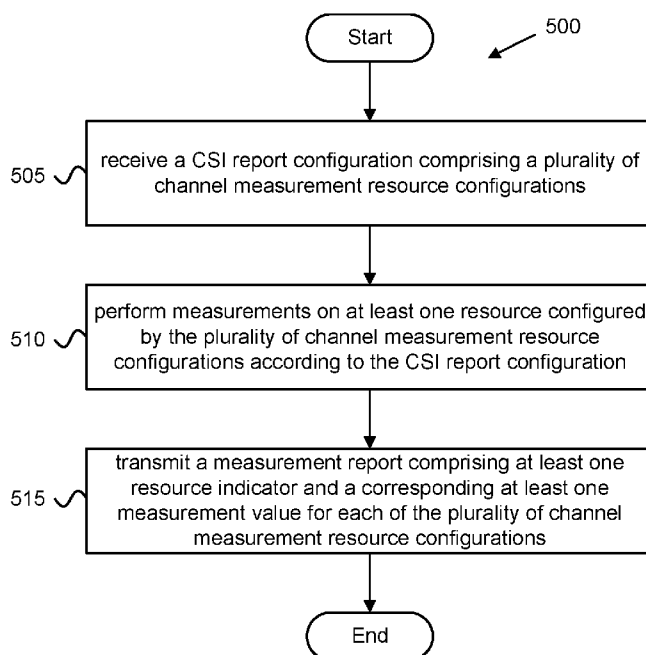


FIG. 5

(57) Abstract: Apparatuses, methods, and systems are disclosed that support techniques for CSI measurement and reporting. An apparatus (300) includes a processor (305) and a memory (310) that is coupled to the processor (305). The memory (310) includes instructions that are executable by the processor to cause the apparatus to receive a CSI report configuration comprising a plurality of channel measurement resource configurations, perform measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration, and transmit a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

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TECHNIQUES FOR CHANNEL STATE INFORMATION MEASUREMENT AND REPORTING

FIELD

[0001] The subject matter disclosed herein relates generally to wireless communications
5 and more particularly relates to techniques for channel state information (“CSI”) measurement and reporting.

BACKGROUND

[0002] A wireless communications system may include one or multiple network
communication devices, such as base stations, which may be otherwise known as an eNodeB
10 (“eNB”), a next-generation NodeB (“gNB”), or other suitable terminology. Each network
communication devices, such as a base station may support wireless communications for one or
multiple user communication devices, which may be otherwise known as user equipment (“UE”),
or other suitable terminology. The wireless communications system may support wireless
communications with one or multiple user communication devices by utilizing resources of the
15 wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or
the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless
communications system may support wireless communications across various radio access
technologies including third generation (“3G”) radio access technology, fourth generation (“4G”) radio
access technology, fifth generation (“5G”) radio access technology, among other suitable
20 radio access technologies beyond 5G (e.g., sixth generation (“6G”)). In the wireless
communications system, one or more of the network communication devices (e.g., base stations)
or the user communication devices (e.g., UEs) may support one or multiple CG configurations for
wireless communications (e.g., downlink communications, uplink communications).

BRIEF SUMMARY

25 [0003] Disclosed are procedures for techniques for CSI measurement and reporting. Said
procedures may be implemented by apparatus, systems, methods, and/or computer program
products.

[0004] A first apparatus, in one embodiment, includes a processor and a memory that is
coupled to the processor. The memory includes instructions that are executable by the processor
30 to cause the apparatus to receive a CSI report configuration comprising a plurality of channel

measurement resource configurations, perform measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration, and transmit a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0005] A first method, in one embodiment, receives a CSI report configuration comprising a plurality of channel measurement resource configurations, performs measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration, and transmits a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0006] A second apparatus, in one embodiment, includes a processor and a memory that is coupled to the processor. The memory includes instructions that are executable by the processor to cause the apparatus to determine a CSI report configuration comprising a plurality of channel measurement resource configurations, transmit the CSI report configuration to a UE, and receive a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0007] A second method, in one embodiment, determines a CSI report configuration comprising a plurality of channel measurement resource configurations, transmits the CSI report configuration to a UE, and receives a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 illustrates an example of a wireless communications system that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure.

[0009] Figure 2A illustrates an example of an information element ("IE") that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure.

[0010] Figure 2B is a continuation of the IE illustrated in Figure 2A.

[0011] Figure 2C is a continuation of the IE illustrated in Figures 2A and 2B.

[0012] Figure 3 is a block diagram illustrating one embodiment of a UE apparatus that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure.

[0013] Figure 4 is a block diagram illustrating one embodiment of a network equipment (“NE”) apparatus that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure.

[0014] Figure 5 illustrates a flowchart of a method that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure.

[0015] Figure 6 illustrates a flowchart of a method that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0016] Generally, the present disclosure describes systems, methods, and apparatuses for techniques for CSI measurement and reporting. In certain embodiments, the methods may be performed using computer code embedded on a computer-readable medium. In certain embodiments, an apparatus or system may include a computer-readable medium containing computer-readable code which, when executed by a processor, causes the apparatus or system to perform at least a portion of the below described solutions.

[0017] In one embodiment, the subject matter herein describes techniques to improve network energy savings for a network, e.g., a gNB and a UE in terms of base station (“BS”) transmission and reception, which may include, without precluding other techniques, how to achieve more efficient operation dynamically and/or semi-statically and finer granularity adaptation of transmissions and/or receptions in one or more of network energy saving techniques in time, frequency, spatial, and power domains, with potential support/feedback from UE, and potential UE assistance information and information exchange/coordination over network interfaces.

[0018] For a network entity operating with multiple antenna panels or multiple transmission and reception points (“TRPs”), it may be more efficient to dynamically turn on/off a certain antenna panel or TRP (or dynamically switch a state of an antenna panel or TRP between an active state and an inactive state) based on traffic conditions to reduce energy consumption. To support such features without impacting user throughput or other performance (e.g., latency), the network entity should be able to properly select an active antenna panel or TRP at a given time.

[0019] This disclosure presents techniques for CSI measurement and reporting to facilitate efficient selection and dynamic turning on/off of an antenna panel or TRP by a network entity. In

one embodiment, a UE receives a CSI report configuration including a plurality of channel measurement resource configurations and indicating reference signal received power (“RSRP”) or signal-to-noise and interference ratio (“SINR”) measurement and reporting for each of the plurality of channel measurement resource configurations. The UE performs measurements on resources configured by the plurality of channel measurement resource configurations and reports a configured number of resource indices and corresponding RSRP or SINR values for each channel measurement resource configuration.

[0020] In one embodiment, if a UE is configured with *groupBasedBeamReporting-r18* set to ‘enabled’, the UE reports in a single reporting instance a first number of group(s) of two CSI reference signal (“CSI-RS”) resource indicators (“CRIs”) or synchronization signal (“SS”)/physical broadcast channel (“PBCH”) resource block indicators (“SSBRIs”) selecting one CSI-RS or SSB from each of two CSI resource sets, where CSI-RS and/or SSB resources of each group may be received simultaneously by the UE, and a second number of CRI(s) or SSBRIs for another CSI resource set not associated with the largest measured value of layer 1 (“L1”)-RSRP for each report setting.

[0021] In one embodiment, when the higher layer parameter *groupBasedBeamReporting-r17* in *CSI-ReportConfig* is configured, a UE reports a configured number of groups of two CRIs or SSBRIs selecting one CSI-RS or SSB from each of two CSI resource sets for a report setting, where CSI-RS and/or SSB resources of each group can be received simultaneously by the UE; however, in such an embodiment, a UE may not report the best *N* beams for each TRP/antenna panel independently.

[0022] In the proposed solution described herein, a UE may report the best *N* number of beams independently for each TRP or gNB antenna panel with or without group reporting in each report setting, when multiple CSI resource sets corresponding to multiple TRPs/antenna panels are configured in each report setting. These new reporting settings allow gNB to dynamically switch between single TRP/antenna panel transmission and multi-TRP/antenna panel transmission and to properly select its active antenna panel(s) or TRP(s) at a given time while maintaining same or similar configuration signaling overhead and measurement time compared to Rel-17 group based beam reporting.

[0023] Figure 1 depicts a wireless communication system 100 supporting techniques for CSI measurement and reporting, according to embodiments of the disclosure. In one embodiment, the wireless communication system 100 includes at least one remote unit 105, a radio access network (“RAN”) 120, and a mobile core network 140. The RAN 120 and the mobile core network 140 form a mobile communication network. The RAN 120 may be composed of a base unit 110

with which the remote unit 105 communicates using wireless communication links 115. Even though a specific number of remote units 105, base units 110, wireless communication links 115, RANs 120, and mobile core networks 140 are depicted in Figure 1, one of skill in the art will recognize that any number of remote units 105, base units 110, wireless communication links 115, RANs 120, and mobile core networks 140 may be included in the wireless communication system 100.

[0024] In one implementation, the RAN 120 is compliant with the 5G system specified in the 3GPP specifications. In another implementation, the RAN 120 is compliant with the LTE system specified in the 3GPP specifications. More generally, however, the wireless communication system 100 may implement some other open or proprietary communication network, for example WiMAX, among other networks. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0025] In one embodiment, the remote units 105 may include computing devices, such as desktop computers, laptop computers, personal digital assistants (“PDAs”), tablet computers, smart phones, smart televisions (e.g., televisions connected to the Internet), smart appliances (e.g., appliances connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, modems), or the like. In some embodiments, the remote units 105 include wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, the remote units 105 may be referred to as the UEs, subscriber units, mobiles, mobile stations, users, terminals, mobile terminals, fixed terminals, subscriber stations, user terminals, wireless transmit/receive unit (“WTRU”), a device, or by other terminology used in the art.

[0026] The remote units 105 may communicate directly with one or more of the base units 110 in the RAN 120 via uplink (“UL”) and downlink (“DL”) communication signals. Furthermore, the UL and DL communication signals may be carried over the wireless communication links 115. Here, the RAN 120 is an intermediate network that provides the remote units 105 with access to the mobile core network 140.

[0027] In some embodiments, the remote units 105 communicate with an application server 151 via a network connection with the mobile core network 140. For example, an application 107 (e.g., web browser, media client, telephone/VoIP application) in a remote unit 105 may trigger the remote unit 105 to establish a PDU session (or other data connection) with the mobile core network 140 via the RAN 120. The mobile core network 140 then relays traffic between the remote unit 105 and the application server 151 in the packet data network 150 using

the PDU session. Note that the remote unit 105 may establish one or more PDU sessions (or other data connections) with the mobile core network 140. As such, the remote unit 105 may concurrently have at least one PDU session for communicating with the packet data network 150 and at least one PDU session for communicating with another data network (not shown).

5 [0028] The base units 110 may be distributed over a geographic region. In certain embodiments, a base unit 110 may also be referred to as an access terminal, an access point, a base, a base station, a Node-B, an eNB, a gNB, a Home Node-B, a relay node, a RAN node, or by any other terminology used in the art. The base units 110 are generally part of a radio access network (“RAN”), such as the RAN 120, that may include one or more controllers communicably
10 coupled to one or more corresponding base units 110. These and other elements of radio access network are not illustrated but are well known generally by those having ordinary skill in the art. The base units 110 connect to the mobile core network 140 via the RAN 120.

[0029] The base units 110 may serve a number of remote units 105 within a serving area, for example, a cell or a cell sector, via a wireless communication link 115. The base units 110
15 may communicate directly with one or more of the remote units 105 via communication signals. Generally, the base units 110 transmit DL communication signals to serve the remote units 105 in the time, frequency, and/or spatial domain. Furthermore, the DL communication signals may be carried over the wireless communication links 115. The wireless communication links 115 may be any suitable carrier in licensed or unlicensed radio spectrum. The wireless communication links
20 115 facilitate communication between one or more of the remote units 105 and/or one or more of the base units 110. Note that the base unit 110 and the remote unit 105 may communicate over unlicensed radio spectrum.

[0030] In one embodiment, the mobile core network 140 is a 5G core (“5GC”) or the evolved packet core (“EPC”), which may be coupled to a packet data network 150, like the Internet
25 and private data networks, among other data networks. A remote unit 105 may have a subscription or other account with the mobile core network 140. Each mobile core network 140 belongs to a single public land mobile network (“PLMN”). The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol.

[0031] The mobile core network 140 includes several network functions (“NFs”). As
30 depicted, the mobile core network 140 includes multiple user plane functions (“UPFs”) 141. The mobile core network 140 also includes multiple control plane functions including, but not limited to, an Access and Mobility Management Function (“AMF”) 143 that serves the RAN 120, a Session Management Function (“SMF”) 145, an Authentication Server Function (“AUSF”) 147, and a Unified Data Management function (“UDM”) 149. In certain embodiments, the mobile core

network 140 may also include a Policy Control Function (“PCF”), a Network Repository Function (“NRF”) (used by the various NFs to discover and communicate with each other over APIs), or other NFs defined for the 5GC.

[0032] In various embodiments, the mobile core network 140 supports different types of mobile data connections and different types of network slices, wherein each mobile data connection utilizes a specific network slice. Here, a “network slice” refers to a portion of the mobile core network 140 optimized for a certain traffic type or communication service. A network instance may be identified by a S-NSSAI, while a set of network slices for which the remote unit 105 is authorized to use is identified by NSSAI. In certain embodiments, the various network slices may include separate instances of network functions, such as the SMF 145 and UPF 141. In some embodiments, the different network slices may share some common network functions, such as the AMF 143. The different network slices are not shown in Figure 1 for ease of illustration, but their support is assumed.

[0033] Although specific numbers and types of network functions are depicted in Figure 1, one of skill in the art will recognize that any number and type of network functions may be included in the mobile core network 140. Moreover, where the mobile core network 140 is an EPC, the depicted network functions may be replaced with appropriate EPC entities, such as an MME, S-GW, P-GW, HSS, and the like. In certain embodiments, the mobile core network 140 may include a AAA server. In various embodiments, the remote units 105 may communicate directly with each other (e.g., device-to-device communication) using sidelink (“SL”) communication signals 117.

[0034] While Figure 1 depicts components of a 5G RAN and a 5G core network, the described embodiments apply to other types of communication networks and RATs, including IEEE 802.11 variants, GSM, GPRS, UMTS, LTE variants, CDMA 2000, Bluetooth, ZigBee, Sigfox, and the like. For example, in an LTE variant involving an EPC, the AMF 141 may be mapped to an MME, the SMF mapped to a control plane portion of a PGW and/or to an MME, the UPF mapped to an SGW and a user plane portion of the PGW, the UDM/UDR maps to an HSS, etc.

[0035] In the following descriptions, the term “gNB” is used for the base station but it is replaceable by any other radio access node, e.g., RAN node, eNB, BS, eNB, gNB, AP, NR, etc. Further the operations are described mainly in the context of 5G NR.

[0036] In Rel-17 3GPP New Radio (“NR”), when the higher layer parameter *groupBasedBeamReporting-r17* in *CSI-ReportConfig* is configured, a UE reports a configured number of groups of two CRIs or SSBRIs selecting one CSI-RS or SSB from each of two CSI resource sets for a report setting, where CSI-RS and/or SSB resources of each group can be

received simultaneously by the UE. The UE indicates the CSI resource set associated with the largest measured value of L1-RSRP, and for each group, CRI or SSBRI of the indicated CSI resource set is present first.

[0037] Further, in Rel-17 NR, a UE may be configured to report up to three CRIs in one reporting instance – (1) a first CRI indicating a resource pair, corresponding two rank indicator (“RIs”), precoding matrix indicators (“PMIs”), and layer indicators (“LIs”) for Resource Group 1 and Resource Group 2, respectively, and one channel quality indicator (“CQI”) for non-coherent joint transmission (“NCJT”); (2) a second CRI for Resource Group 1, corresponding one RI/PMI/LI, and one or two CQIs; and (3) a third CRI for Resource Group 2, corresponding one RI/PMI/LI, and one or two CQIs.

[0038] In one embodiment, according to TS 38.214 (incorporated herein by reference), each CSI resource setting *CSI-ResourceConfig* contains a configuration of a list of $S \geq 1$ CSI resource sets (given by higher layer parameter *csi-RS-ResourceSetList*), where the list is comprised of references to either or both of non-zero power (“NZP”) CSI-RS resource set(s) and SSB set(s) or the list is comprised of references to CSI-interference measurement (“IM”) resource set(s). Each CSI resource setting may be located in the downlink (“DL”) bandwidth part (“BWP”) identified by the higher layer parameter *BWP-id*, where CSI resource settings linked to a CSI report setting have the same DL BWP.

[0039] In one embodiment, the time domain behavior of the CSI-RS resources within a CSI resource setting are indicated by the higher layer parameter *resourceType* and can be set to aperiodic, periodic, or semi-persistent. For periodic and semi-persistent CSI resource settings, in one embodiment, when the UE is configured with *groupBasedBeamReporting-r17*, the number of CSI resource sets configured is $S=2$, otherwise the number of CSI-RS Resource sets configured is limited to $S=1$. For periodic and semi-persistent CSI resource settings, in one embodiment, the configured periodicity and slot offset is given in the numerology of its associated DL BWP, as given by *BWP-id*. In one embodiment, when a UE is configured with multiple *CSI-ResourceConfigs* consisting of the same NZP CSI-RS resource ID, the same time domain behavior shall be configured for the *CSI-ResourceConfigs*. In one embodiment, when a UE is configured with multiple *CSI-ResourceConfigs* consisting of the same CSI-IM resource ID, the same time-domain behavior shall be configured for the *CSI-ResourceConfigs*. In one embodiment, CSI resource settings linked to a CSI report setting have the same time domain behavior.

[0040] The following are configured via higher layer signaling for one or more CSI resource settings for channel and interference measurement - CSI-IM resource for interference

measurement, NZP CSI-RS resource for interference measurement, and NZP CSI-RS resource for channel measurement.

[0041] In one embodiment, the UE assumes that the NZP CSI-RS resource(s) for channel measurement and the CSI-IM resource(s) for interference measurement configured for one CSI reporting are resource-wise quasi-co-located (“QCLed”) with respect to 'typeD'. When a NZP CSI-RS resource(s) is used for interference measurement, in one embodiment, the UE may assume that the NZP CSI-RS resource for channel measurement and the CSI-IM resource or NZP CSI-RS resource(s) for interference measurement configured for one CSI reporting are QCLed with respect to 'typeD'.

[0042] For L1-SINR measurement, when one resource setting is configured, the resource setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel and interference measurement on NZP CSI-RS for L1-SINR computation. The UE may assume that same 1 port NZP CSI-RS resource(s) with density three resource elements (“Res”) per resource block (“RB”) is used for both channel and interference measurements.

[0043] In one embodiment, when two resource settings are configured, the first resource setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement on SSB or NZP CSI-RS and the second one (given by either higher layer parameter *csi-IM-ResourcesForInterference* or higher layer parameter *nzp-CSI-RS-ResourcesForInterference*) is for interference measurement performed on CSI-IM or on 1 port NZP CSI-RS with density three REs/RB, where each SSB or NZP CSI-RS resource for channel measurement is associated with one CSI-IM resource or one NZP CSI-RS resource for interference measurement by the ordering of the SSB or NZP CSI-RS resource for channel measurement and CSI-IM resource or NZP CSI-RS resource for interference measurement in the corresponding resource sets. The number of SSB(s) or CSI-RS resources for channel measurement equals the number of CSI-IM resources or the number of NZP CSI-RS resource for interference measurement.

[0044] In one embodiment, the UE may apply the SSB, or 'typeD' RS configured with *qcl-Type* set to 'typeD' to the NZP CSI-RS resource for channel measurement, as the reference RS for determining 'typeD' assumption for the corresponding CSI-IM resource or the corresponding NZP CSI-RS resource for interference measurement configured for one CSI reporting.

[0045] In one embodiment, the UE may expect that the NZP CSI-RS resource set for channel measurement and the NZP-CSI-RS resource set for interference measurement, if any, are configured with the higher layer parameter *repetition*.

[0046] For aperiodic CSI, and for periodic and semi-persistent CSI resource settings, , in one embodiment, if *groupBasedBeamReporting-r17* is configured, each trigger state configured using the higher layer parameter *CSI-AperiodicTriggerState* is associated with one or multiple *CSI-ReportConfig* where each *CSI-ReportConfig* is linked to periodic or semi-persistent, setting(s).

[0047] In one embodiment, when one resource setting is configured, the resource setting is given by *resourcesForChannelMeasurement* for L1-RSRP measurement. In such a case, the number of configured CSI resource sets in the resource setting is S=2.

[0048] For aperiodic CSI, and for aperiodic CSI resource settings, in one embodiment, if *groupBasedBeamReporting-r17* is configured, each trigger state configured using the higher layer parameter *CSI-AperiodicTriggerState* is associated with *resourcesForChannel* and *resourcesForChannel2*, which correspond to first and second resource sets, respectively, for L1-RSRP measurement.

[0049] For semi-persistent or periodic CSI, in one embodiment, each *CSI-ReportConfig* is linked to periodic or semi-persistent Resource setting(s). In one embodiment, when one resource setting (given by higher layer parameter *resourcesForChannelMeasurement*) is configured, the resource setting is for channel measurement for L1-RSRP or for channel and interference measurement for L1-SINR computation.

[0050] In one embodiment, when two resource settings are configured, the first resource setting (given by higher layer parameter *resourcesForChannelMeasurement*) is for channel measurement and the second resource setting (given by higher layer parameter *csi-IM-ResourcesForInterference*) is used for interference measurement performed on CSI-IM. For L1-SINR computation, the second resource setting (given by higher layer parameter *csi-IM-ResourcesForInterference* or higher layer parameter *nzp-CSI-RS-ResourceForInterference*) is used for interference measurement performed on CSI-IM or on NZP CSI-RS.

[0051] In one embodiment, a UE is not expected to be configured with more than 64 NZP CSI-RS resources and/or SS/PBCH block resources in resource setting for channel measurement for a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'none', 'cri-RI-CQI', 'cri-RSRP', 'ssb-Index-RSRP', 'cri-SINR' or 'ssb-Index-SINR', 'cri-RSRP-Capability[Set]Index', 'ssb-Index-RSRP-Capability[Set]Index', 'cri-SINR-Capability[Set]Index' or 'ssb-Index-SINR-Capability[Set]Index'.

[0052] In one embodiment, if interference measurement is performed on CSI-IM, each CSI-RS resource for channel measurement is resource-wise associated with a CSI-IM resource by

the ordering of the CSI-RS resource and CSI-IM resource in the corresponding resource sets. The number of CSI-RS resources for channel measurement equals to the number of CSI-IM resources.

[0053] In one embodiment, an NZP CSI-RS resource set for channel measurement with $2 \leq K_s \leq 8$ resources can be configured with two Resource Groups, with $K_1 \geq 1$ resources in Group 1 and $K_2 \geq 1$ resources in Group 2, such that $K_1 + K_2 = K_s$, and with $N \in \{1,2\}$ resource pairs. Each resource pair consists of one resource from Group 1 and one resource from Group 2. The same resource can be associated with two resource pairs in frequency range 1 but not in frequency range 2.

[0054] Except for L1-SINR, in one embodiment, if interference measurement is performed on NZP CSI-RS, a UE does not expect to be configured with more than one NZP CSI-RS resource in the associated resource set within the resource setting for channel measurement. Except for L1-SINR, the UE configured with the higher layer parameter *nzp-CSI-RS-ResourcesForInterference* may expect no more than 18 NZP CSI-RS ports configured in a NZP CSI-RS resource set.

[0055] For CSI measurement(s) other than L1-SINR, in one embodiment, a UE assumes each NZP CSI-RS port configured for interference measurement corresponds to an interference transmission layer; interference transmission layers on NZP CSI-RS ports for interference measurement take into account the associated EPRE ratios configured in 5.2.2.3.1 (incorporated herein by reference); and other interference signal on REs of NZP CSI-RS resource for channel measurement, NZP CSI-RS resource for interference measurement, or CSI-IM resource for interference measurement.

[0056] For L1-SINR measurement with dedicated interference measurement resources, in one embodiment, a UE assumes the total received power on dedicated NZP CSI-RS resource for interference measurement or dedicated CSI-IM resource for interference measurement corresponds to interference and noise.

[0057] For L1-RSRP computation, in one embodiment, the UE may be configured with CSI-RS resources, SS/PBCH Block resources or both CSI-RS and SS/PBCH block resources, when resource-wise quasi co-located with 'type C' and 'typeD' when applicable. In one embodiment, the UE may be configured with CSI-RS resource setting up to 16 CSI-RS resource sets having up to 64 resources within each set. The total number of different CSI-RS resources over all resource sets is no more than 128.

[0058] For L1-RSRP reporting, in one embodiment, if the higher layer parameter *nrofReportedRS* in *CSI-ReportConfig* is configured to be one, the reported L1-RSRP value is defined by a 7-bit value in the range [-140, -44] dBm with 1dB step size, if the higher layer parameter *nrofReportedRS* is configured to be larger than one, or if the higher layer parameter

groupBasedBeamReporting is configured as 'enabled', or if the higher layer parameter *groupBasedBeamReporting-r17* is configured, the UE shall use differential L1-RSRP based reporting, where the largest measured value of L1-RSRP is quantized to a 7-bit value in the range [-140, -44] dBm with 1dB step size, and the differential L1-RSRP is quantized to a 4-bit value.

- 5 The differential L1-RSRP value is computed with 2 dB step size with a reference to the largest measured L1-RSRP value which is part of the same L1-RSRP reporting instance. The mapping between the reported L1-RSRP value and the measured quantity is described in TS 38.133 (incorporated herein by reference).

- 10 [0059] When the higher layer parameter *groupBasedBeamReporting-r17* in *CSI-ReportConfig* is configured, in one embodiment, the UE shall indicate the CSI resource set associated with the largest measured value of L1-RSRP, and for each group, CRI or SSRI of the indicated CSI resource set is present first.

- 15 [0060] If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to "notConfigured", in one embodiment, the UE shall derive the channel measurements for computing L1-RSRP value reported in uplink slot *n* based on only the SS/PBCH or NZP CSI-RS, no later than the CSI reference resource, (defined in TS 38.211, which is incorporated herein by reference) associated with the CSI resource setting.

- 20 [0061] If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to "Configured", in one embodiment, the UE shall derive the channel measurements for computing L1-RSRP reported in uplink slot *n* based on only the most recent, no later than the CSI reference resource, occasion of SS/PBCH or NZP CSI-RS (defined in TS 38.211) associated with the CSI resource setting.

- 25 [0062] When the UE is configured with *NumberOfAdditionalPCI*, in one embodiment, a CSI-SSB-ResourceSet configured for L1-RSRP reporting includes one or more sets of SSB indices where PCI indices are associated with the sets of SSB indices, respectively.

- 30 [0063] When the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RSRP-Capability[Set]Index' or 'ssb-Index-RSRP-Capability[Set]Index', in one embodiment, an index of UE capability value set, indicating the maximum supported number of SRS antenna ports, is reported along with the pair of SSRI/CRI and L1-RSRP.

[0064] For L1-SINR computation, for channel measurement, in one embodiment, the UE may be configured with NZP CSI-RS resources and/or SS/PBCH Block resources. For interference measurement, in one embodiment, the UE may be configured with NZP CSI-RS or CSI-IM resources. In one embodiment, for channel measurement, the UE may be configured with

CSI-RS resource setting with up to 16 resource sets, with a total of up to 64 CSI-RS resources or up to 64 SS/PBCH Block resources.

[0065] For L1-SINR reporting, in one embodiment, if the higher layer parameter *nrofReportedRS* in *CSI-ReportConfig* is configured to be one, the reported L1-SINR value is defined by a 7-bit value in the range [-23, 40] dB with 0.5 dB step size, and if the higher layer parameter *nrofReportedRS* is configured to be larger than one, or if the higher layer parameter *groupBasedBeamReporting* is configured as 'enabled', the UE shall use differential L1-SINR based reporting, where the largest measured value of L1-SINR is quantized to a 7-bit value in the range [-23, 40] dB with 0.5 dB step size, and the differential L1-SINR is quantized to a 4-bit value. The differential L1-SINR is computed with 1 dB step size with a reference to the largest measured L1-SINR value which is part of the same L1-SINR reporting instance. When NZP CSI-RS is configured for channel measurement and/or interference measurement, in one embodiment, the reported L1-SINR values should not be compensated by the power offset(s) given by higher layer parameter *powerControlOffsetSS* or *powerControlOffset*.

[0066] When one or two resource settings are configured for L1-SINR measurement, in one embodiment, if the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to 'notConfigured', the UE shall derive the channel measurements for computing L1-SINR reported in uplink slot n based on only the SSB or NZP CSI-RS, no later than the CSI reference resource, (defined in TS 38.211) associated with the CSI resource setting.

[0067] If the higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to 'configured', the UE shall derive the channel measurements for computing L1-SINR reported in uplink slot n based on only the most recent, no later than the CSI reference resource, occasion of SSB or NZP CSI-RS (defined in TS 38.211) associated with the CSI resource setting.

[0068] If the higher layer parameter *timeRestrictionForInterferenceMeasurements* in *CSI-ReportConfig* is set to 'notConfigured', the UE shall derive the interference measurements for computing L1-SINR reported in uplink slot n based on only the CSI-IM or NZP CSI-RS for interference measurement (defined in TS 38.211) or NZP CSI-RS for channel and interference measurement no later than the CSI reference resource associated with the CSI resource setting.

[0069] If the higher layer parameter *timeRestrictionForInterferenceMeasurements* in *CSI-ReportConfig* is set to 'configured', the UE shall derive the interference measurements for computing the L1-SINR reported in uplink slot n based on the most recent, no later than the CSI reference resource, occasion of CSI-IM or NZP CSI-RS for interference measurement (defined in

TS 38.211) or NZP CSI-RS for channel and interference measurement associated with the CSI resource setting.

[0070] In one embodiment, when the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-SINR-Capability[Set]Index' or 'ssb-Index-SINR-Capability[Set]Index' an index of UE capability value, indicating the maximum supported number of SRS antenna ports, is reported along with the pair of SSBRI/CRI and L1-SINR.

[0071] As described in more detail below, to assist a network entity in properly selecting its active antenna panel(s) or TRP(s) at a given time, a UE can report one or multiple candidate beams for each antenna panel or TRP, respectively, in a single CSI report.

[0072] In one embodiment, a UE receives a CSI report configuration that includes a plurality of channel measurement resource configurations (or a plurality of channel measurement resource groups/sets) and an indication to perform RSRP (or SINR) measurement and reporting (e.g., report quantity set to at least one resource index and at least one corresponding RSRP or SINR value) for each of the plurality of channel measurement resource configurations (or for each of the plurality of channel measurement resource groups/sets). The UE, in such an embodiment, performs measurements on resources configured by the plurality of channel measurement resource configurations (or the plurality of channel measurement resource groups/sets) and reports a configured or predefined number of resource indices and corresponding RSRP or SINR values for each channel measurement resource configuration (or for each channel measurement resource group/set).

[0073] In another embodiment, a UE receives a CSI report configuration that includes a plurality of channel measurement resource sets, each channel measurement resource set comprising one or more resource subsets, and an indication to perform RSRP (or SINR) measurement and reporting for each channel measurement resource set. The CSI report configuration, in one embodiment, further includes an indication to perform group-based beam reporting using one or more resource subsets of a given channel measurement resource set for some channel measurement resource sets (e.g. one CRI from resource subset 1 and another CRI from resource subset 2, which can be received by the UE simultaneously) and an indication to report a configured number of resource indicators (e.g., beams) of a given channel measurement resource set for other channel measurement resource sets. In one embodiment, the UE reports a configured number of groups of resource indicators and corresponding groups of RSRP/SINR values for some channel measurement resource sets configured with group-based beam reporting and reports a configured number of resource indicators and corresponding RSRP/SINR values for other channel measurement resource sets configured with non-group based beam reporting.

[0074] In an implementation, a UE receives a first parameter (e.g., parameter *nrofReportedRS*) requesting a first number of CRIs/SSBRIs and corresponding RSRP/SINR values to be reported for a first CSI resource configuration (or a first CSI resource set) and a second parameter (e.g., *nrofReportedRS2*) requesting a second number of CRIs/SSBRIs and corresponding RSRP/SINR values to be reported for a second CSI resource configuration (or a second CSI resource set). The UE, in one embodiment, measures CSI resources of the first and second CSI resource configurations (or CSI resource sets) and selects and reports the first number of CRIs/SSBRIs and corresponding RSRP/SINR values for the first CSI resource configuration and the second number of CRIs/SSBRIs and corresponding RSRP/SINR values for the second CSI resource configuration. If the second parameter is not configured, in one embodiment, the UE reports the first number of CRIs/SSBRIs and corresponding RSRP/SINR values for the second CSI resource configuration. Alternatively, in one embodiment, if the second parameter is not configured, the UE reports one CRI/SSBRI and a corresponding RSRP/SINR value for the second CSI resource configuration.

[0075] In another implementation, a UE receives a first parameter (e.g., parameter *nrofReportedRSgroup*) requesting a first number of groups of CRIs/SSBRIs and corresponding RSRP/SINR values to be reported for first and second CSI resource configurations (or first and second CSI resource sets) and a second parameter (e.g., *nrofReportedRS2*) requesting a second number of CRIs/SSBRIs and corresponding RSRP/SINR values to be reported for the second CSI resource configuration (or the second CSI resource set), where the first CSI resource configuration (or the first CSI resource set) corresponds to the CSI resource configuration/set associated with the largest measured value of L1-RSRP or L1-SINR. The UE, in one embodiment, measures CSI resources of the first and second CSI resource configurations (or CSI resource sets), determines the first CSI resource configuration/set, and reports the first number of groups of two CRIs/SSBRIs, for each group a first CRI/SSBRI from the first CSI resource configuration/set and a second CRI/SSBRI from the second CSI resource configuration/set, and corresponding first number of pairs of RSRP/SINR values, and the second number of CRIs and corresponding RSRP values for the second CSI resource configuration.

[0076] For example, if a UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RSRP', 'ssb-Index-RSRP', 'cri-RSRP-Capability[Set]Index' or 'ssb-Index-RSRP-Capability[Set]Index', or if the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-SINR', 'ssb-Index-SINR', 'cri-SINR-Capability[Set]Index' or 'ssb-Index-SINR-Capability[Set]Index', if the UE is configured with the higher layer parameter *groupBasedBeamReporting-r18* set to 'disabled', the UE is not required to

update measurements for more than 64 CSI-RS and/or SSB resources, and the UE shall report in a single report *nrofReportedRS* (higher layer configured) different CRI(s) or SSBRI(s) for a first CSI resource set and *nrofReportedRS2* (higher layer configured) different CRI(s) or SSBRI(s) for a second CSI resource set for each report setting; otherwise, if the UE is configured with the higher layer parameter *groupBasedBeamReporting-r18* set to 'enabled', the UE is not required to update measurements for more than 64 CSI-RS and/or SSB resources, and the UE shall report in a single reporting instance *nrofReportedRSgroup*, if configured, group(s) of two CRIs or SSBRI(s) selecting one CSI-RS or SSB from each of the two CSI resource sets for each report setting, where for each group, CRI or SSBRI of the CSI resource set associated with the largest measured value of L1-RSRP is present first and CSI-RS and/or SSB resources of each group can be received simultaneously by the UE. Further, the UE shall report in the same reporting instance *nrofReportedRS2* (higher layer configured) different CRI(s) or SSBRI(s) for another CSI resource set not associated with the largest measured value of L1-RSRP for each report setting.

[0077] Figures 2A-2C illustrate an example of an enhanced CSI-ReportConfig information element ("IE") for techniques for CSI measurement and reporting. In one embodiment, the IE *CSI-ReportConfig* is used to configure a periodic or semi-persistent report sent on physical uplink control channel ("PUCCH") on the cell in which the *CSI-ReportConfig* is included, or to configure a semi-persistent or aperiodic report sent on physical uplink shared channel ("PUSCH") triggered by downlink control information ("DCI") received on the cell in which the *CSI-ReportConfig* is included (in this case, the cell on which the report is sent is determined by the received DCI).

[0078] In one embodiment, the carrier 202 indicates in which serving cell the *CSI-ResourceConfig* indicated below are to be found. If the field is absent, the resources are on the same serving cell as this report configuration.

[0079] In one embodiment, the *resourcesForChannelMeasurement* 204 and the *resourcesForChannelMeasurement2List* 206 indicate resources for channel measurement or a list of resource sets for channel measurement. *csi-ResourceConfigId* 208 of a *CSI-ResourceConfig* is included in the configuration of the serving cell indicated with the field "carrier" above.

[0080] In one embodiment, the *csi-IM-ResourcesForInterference* 210 indicates CSI-IM resources for interference measurement. *csi-ResourceConfigId* 208 of a *CSI-ResourceConfig* is included in the configuration of the serving cell indicated with the field "carrier" above. The *CSI-ResourceConfig* indicated here, in one embodiment, contains only CSI-IM resources. In one embodiment, the *bwp-Id* in that *CSI-ResourceConfig* is the same value as the *bwp-Id* in the *CSI-ResourceConfig* indicated by *resourcesForChannelMeasurement* 204.

[0081] In one embodiment, the *nzp-CSI-RS-ResourcesForInterference* 212 indicates NZP-CSI-RS resources for interference measurement. *csi-ResourceConfigId* 208 of a *CSI-ResourceConfig* is included in the configuration of the serving cell indicated with the field “carrier” above. The *CSI-ResourceConfig* indicated here, in one embodiment, contains only NZP-CSI-RS resources. In one embodiment, the *bwp-Id* in that *CSI-ResourceConfig* is the same value as the *bwp-Id* in the *CSI-ResourceConfig* indicated by *resourcesForChannelMeasurement*.

[0082] In one embodiment, the *nrofReportedRS* 214, *nrofReportedRS2* 216 indicate the number (*N*) of measured RS resources to be reported in first and second channel measurement resource configurations in a non-group-based report. When the field is absent, in one embodiment, the UE applies the value 1.

[0083] In one embodiment, the *nrofReportedRSgroup* 218 indicates the number (*N*) of measured RS resource groups to be reported in a group-based report. When the field is absent the UE applies the value 1.

[0084] In some embodiments, the terms antenna, panel, and antenna panel are used interchangeably. An antenna panel may be a hardware that is used for transmitting and/or receiving radio signals at frequencies lower than 6GHz, e.g., frequency range 1 (“FR1”), or higher than 6GHz, e.g., frequency range 2 (“FR2”) or millimeter wave (“mmWave”). In some embodiments, an antenna panel may comprise an array of antenna elements, wherein each antenna element is connected to hardware such as a phase shifter that allows a control module to apply spatial parameters for transmission and/or reception of signals. The resulting radiation pattern may be called a beam, which may or may not be unimodal and may allow the device (e.g., UE, node) to amplify signals that are transmitted or received from one or multiple spatial directions.

[0085] In some embodiments, an antenna panel may or may not be virtualized as an antenna port in the specifications. An antenna panel may be connected to a baseband processing module through a radio frequency (“RF”) chain for each of transmission (egress) and reception (ingress) directions. A capability of a device in terms of the number of antenna panels, their duplexing capabilities, their beamforming capabilities, and so on, may or may not be transparent to other devices. In some embodiments, capability information may be communicated via signaling or, in some embodiments, capability information may be provided to devices without a need for signaling. In the case that such information is available to other devices such as a CU, it can be used for signaling or local decision making.

[0086] In some embodiments, an antenna panel may be a physical or logical antenna array comprising a set of antenna elements or antenna ports that share a common or a significant portion of an RF chain (e.g., in-phase/quadrature (“I/Q”) modulator, analog to digital (“A/D”) converter,

local oscillator, phase shift network). The antenna panel may be a logical entity with physical antennas mapped to the logical entity. The mapping of physical antennas to the logical entity may be up to implementation. Communicating (receiving or transmitting) on at least a subset of antenna elements or antenna ports active for radiating energy (also referred to herein as active elements) of an antenna panel requires biasing or powering on of the RF chain which results in current drain or power consumption in the device (e.g., node) associated with the antenna panel (including power amplifier/low noise amplifier ("LNA") power consumption associated with the antenna elements or antenna ports). The phrase "active for radiating energy," as used herein, is not meant to be limited to a transmit function but also encompasses a receive function. Accordingly, an antenna element that is active for radiating energy may be coupled to a transmitter to transmit radio frequency energy or to a receiver to receive radio frequency energy, either simultaneously or sequentially, or may be coupled to a transceiver in general, for performing its intended functionality. Communicating on the active elements of an antenna panel enables generation of radiation patterns or beams.

[0087] In some embodiments, depending on implementation, a "panel" can have at least one of the following functionalities as an operational role of Unit of antenna group to control its Tx beam independently, Unit of antenna group to control its transmission power independently, Unit of antenna group to control its transmission timing independently. The "panel" may be transparent to another node (e.g., next hop neighbor node). For certain condition(s), another node or network entity can assume the mapping between device's physical antennas to the logical entity "panel" may not be changed. For example, the condition may include until the next update or report from device or comprise a duration of time over which the network entity assumes there will be no change to the mapping. Device may report its capability with respect to the "panel" to the network entity. The device capability may include at least the number of "panels". In one implementation, the device may support transmission from one beam within a panel; with multiple panels, more than one beam (one beam per panel) may be used for transmission. In another implementation, more than one beam per panel may be supported/used for transmission.

[0088] In some of the embodiments described, an antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed.

[0089] Two antenna ports are said to be quasi co-located ("QCL") if the large-scale properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. The large-scale properties include one or more of delay spread, Doppler spread, Doppler shift, average gain,

average delay, and spatial Rx parameters. Two antenna ports may be quasi-located with respect to a subset of the large-scale properties and different subset of large-scale properties may be indicated by a QCL Type. The QCL Type can indicate which channel properties are the same between the two reference signals (e.g., on the two antenna ports). Thus, the reference signals can be linked to each other with respect to what the device can assume about their channel statistics or QCL properties. For example, qcl-Type may take one of the following values. Other qcl-Types may be defined based on combination of one or large-scale properties - 'QCL-TypeA': {Doppler shift, Doppler spread, average delay, delay spread}; 'QCL-TypeB': {Doppler shift, Doppler spread}; 'QCL-TypeC': {Doppler shift, average delay}; and 'QCL-TypeD': {Spatial Rx parameter}.

[0090] Spatial Rx parameters may include one or more of: angle of arrival ("AoA") Dominant AoA, average AoA, angular spread, Power Angular Spectrum ("PAS") of AoA, average AoD (angle of departure), PAS of AoD, transmit/receive channel correlation, transmit/receive beamforming, spatial channel correlation etc.

[0091] The QCL-TypeA, QCL-TypeB and QCL-TypeC may be applicable for all carrier frequencies, but the QCL-TypeD may be applicable only in higher carrier frequencies (e.g., mmWave, FR2 and beyond), where essentially the device may not be able to perform omnidirectional transmission, i.e. the device would need to form beams for directional transmission. A QCL-TypeD between two reference signals A and B, the reference signal A is considered to be spatially co-located with reference signal B and the device may assume that the reference signals A and B can be received with the same spatial filter (e.g., with the same RX beamforming weights).

[0092] An "antenna port" according to an embodiment may be a logical port that may correspond to a beam (resulting from beamforming) or may correspond to a physical antenna on a device. In some embodiments, a physical antenna may map directly to a single antenna port, in which an antenna port corresponds to an actual physical antenna. Alternately, a set or subset of physical antennas, or antenna set or antenna array or antenna sub-array, may be mapped to one or more antenna ports after applying complex weights, a cyclic delay, or both to the signal on each physical antenna. The physical antenna set may have antennas from a single module or panel or from multiple modules or panels. The weights may be fixed as in an antenna virtualization scheme, such as cyclic delay diversity ("CDD"). The procedure used to derive antenna ports from physical antennas may be specific to a device implementation and transparent to other devices.

[0093] In some of the embodiments described, a TCI-state (Transmission Configuration Indication) associated with a target transmission can indicate parameters for configuring a quasi-collocation relationship between the target transmission (e.g., target RS or DM-RS ports of the target transmission during a transmission occasion) and a source reference signal(s) (e.g.,

SSB/CSI-RS/SRS) with respect to quasi co-location type parameter(s) indicated in the corresponding TCI state. The TCI describes which reference signals are used as QCL source, and what QCL properties can be derived from each reference signal. A device can receive a configuration of a plurality of transmission configuration indicator states for a serving cell for transmissions on the serving cell. In some of the embodiments described, a TCI state comprises at least one source RS to provide a reference (device assumption) for determining QCL and/or spatial filter.

[0094] In some of the embodiments described, a spatial relation information associated with a target transmission can indicate parameters for configuring a spatial setting between the target transmission and a reference RS (e.g., SSB/CSI-RS/SRS). For example, the device may transmit the target transmission with the same spatial domain filter used for reception the reference RS (e.g., DL RS such as SSB/CSI-RS). In another example, the device may transmit the target transmission with the same spatial domain transmission filter used for the transmission of the reference RS (e.g., UL RS such as SRS). A device can receive a configuration of a plurality of spatial relation information configurations for a serving cell for transmissions on the serving cell.

[0095] Figure 3 depicts a UE apparatus 300 that may be used for techniques for CSI measurement and reporting, according to embodiments of the disclosure. In various embodiments, the UE apparatus 300 is used to implement one or more of the solutions described above. The UE apparatus 300 may be one embodiment of the remote unit 105 and/or the UE 305, described above. Furthermore, the UE apparatus 300 may include a processor 305, a memory 310, an input device 315, an output device 320, and a transceiver 325.

[0096] In some embodiments, the input device 315 and the output device 320 are combined into a single device, such as a touchscreen. In certain embodiments, the UE apparatus 300 may not include any input device 315 and/or output device 320. In various embodiments, the UE apparatus 300 may include one or more of: the processor 305, the memory 310, and the transceiver 325, and may not include the input device 315 and/or the output device 320.

[0097] As depicted, the transceiver 325 includes at least one transmitter 330 and at least one receiver 335. In some embodiments, the transceiver 325 communicates with one or more cells (or wireless coverage areas) supported by one or more base units 121. In various embodiments, the transceiver 325 is operable on unlicensed spectrum. Moreover, the transceiver 325 may include multiple UE panel supporting one or more beams. Additionally, the transceiver 325 may support at least one network interface 340 and/or application interface 345. The application interface(s) 345 may support one or more APIs. The network interface(s) 340 may support 3GPP

reference points, such as Uu, N1, PC5, etc. Other network interfaces 340 may be supported, as understood by one of ordinary skill in the art.

[0098] The processor 305, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For example, the processor 305 may be a microcontroller, a microprocessor, a central processing unit (“CPU”), a graphics processing unit (“GPU”), an auxiliary processing unit, a field programmable gate array (“FPGA”), or similar programmable controller. In some embodiments, the processor 305 executes instructions stored in the memory 310 to perform the methods and routines described herein. The processor 305 is communicatively coupled to the memory 310, the input device 315, 10 the output device 320, and the transceiver 325. In certain embodiments, the processor 305 may include an application processor (also known as “main processor”) which manages application-domain and operating system (“OS”) functions and a baseband processor (also known as “baseband radio processor”) which manages radio functions.

[0099] The memory 310, in one embodiment, is a computer readable storage medium. In some embodiments, the memory 310 includes volatile computer storage media. For example, the 15 memory 310 may include a RAM, including dynamic RAM (“DRAM”), synchronous dynamic RAM (“SDRAM”), and/or static RAM (“SRAM”). In some embodiments, the memory 310 includes non-volatile computer storage media. For example, the memory 310 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some 20 embodiments, the memory 310 includes both volatile and non-volatile computer storage media.

[0100] In some embodiments, the memory 310 stores data related to techniques for CSI measurement and reporting. For example, the memory 310 may store various parameters, panel/beam configurations, resource assignments, policies, and the like, as described above. In certain embodiments, the memory 310 also stores program code and related data, such as an 25 operating system or other controller algorithms operating on the UE apparatus 300.

[0101] The input device 315, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 315 may be integrated with the output device 320, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device 315 30 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 315 includes two or more different devices, such as a keyboard and a touch panel.

[0102] The output device 320, in one embodiment, is designed to output visual, audible, and/or haptic signals. In some embodiments, the output device 320 includes an electronically

controllable display or display device capable of outputting visual data to a user. For example, the output device 320 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 320 may include a wearable display
5 separate from, but communicatively coupled to, the rest of the UE apparatus 300, such as a smart watch, smart glasses, a heads-up display, or the like. Further, the output device 320 may be a component of a smart phone, a personal digital assistant, a television, a tablet computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0103] In certain embodiments, the output device 320 includes one or more speakers for
10 producing sound. For example, the output device 320 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the output device 320 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all, or portions of the output device 320 may be integrated with the input device 315. For example, the input device 315 and output device 320 may form a touchscreen or similar touch-sensitive display.
15 In other embodiments, the output device 320 may be located near the input device 315.

[0104] The transceiver 325 communicates with one or more network functions of a mobile communication network via one or more access networks. The transceiver 325 operates under the control of the processor 305 to transmit messages, data, and other signals and also to receive messages, data, and other signals. For example, the processor 305 may selectively activate the
20 transceiver 325 (or portions thereof) at particular times in order to send and receive messages.

[0105] The transceiver 325 includes at least transmitter 330 and at least one receiver 335. One or more transmitters 330 may be used to provide UL communication signals to a base unit 121, such as the UL transmissions described herein. Similarly, one or more receivers 335 may be used to receive DL communication signals from the base unit 121, as described herein. Although
25 only one transmitter 330 and one receiver 335 are illustrated, the UE apparatus 300 may have any suitable number of transmitters 330 and receivers 335. Further, the transmitter(s) 330 and the receiver(s) 335 may be any suitable type of transmitters and receivers. In one embodiment, the transceiver 325 includes a first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio spectrum and a second transmitter/receiver pair used
30 to communicate with a mobile communication network over unlicensed radio spectrum.

[0106] In certain embodiments, the first transmitter/receiver pair used to communicate with a mobile communication network over licensed radio spectrum and the second transmitter/receiver pair used to communicate with a mobile communication network over unlicensed radio spectrum may be combined into a single transceiver unit, for example a single

chip performing functions for use with both licensed and unlicensed radio spectrum. In some embodiments, the first transmitter/receiver pair and the second transmitter/receiver pair may share one or more hardware components. For example, certain transceivers 325, transmitters 330, and receivers 335 may be implemented as physically separate components that access a shared hardware resource and/or software resource, such as for example, the network interface 340.

[0107] In various embodiments, one or more transmitters 330 and/or one or more receivers 335 may be implemented and/or integrated into a single hardware component, such as a multi-transceiver chip, a system-on-a-chip, an ASIC, or other type of hardware component. In certain embodiments, one or more transmitters 330 and/or one or more receivers 335 may be implemented and/or integrated into a multi-chip module. In some embodiments, other components such as the network interface 340 or other hardware components/circuits may be integrated with any number of transmitters 330 and/or receivers 335 into a single chip. In such embodiment, the transmitters 330 and receivers 335 may be logically configured as a transceiver 325 that uses one more common control signals or as modular transmitters 330 and receivers 335 implemented in the same hardware chip or in a multi-chip module.

[0108] In one embodiment, the memory 310 includes instructions that are executable by the processor 305 to cause the apparatus 300 to receive a CSI report configuration comprising a plurality of channel measurement resource configurations, perform measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration, and transmit a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0109] In one embodiment, the instructions are executable by the processor 305 to cause the apparatus 300 to measure values associated with a RSRP, a SINR, or both.

[0110] In one embodiment, the measurement report comprises a first set of groups of resource indicators and corresponding measurement values, each group of the first set comprising a first resource indicator from a first channel measurement resource configuration and a second resource indicator from a second channel measurement resource configuration and a second set of groups of resource indicators from the second channel measurement resource configuration and corresponding measurement values.

[0111] In one embodiment, the instructions are executable by the processor 305 to cause the apparatus 300 to receive resources indicated by each group of resource indicators of the first set simultaneously.

[0112] In one embodiment, the instructions are executable by the processor 305 to cause the apparatus 300 to indicate the first channel measurement resource configuration as a channel measurement resource configuration associated with a largest measurement value.

5 [0113] In one embodiment, the measurement report comprises a first set of resource indicators from a first channel measurement resource configuration and corresponding measurement values and a second set of resource indicators from a second channel measurement resource configuration and corresponding measurement quantity values.

[0114] In one embodiment, the instructions are executable by the processor 305 to cause the apparatus 300 to receive information indicating a number of elements of the first set.

10 [0115] In one embodiment, the instructions are executable by the processor 305 to cause the apparatus 300 to receive information indicating a number of elements of the second set.

[0116] In one embodiment, the instructions are executable by the processor 305 to cause the apparatus 300 to determine the number of elements of the second set based at least in part on the number of elements of the first set.

15 [0117] In one embodiment, the at least one resource indicator comprises a CSI-RS resource indicator, an SSB resource indicator, or both.

[0118] Figure 4 depicts a NE apparatus 400 that may be used for techniques for CSI measurement and reporting, according to embodiments of the disclosure. In one embodiment, NE apparatus 400 may be one implementation of a RAN node, such as the base unit 121, the RAN node 210, or gNB, described above. Furthermore, the base NE apparatus 400 may include a
20 processor 405, a memory 410, an input device 415, an output device 420, and a transceiver 425.

[0119] In some embodiments, the input device 415 and the output device 420 are combined into a single device, such as a touchscreen. In certain embodiments, the NE apparatus 400 may not include any input device 415 and/or output device 420. In various embodiments, the NE
25 apparatus 400 may include one or more of: the processor 405, the memory 410, and the transceiver 425, and may not include the input device 415 and/or the output device 420.

[0120] As depicted, the transceiver 425 includes at least one transmitter 430 and at least one receiver 435. Here, the transceiver 425 communicates with one or more remote units 105. Additionally, the transceiver 425 may support at least one network interface 440 and/or application
30 interface 445. The application interface(s) 445 may support one or more. The network interface(s) 440 may support 3GPP reference points, such as Uu, N1, N2 and N3. Other network interfaces 440 may be supported, as understood by one of ordinary skill in the art.

[0121] The processor 405, in one embodiment, may include any known controller capable of executing computer-readable instructions and/or capable of performing logical operations. For

example, the processor 405 may be a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or similar programmable controller. In some embodiments, the processor 405 executes instructions stored in the memory 410 to perform the methods and routines described herein. The processor 405 is communicatively coupled to the memory 410, the
5 input device 415, the output device 420, and the transceiver 425. In certain embodiments, the processor 405 may include an application processor (also known as “main processor”) which manages application-domain and OS functions and a baseband processor (also known as “baseband radio processor”) which manages radio function.

[0122] The memory 410, in one embodiment, is a computer readable storage medium. In
10 some embodiments, the memory 410 includes volatile computer storage media. For example, the memory 410 may include a RAM, including DRAM, SDRAM, and/or SRAM. In some embodiments, the memory 410 includes non-volatile computer storage media. For example, the memory 410 may include a hard disk drive, a flash memory, or any other suitable non-volatile computer storage device. In some embodiments, the memory 410 includes both volatile and non-
15 volatile computer storage media.

[0123] In some embodiments, the memory 410 stores data related to techniques for CSI measurement and reporting. For example, the memory 410 may store parameters, configurations, resource assignments, policies, and the like, as described above. In certain embodiments, the memory 410 also stores program code and related data, such as an operating system or other
20 controller algorithms operating on the NE apparatus 400.

[0124] The input device 415, in one embodiment, may include any known computer input device including a touch panel, a button, a keyboard, a stylus, a microphone, or the like. In some embodiments, the input device 415 may be integrated with the output device 420, for example, as a touchscreen or similar touch-sensitive display. In some embodiments, the input device 415
25 includes a touchscreen such that text may be input using a virtual keyboard displayed on the touchscreen and/or by handwriting on the touchscreen. In some embodiments, the input device 415 includes two or more different devices, such as a keyboard and a touch panel.

[0125] The output device 420, in one embodiment, is designed to output visual, audible, and/or haptic signals. In some embodiments, the output device 420 includes an electronically
30 controllable display or display device capable of outputting visual data to a user. For example, the output device 420 may include, but is not limited to, an LCD display, an LED display, an OLED display, a projector, or similar display device capable of outputting images, text, or the like to a user. As another, non-limiting, example, the output device 420 may include a wearable display separate from, but communicatively coupled to, the rest of the NE apparatus 400, such as a smart

watch, smart glasses, a heads-up display, or the like. Further, the output device 420 may be a component of a smart phone, a personal digital assistant, a television, a tablet computer, a notebook (laptop) computer, a personal computer, a vehicle dashboard, or the like.

[0126] In certain embodiments, the output device 420 includes one or more speakers for producing sound. For example, the output device 420 may produce an audible alert or notification (e.g., a beep or chime). In some embodiments, the output device 420 includes one or more haptic devices for producing vibrations, motion, or other haptic feedback. In some embodiments, all, or portions of the output device 420 may be integrated with the input device 415. For example, the input device 415 and output device 420 may form a touchscreen or similar touch-sensitive display. In other embodiments, the output device 420 may be located near the input device 415.

[0127] The transceiver 425 includes at least transmitter 430 and at least one receiver 435. One or more transmitters 430 may be used to communicate with the UE, as described herein. Similarly, one or more receivers 435 may be used to communicate with network functions in the NPN, PLMN and/or RAN, as described herein. Although only one transmitter 430 and one receiver 435 are illustrated, the NE apparatus 400 may have any suitable number of transmitters 430 and receivers 435. Further, the transmitter(s) 430 and the receiver(s) 435 may be any suitable type of transmitters and receivers.

[0128] In one embodiment, the memory 410 includes instructions that are executable by the processor 405 to cause the apparatus 400 to determine a CSI report configuration comprising a plurality of channel measurement resource configurations, transmit the CSI report configuration to a UE, and receive a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0129] Figure 5 illustrates a flowchart of a method 500 that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure. The method 500 may be performed by a UE as described herein, for example, the remote unit 105 and/or the UE apparatus 300. In some embodiments, the method 500 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0130] In one embodiment, the method 500 begins and receives 505 a CSI report configuration comprising a plurality of channel measurement resource configurations. In one embodiment, the method 500 performs 510 measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration. In one embodiment, the method 500 transmits 515 a measurement report

comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations, and the method 500 ends.

[0131] Figure 6 illustrates a flowchart of a method 600 that supports techniques for CSI measurement and reporting in accordance with aspects of the present disclosure. The method 600 may be performed by a NE as described herein, for example, the base unit 110, the gNB, and/or the NE apparatus 400. In some embodiments, the method 600 may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0132] In one embodiment, the method 600 begins and determines 605 a CSI report configuration comprising a plurality of channel measurement resource configurations. In one embodiment, the method 600 transmits 610 the CSI report configuration to a UE. In one embodiment, the method 600 receives 615 a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations, and the method 600 ends.

[0133] A first apparatus is disclosed for techniques for CSI measurement and reporting. The first apparatus may include a UE as described herein, for example, the remote unit 105 and/or the UE apparatus 300. In some embodiments, the first apparatus includes a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0134] A first apparatus, in one embodiment, includes a processor and a memory that is coupled to the processor. The memory includes instructions that are executable by the processor to cause the apparatus to receive a CSI report configuration comprising a plurality of channel measurement resource configurations, perform measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration, and transmit a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0135] In one embodiment, the instructions are executable by the processor to cause the apparatus to measure values associated with a RSRP, a SINR, or both.

[0136] In one embodiment, the measurement report comprises a first set of groups of resource indicators and corresponding measurement values, each group of the first set comprising a first resource indicator from a first channel measurement resource configuration and a second resource indicator from a second channel measurement resource configuration and a second set of

groups of resource indicators from the second channel measurement resource configuration and corresponding measurement values.

[0137] In one embodiment, the instructions are executable by the processor to cause the apparatus to receive resources indicated by each group of resource indicators of the first set
5 simultaneously.

[0138] In one embodiment, the instructions are executable by the processor to cause the apparatus to indicate the first channel measurement resource configuration as a channel measurement resource configuration associated with a largest measurement value.

[0139] In one embodiment, the measurement report comprises a first set of resource
10 indicators from a first channel measurement resource configuration and corresponding measurement values and a second set of resource indicators from a second channel measurement resource configuration and corresponding measurement quantity values.

[0140] In one embodiment, the instructions are executable by the processor to cause the apparatus to receive information indicating a number of elements of the first set.

[0141] In one embodiment, the instructions are executable by the processor to cause the
15 apparatus to receive information indicating a number of elements of the second set.

[0142] In one embodiment, the instructions are executable by the processor to cause the apparatus to determine the number of elements of the second set based at least in part on the number of elements of the first set.

[0143] In one embodiment, the at least one resource indicator comprises a CSI-RS resource
20 indicator, an SSB resource indicator, or both.

[0144] A first method is disclosed for techniques for CSI measurement and reporting. The first method may be performed by a UE as described herein, for example, the remote unit 105 and/or the UE apparatus 300. In some embodiments, the first method may be performed by a
25 processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0145] A first method, in one embodiment, receives a CSI report configuration comprising a plurality of channel measurement resource configurations, performs measurements on at least one resource configured by the plurality of channel measurement resource configurations
30 according to the CSI report configuration, and transmits a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0146] In one embodiment, the instructions are executable by the processor to cause the apparatus to measure values associated with a RSRP, a SINR, or both.

[0147] In one embodiment, the measurement report comprises a first set of groups of resource indicators and corresponding measurement values, each group of the first set comprising a first resource indicator from a first channel measurement resource configuration and a second resource indicator from a second channel measurement resource configuration and a second set of groups of resource indicators from the second channel measurement resource configuration and corresponding measurement values.

[0148] In one embodiment, the first method includes receiving resources indicated by each group of resource indicators of the first set simultaneously.

[0149] In one embodiment, the first method includes indicating the first channel measurement resource configuration as a channel measurement resource configuration associated with a largest measurement value.

[0150] In one embodiment, the measurement report comprises a first set of resource indicators from a first channel measurement resource configuration and corresponding measurement values and a second set of resource indicators from a second channel measurement resource configuration and corresponding measurement quantity values.

[0151] In one embodiment, the first method includes receiving information indicating a number of elements of the first set.

[0152] In one embodiment, the first method includes receiving information indicating a number of elements of the second set.

[0153] In one embodiment, the first method includes determining the number of elements of the second set based at least in part on the number of elements of the first set.

[0154] In one embodiment, the at least one resource indicator comprises a CSI-RS resource indicator, an SSB resource indicator, or both.

[0155] A second apparatus is disclosed for techniques for CSI measurement and reporting. The second apparatus may include a NE as described herein, for example, the base unit 110, the gNB, and/or the NE apparatus 400. In some embodiments, the second apparatus includes a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0156] A second apparatus, in one embodiment, includes a processor and a memory that is coupled to the processor. The memory includes instructions that are executable by the processor to cause the apparatus to determine a CSI report configuration comprising a plurality of channel measurement resource configurations, transmit the CSI report configuration to a UE, and receive a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0157] A second method is disclosed for techniques for CSI measurement and reporting. The second method may be performed by a NE as described herein, for example, the base unit 110, the gNB, and/or the NE apparatus 400. In some embodiments, the second method may be performed by a processor executing program code, for example, a microcontroller, a microprocessor, a CPU, a GPU, an auxiliary processing unit, a FPGA, or the like.

[0158] A second method, in one embodiment, determines a CSI report configuration comprising a plurality of channel measurement resource configurations, transmits the CSI report configuration to a UE, and receives a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

[0159] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0160] As will be appreciated by one skilled in the art, aspects of the embodiments may be embodied as a system, apparatus, method, or program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects.

[0161] For example, the disclosed embodiments may be implemented as a hardware circuit comprising custom very-large-scale integration ("VLSI") circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. The disclosed embodiments may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like. As another example, the disclosed embodiments may include one or more physical or logical blocks of executable code which may, for instance, be organized as an object, procedure, or function.

[0162] Furthermore, embodiments may take the form of a program product embodied in one or more computer readable storage devices storing machine readable code, computer readable code, and/or program code, referred hereafter as code. The storage devices may be tangible, non-transitory, and/or non-transmission. The storage devices may not embody signals. In a certain embodiment, the storage devices only employ signals for accessing code.

[0163] Any combination of one or more computer readable medium may be utilized. The computer readable medium may be a computer readable storage medium. The computer readable

storage medium may be a storage device storing the code. The storage device may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, holographic, micromechanical, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing.

5 [0164] More specific examples (a non-exhaustive list) of the storage device would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random-access memory (“RAM”), a read-only memory (“ROM”), an erasable programmable read-only memory (“EPROM” or Flash memory), a portable compact disc read-only memory (“CD-ROM”), an optical storage device, a magnetic storage device, or any suitable
10 combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0165] Code for carrying out operations for embodiments may be any number of lines and may be written in any combination of one or more programming languages including an object-
15 oriented programming language such as Python, Ruby, Java, Smalltalk, C++, or the like, and conventional procedural programming languages, such as the “C” programming language, or the like, and/or machine languages such as assembly languages. The code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In
20 the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (“LAN”), wireless LAN (“WLAN”), or a wide area network (“WAN”), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider (“ISP”)).

[0166] Furthermore, the described features, structures, or characteristics of the
25 embodiments may be combined in any suitable manner. In the following description, numerous specific details are provided, such as examples of programming, software modules, user selections, network transactions, database queries, database structures, hardware modules, hardware circuits, hardware chips, etc., to provide a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that embodiments may be practiced without one or more of
30 the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of an embodiment.

[0167] Reference throughout this specification to “one embodiment,” “an embodiment,” or similar language means that a particular feature, structure, or characteristic described in

connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment,” “in an embodiment,” and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment, but mean “one or more but not all embodiments” unless expressly specified otherwise. The terms “including,”
5 “comprising,” “having,” and variations thereof mean “including but not limited to,” unless expressly specified otherwise. An enumerated listing of items does not imply that any or all of the items are mutually exclusive, unless expressly specified otherwise. The terms “a,” “an,” and “the” also refer to “one or more” unless expressly specified otherwise.

[0168] As used herein, a list with a conjunction of “and/or” includes any single item in the
10 list or a combination of items in the list. For example, a list of A, B and/or C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology “one or more of” includes any single item in the list or a combination of items in the list. For example, one or more
15 of A, B and C includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C. As used herein, a list using the terminology “one of” includes one and only one of any single item in the list. For example, “one of A, B and C” includes only A, only B or only C and excludes combinations of A, B and C. As
used herein, “a member selected from the group consisting of A, B, and C,” includes one and only one of A, B, or C, and excludes combinations of A, B, and C. As used herein, “a member selected
20 from the group consisting of A, B, and C and combinations thereof” includes only A, only B, only C, a combination of A and B, a combination of B and C, a combination of A and C or a combination of A, B and C.

[0169] Aspects of the embodiments are described below with reference to schematic flowchart diagrams and/or schematic block diagrams of methods, apparatuses, systems, and
25 program products according to embodiments. It will be understood that each block of the schematic flowchart diagrams and/or schematic block diagrams, and combinations of blocks in the schematic flowchart diagrams and/or schematic block diagrams, can be implemented by code. This code may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the
30 instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart diagrams and/or block diagrams.

[0170] The code may also be stored in a storage device that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner, such

that the instructions stored in the storage device produce an article of manufacture including instructions which implement the function/act specified in the flowchart diagrams and/or block diagrams.

[0171] The code may also be loaded onto a computer, other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus, or other devices to produce a computer implemented process such that the code which execute on the computer or other programmable apparatus provide processes for implementing the functions/acts specified in the flowchart diagrams and/or block diagrams.

[0172] The flowchart diagrams and/or block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of apparatuses, systems, methods, and program products according to various embodiments. In this regard, each block in the flowchart diagrams and/or block diagrams may represent a module, segment, or portion of code, which includes one or more executable instructions of the code for implementing the specified logical function(s).

[0173] It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more blocks, or portions thereof, of the illustrated Figures.

[0174] Although various arrow types and line types may be employed in the flowchart and/or block diagrams, they are understood not to limit the scope of the corresponding embodiments. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the depicted embodiment. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted embodiment. It will also be noted that each block of the block diagrams and/or flowchart diagrams, and combinations of blocks in the block diagrams and/or flowchart diagrams, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and code.

[0175] The description of elements in each figure may refer to elements of proceeding figures. Like numbers refer to like elements in all figures, including alternate embodiments of like elements.

CLAIMS

1. An apparatus, comprising:
 - a processor; and
 - a memory coupled to the processor, the memory comprising instructions that are
 - 5 executable by the processor to cause the apparatus to:
 - receive a channel state information (“CSI”) report configuration
 - comprising a plurality of channel measurement resource
 - configurations;
 - perform measurements on at least one resource configured by the plurality
 - 10 of channel measurement resource configurations according to the
 - CSI report configuration; and
 - transmit a measurement report comprising at least one resource indicator
 - and a corresponding at least one measurement value for each of the
 - plurality of channel measurement resource configurations.
- 15 2. The apparatus of claim 1, wherein the instructions are executable by the processor to cause the apparatus to measure values associated with a reference signal received power (“RSRP”), a signal-to-interference and noise ratio (“SINR”), or both.
3. The apparatus of claim 1, wherein the measurement report comprises:
 - a first set of groups of resource indicators and corresponding measurement values,
 - 20 each group of the first set comprising a first resource indicator from a first
 - channel measurement resource configuration and a second resource
 - indicator from a second channel measurement resource configuration; and
 - a second set of groups of resource indicators from the second channel
 - measurement resource configuration and corresponding measurement
 - 25 values.
4. The apparatus of claim 3, wherein the instructions are executable by the processor to cause the apparatus to receive resources indicated by each group of resource indicators of the first set simultaneously.
5. The apparatus of claim 3, wherein the instructions are executable by the processor to
- 30 cause the apparatus to indicate the first channel measurement resource configuration as a

channel measurement resource configuration associated with a largest measurement value.

6. The apparatus of claim 1, wherein the measurement report comprises a first set of resource indicators from a first channel measurement resource configuration and
5 corresponding measurement values and a second set of resource indicators from a second channel measurement resource configuration and corresponding measurement quantity values.
7. The apparatus of claim 6, wherein the instructions are executable by the processor to cause the apparatus to receive information indicating a number of elements of the first
10 set.
8. The apparatus of claim 7, wherein the instructions are executable by the processor to cause the apparatus to receive information indicating a number of elements of the second set.
9. The apparatus of claim 7, wherein the instructions are executable by the processor to
15 cause the apparatus to determine the number of elements of the second set based at least in part on the number of elements of the first set.
10. The apparatus of claim 1, wherein the at least one resource indicator comprises a CSI reference signal ("CSI-RS") resource indicator, a synchronization signal block ("SSB") resource indicator, or both.
- 20 11. A method, comprising:
receiving a channel state information ("CSI") report configuration comprising a plurality of channel measurement resource configurations;
performing measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report
25 configuration; and
transmitting a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

12. The method of claim 11, further comprising measuring values associated with a reference signal received power (“RSRP”), a signal-to-interference and noise ratio (“SINR”), or both.
13. The method of claim 11, wherein the measurement report comprises:
- 5 a first set of groups of resource indicators and corresponding measurement values, each group of the first set comprising a first resource indicator from a first channel measurement resource configuration and a second resource indicator from a second channel measurement resource configuration; and
- 10 a second set of groups of resource indicators from the second channel measurement resource configuration and corresponding measurement values.
14. The method of claim 13, further comprising receiving resources indicated by each group of resource indicators of the first set simultaneously.
15. The method of claim 13, further comprising indicating the first channel measurement resource configuration as a channel measurement resource configuration associated with a largest measurement value.
16. The method of claim 11, wherein the measurement report comprises a first set of resource indicators from a first channel measurement resource configuration and corresponding measurement values and a second set of resource indicators from a second channel measurement resource configuration and corresponding measurement quantity values.
- 20 17. The method of claim 16, further comprising receiving information indicating a number of elements of the first set, a number of elements of the second set, or both.
18. The method of claim 17, wherein the number of elements of the second set is determined based at least in part on the number of elements of the first set.
- 25 19. The method of claim 11, wherein the at least one resource indicator comprises a CSI reference signal (“CSI-RS”) resource indicator, a synchronization signal block (“SSB”) resource indicator, or both.
20. An apparatus, comprising:
- a processor; and

a memory coupled to the processor, the memory comprising instructions that are executable by the processor to cause the apparatus to:

determine a channel state information (“CSI”) report configuration comprising a plurality of channel measurement resource configurations;

transmit the CSI report configuration to a user equipment (“UE”); and

receive a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

5

10

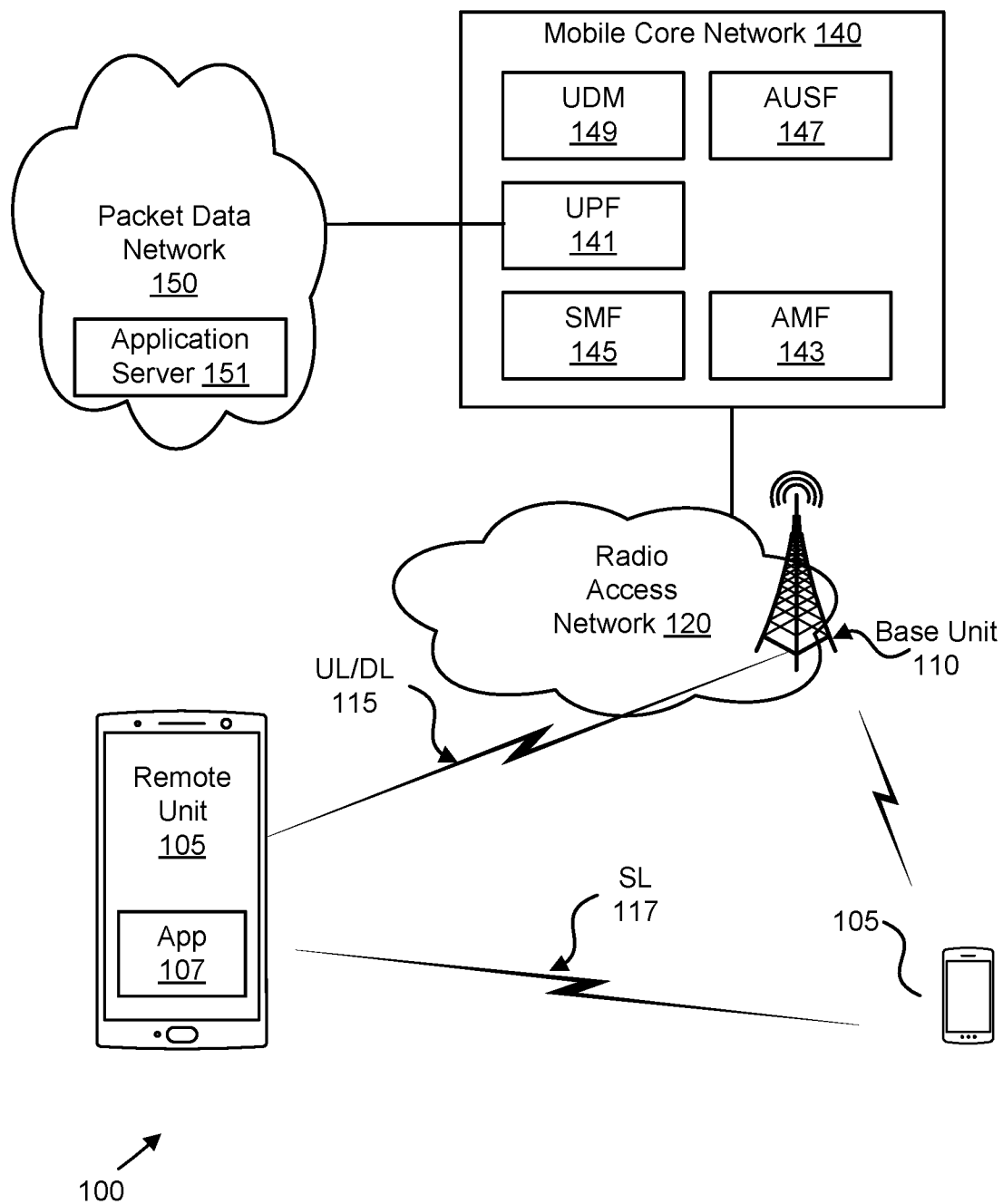


FIG. 1

```

-- ASN1START
-- TAG-CSI-REPORTCONFIG-START

CSI-ReportConfig-r18 ::= SEQUENCE {
    reportConfigId          CSI-ReportConfigId,
    202 carrier              ServCellIndex OPTIONAL, -- Need S
    204 resourcesForChannelMeasurement CSI-ResourceConfigId, 208
    206 resourcesForChannelMeasurement2List SEQUENCE(SIZE(1..maxNrofCSI-
    ResourceConfigs-1)) OF CSI-ResourceConfigId, 208 OPTIONAL, -- Need R
    210 csi-IM-ResourcesForInterference CSI-ResourceConfigId, 208 OPTIONAL, -- Need R
    212 nzp-CSI-RS-ResourcesForInterference CSI-ResourceConfigId, 208 OPTIONAL, -- Need R
    reportConfigType        CHOICE {
        periodic              SEQUENCE {
            reportSlotConfig    CSI-ReportPeriodicityAndOffset,
            pucch-CSI-ResourceList SEQUENCE (SIZE (1..maxNrofBWPs)) OF PUCCH-CSI-
            Resource
        },
        semiPersistentOnPUCCH SEQUENCE {
            reportSlotConfig    CSI-ReportPeriodicityAndOffset,
            pucch-CSI-ResourceList SEQUENCE (SIZE (1..maxNrofBWPs)) OF PUCCH-CSI-
            Resource
        },
        semiPersistentOnPUSCH SEQUENCE {
            reportSlotConfig    ENUMERATED {sl5, sl10, sl20, sl40, sl80, sl160, sl320},
            reportSlotOffsetList SEQUENCE (SIZE (1.. maxNrofUL-Allocations)) OF
            INTEGER(0..32),
            p0alpha              P0-PUSCH-AlphaSetId
        },
        aperiodic              SEQUENCE {
            reportSlotOffsetList SEQUENCE (SIZE (1..maxNrofUL-Allocations)) OF
            INTEGER(0..32)
        }
    },
    reportQuantity           CHOICE {
        none                   NULL,
        cri-RI-PMI-CQI         NULL,
        cri-RI-i1              NULL,
        cri-RI-i1-CQI          SEQUENCE {
            pdsch-BundleSizeForCSI ENUMERATED {n2, n4}
        },
        OPTIONAL -- Need S
    },
    cri-RI-CQI               NULL,
    cri-RSRP                 NULL,
    ssb-Index-RSRP           NULL,
    cri-RI-LI-PMI-CQI        NULL
    },
    reportFreqConfiguration SEQUENCE {
        cqi-FormatIndicator    ENUMERATED { widebandCQI, subbandCQI }
        OPTIONAL, -- Need R
        pmi-FormatIndicator    ENUMERATED { widebandPMI, subbandPMI }
    }
}

```

FIG. 2A

```

OPTIONAL, -- Need R
    csi-ReportingBand
        subbands3
        subbands4
        subbands5
        subbands6
        subbands7
        subbands8
        subbands9
        subbands10
        subbands11
        subbands12
        subbands13
        subbands14
        subbands15
        subbands16
        subbands17
        subbands18
        ...,
        subbands19-v1530
    } OPTIONAL -- Need S

    CHOICE {
        BIT STRING(SIZE(3)),
        BIT STRING(SIZE(4)),
        BIT STRING(SIZE(5)),
        BIT STRING(SIZE(6)),
        BIT STRING(SIZE(7)),
        BIT STRING(SIZE(8)),
        BIT STRING(SIZE(9)),
        BIT STRING(SIZE(10)),
        BIT STRING(SIZE(11)),
        BIT STRING(SIZE(12)),
        BIT STRING(SIZE(13)),
        BIT STRING(SIZE(14)),
        BIT STRING(SIZE(15)),
        BIT STRING(SIZE(16)),
        BIT STRING(SIZE(17)),
        BIT STRING(SIZE(18)),
        ...,
        BIT STRING(SIZE(19))
    }

    }
    timeRestrictionForChannelMeasurements ENUMERATED {configured, notConfigured},
    timeRestrictionForInterferenceMeasurements ENUMERATED {configured, notConfigured},
    codebookConfig CodebookConfig OPTIONAL, --
Need R
    dummy ENUMERATED {n1, n2} OPTIONAL, --
Need R
    groupBasedBeamReporting-r18 CHOICE {
        enabled SEQUENCE {
218 ── nrofReportedRSgroup-r18 ENUMERATED {n1, n2, n3, n4}
OPTIONAL -- Need S
216 ── nrofReportedRS2-r18 ENUMERATED {n1, n2, n3, n4}
OPTIONAL -- Need S
        }
        disabled SEQUENCE {
214 ── nrofReportedRS-r18 ENUMERATED {n1, n2, n3, n4}
OPTIONAL -- Need S
216 ── nrofReportedRS2-r18 ENUMERATED {n1, n2, n3, n4}
OPTIONAL -- Need S
        }
    },
    cqi-Table ENUMERATED {table1, table2, table3, spare1}
OPTIONAL, -- Need R
    subbandSize ENUMERATED {value1, value2},
    non-PMI-PortIndication SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourcesPerConfig)) OF
PortIndexFor8Ranks OPTIONAL, -- Need R
    ...,
    [[
    semiPersistentOnPUSCH-v1530 SEQUENCE {
        reportSlotConfig-v1530 ENUMERATED {sl4, sl8, sl16}
    }
    ]],
    [[

```

FIG. 2B

```

semiPersistentOnPUSCH-v1610    SEQUENCE {
  reportSlotOffsetListDCI-0-2-r16 SEQUENCE (SIZE (1.. maxNrofUL-Allocations-r16)) OF
INTEGER(0..32) OPTIONAL, -- Need R
  reportSlotOffsetListDCI-0-1-r16 SEQUENCE (SIZE (1.. maxNrofUL-Allocations-r16)) OF
INTEGER(0..32) OPTIONAL -- Need R
}                                OPTIONAL, -- Need R
aperiodic-v1610                SEQUENCE {
  reportSlotOffsetListDCI-0-2-r16 SEQUENCE (SIZE (1.. maxNrofUL-Allocations-r16)) OF
INTEGER(0..32) OPTIONAL, -- Need R
  reportSlotOffsetListDCI-0-1-r16 SEQUENCE (SIZE (1.. maxNrofUL-Allocations-r16)) OF
INTEGER(0..32) OPTIONAL -- Need R
}                                OPTIONAL, -- Need R
reportQuantity-r16             CHOICE {
  cri-SINR-r16                  NULL,
  ssb-Index-SINR-r16           NULL
}                                OPTIONAL, -- Need R
codebookConfig-r16             CodebookConfig-r16                      OPTIONAL -- Need
R
]]
}

CSI-ReportPeriodicityAndOffset ::= CHOICE {
  slots4          INTEGER(0..3),
  slots5          INTEGER(0..4),
  slots8          INTEGER(0..7),
  slots10         INTEGER(0..9),
  slots16         INTEGER(0..15),
  slots20         INTEGER(0..19),
  slots40         INTEGER(0..39),
  slots80         INTEGER(0..79),
  slots160        INTEGER(0..159),
  slots320        INTEGER(0..319)
}

PUCCH-CSI-Resource ::= SEQUENCE {
  uplinkBandwidthPartId    BWP-Id,
  pucch-Resource           PUCCH-ResourceId
}

...

-- TAG-CSI-REPORTCONFIG-STOP
-- ASN1STOP

```

FIG. 2C

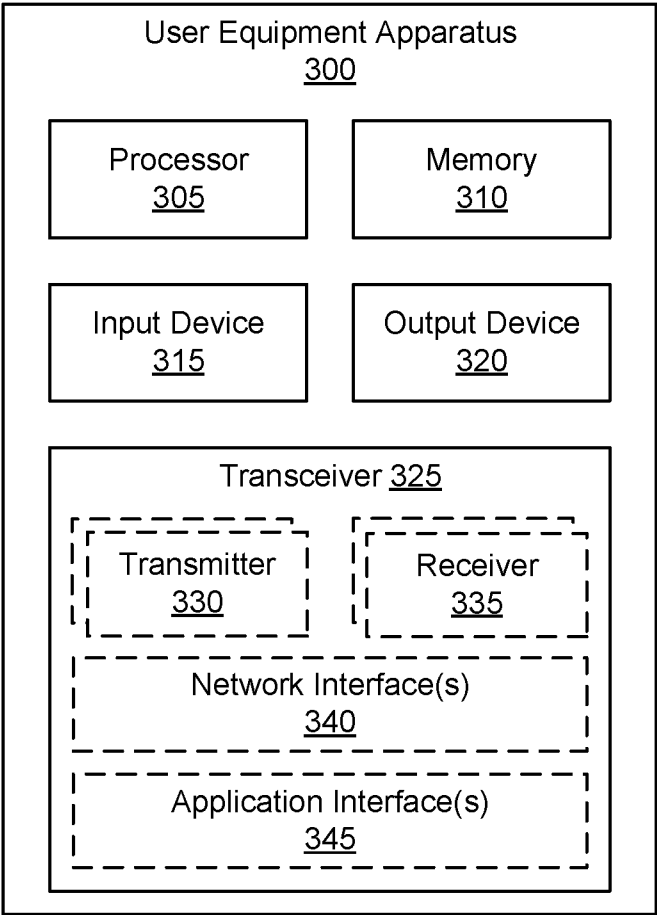


FIG. 3

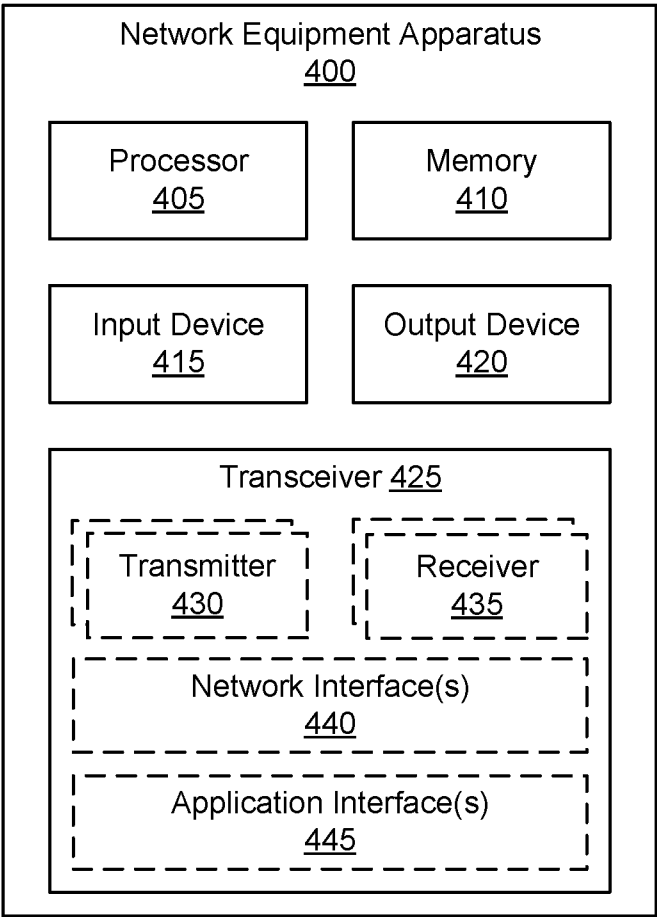


FIG. 4

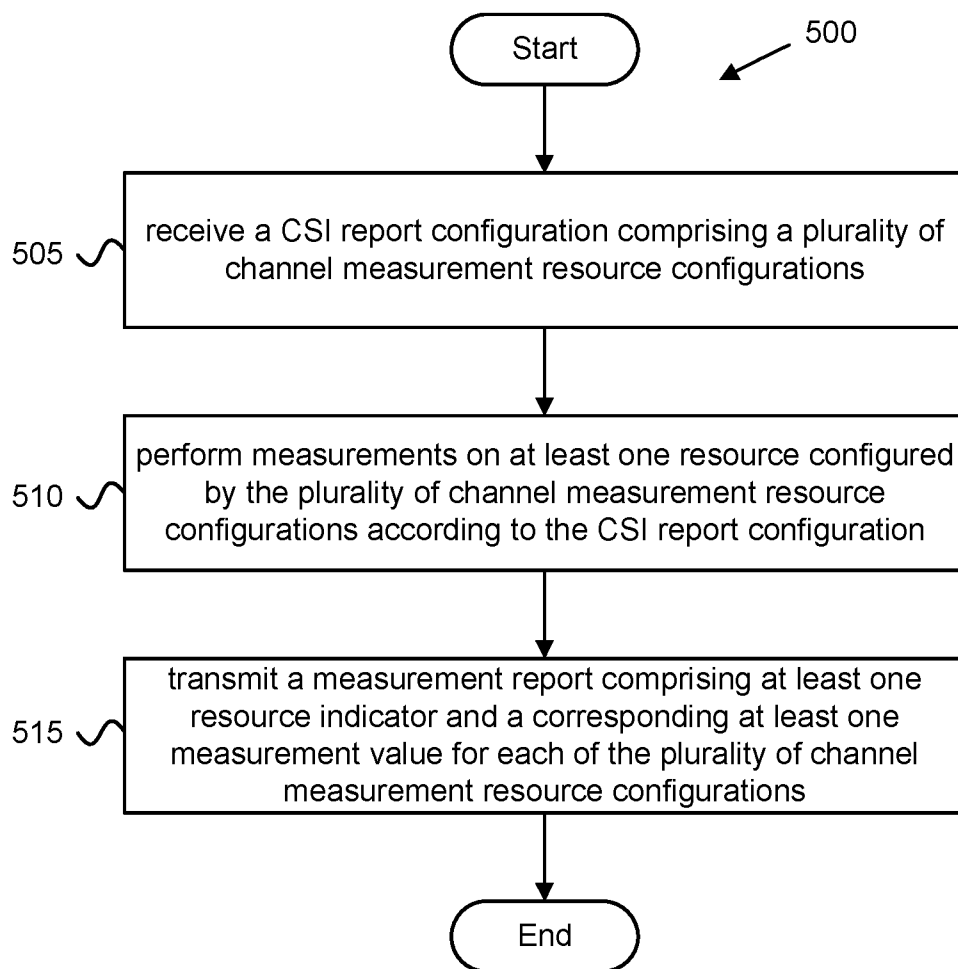


FIG. 5

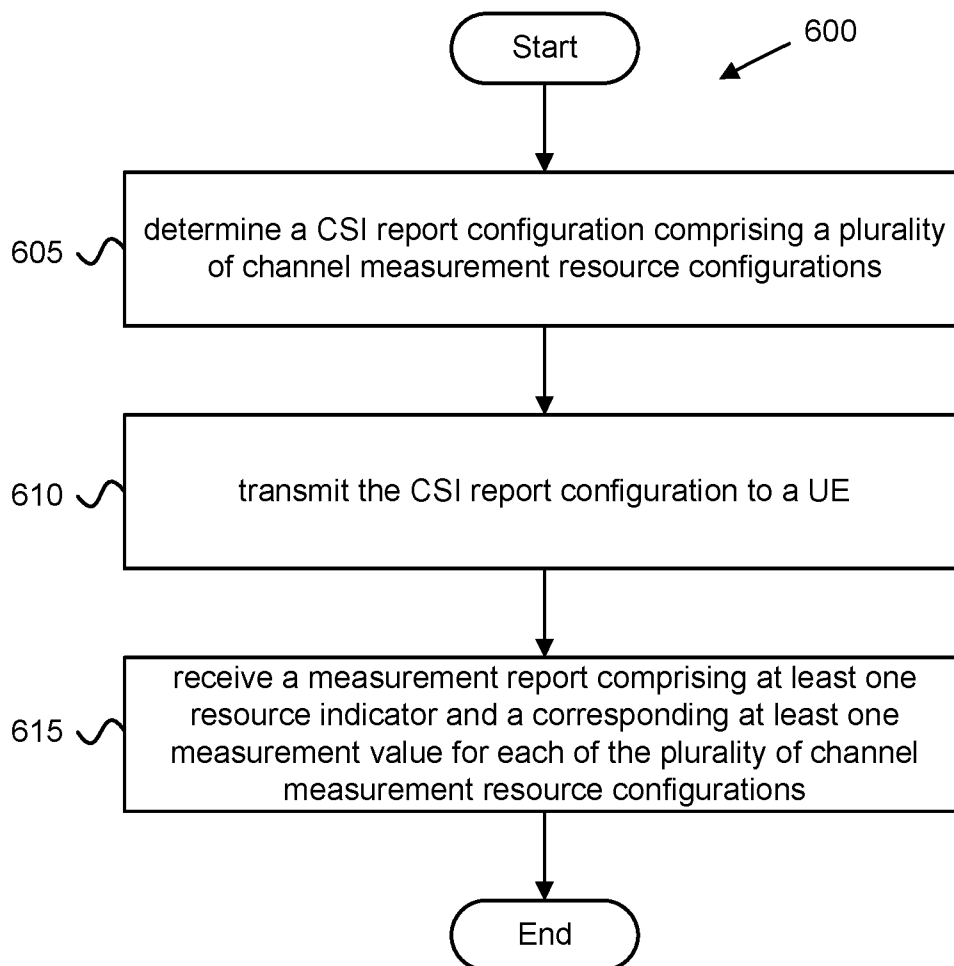


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2023/054811

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B7/06

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)

H04B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020/214168 A1 (NOKIA TECHNOLOGIES OY [FI]; NOKIA USA INC [US]) 22 October 2020 (2020-10-22) abstract paragraphs [0039] - [0043], [0078], [0134] figure 12 -----	1, 2, 10-12, 19, 20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

7 August 2023

Date of mailing of the international search report

06/10/2023

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Helms, Jochen

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2023/054811

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:
1, 2, 10–12, 19, 20

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1, 2, 10-12, 19, 20

Independent claim 1 relates to an apparatus, comprising:
 a processor; and
 a memory coupled to the processor, the memory comprising instructions that are executable by the processor to cause the apparatus to:
 receive a channel state information ("CSI") report configuration comprising a plurality of channel measurement resource configurations;
 perform measurements on at least one resource configured by the plurality of channel measurement resource configurations according to the CSI report configuration; and
 transmit a measurement report comprising at least one resource indicator and a corresponding at least one measurement value for each of the plurality of channel measurement resource configurations.

Independent claims 11 and 20 correspond to claim 1.
 Dependent claims 2 and 12 state that the instructions are executable by the processor to cause the apparatus to measure values associated with a reference signal received power ("RSRP"), a signal-to-interference and noise ratio ("SINR"), or both.

1.1. claims: 10, 19

Dependent claims 10 and 19 state that the at least one resource indicator comprises a CSI reference signal ("CSI-RS") resource indicator, a synchronization signal block ("SSB") resource indicator, or both.

2. claims: 3-5, 13-15

Dependent claim 3 and 13 state that the measurement report comprises:
 a first set of groups of resource indicators and corresponding measurement values,
 each group of the first set comprising a first resource indicator from a first channel measurement resource configuration and a second resource indicator from a second channel measurement resource configuration; and a second set of groups of resource indicators from the second channel measurement resource configuration and corresponding measurement values.

3. claims: 6-9, 16-18

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Dependent claim 6 and 16 state that the measurement report comprises a first set of resource indicators from a first channel measurement resource configuration and corresponding measurement values and a second set of resource indicators from a second channel measurement resource configuration and corresponding measurement quantity values.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2023/054811

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2020214168 A1	22-10-2020	CN 113994598 A	28-01-2022
		EP 3956992 A1	23-02-2022
		US 2022190883 A1	16-06-2022
		WO 2020214168 A1	22-10-2020
