RESOURCE CONFIGURATION AND UCI DESIGN FOR CSI REPORTING

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a user equipment (UE), a network entity, a processor for wireless communication, methods, and a computer readable medium for resource configuration and uplink control information (UCI) design for channel state information (CSI) 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 (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 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 radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0003] To address the issue of coverage, higher downlink spectrum efficiency, larger antenna arrays for single transmission point transmissions with an increased number of antennas have an increased interest in the industry, partly due to new available frequency bands. This interest is partly spurred by the availability of new frequency bands. However, enhancements to existing specifications are required to support both hybrid beamforming, for example, with one beam for each downlink (DL) transmission, and gNB implementation options. These enhancements are necessary to maintain the cost-effectiveness vs performance tradeoff in implementation.

[0004] Currently, specifications offer limited support for large antenna arrays with a significant number of CSI-RS (Channel State Information Reference Signal) ports for CSI (Channel State Information) measurement and reporting. Therefore, it is justified to enhance hybrid beamforming to support multi-beam reporting, extending it to accommodate larger antenna arrays and providing increased MU-MIMO (Multi-User Multiple Input Multiple Output) scheduling opportunities. This extension would involve supporting up to 32 ports per reported beam along with PMI (Precoding Matrix Indicator), CQI (Channel Quality Indicator), and RI (Rank Indicator) per beam.

SUMMARY

[0005] The present disclosure relates to a user equipment (UE), a network entity, a processor for wireless communication, methods, and a computer readable medium for resource configuration and uplink control information (UCI) design for channel state information (CSI) reporting.

[0006] In a first aspect, there is provided a UE. The UE comprises: A user equipment (UE) comprising: a processor; and a transceiver coupled to the processor, wherein the processor is configured to: receive, from a network entity, a channel state information (CSI) report configuration associated with a first number (Ks) of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and transmit, to the network entity, a CSI report including a second number (M) of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0007] In a second aspect, there is provided a network entity. The network entity comprises: a processor; and a transceiver coupled to the processor, wherein the processor is configured to: transmit, to a user equipment (UE), a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS)

resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and receive, from the UE, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0008] In a third aspect, there is provided a processor for wireless communication. The processor comprises: at least one memory; and a controller coupled with the at least one memory and configured to cause the controller to: receive, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and transmit, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0009] In a fourth aspect, there is provided a method performed by a user equipment (UE), the method comprising: receiving, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and transmitting, to the network entity, a CSI report including a second number of quadruplets

in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0010] In a fifth aspect, there is provided a method performed by a network entity, the method comprising: transmitting, to a user equipment (UE), a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and receiving, from the UE, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0011] In a sixth aspect, there is provided a computer readable medium having instructions stored thereon, the instructions, when executed by a processor of an apparatus, causing the apparatus to perform the method according to the fourth or the fifth aspect of the disclosure.

[0012] In some implementations of the methods, the UE and the network entity described herein, all the first number of CSI-RS resources for channel measurement have a same number of antenna ports, and wherein in case that the CSI-IM resources are non-zero power (NZP) CSI-RS resources, the NZP CSI-RS resources have different numbers of antenna ports, each antenna port corresponding to an interference layer.

[0013] In some implementations of the methods, the UE and the network entity described herein, all the first number of CSI-RS resources for channel measurement are

configured with a same *powerControlOffset* value and a same *powerControlOffsetSS* value.

[0014] In some implementations of the methods, the UE and the network entity described herein, the UE may apply "typeD" RS that is configured with *qcl-Type* set to "typeD" to a NZP CSI-RS resource for channel measurement, as the reference RS for determining "typeD" assumption for a corresponding CSI-IM resource or a corresponding NZP CSI-RS resource for interference measurement configured for the CSI report.

[0015] In some implementations of the methods, the UE and the network entity described herein, the UE may receive, from the network entity, at least one of the following: a first indication indicating a first subset of the first number of CSI-RS resources to be included in the CSI report; or a second indication indicating a second subset of the first number of CSI-RS resources that to be excluded from the CSI report.

[0016] In some implementations of the methods, the UE and the network entity described herein, the CSI report comprises a joint CRI indicator field indicating the second number of CSI-RS resources that are reported in the CSI report.

[0017] In some implementations of the methods, the UE and the network entity described herein, the second number is configured by the network entity, and a length of the joint CRI indicator field is based on the first number and the second number, and wherein each codepoint of the joint CRI indicator field is mapped with a set of CRI values comprising the second number of CRI values.

[0018] In some implementations of the methods, the UE and the network entity described herein, the second number is determined by the UE and a maximum of the second number is configured by the network entity, and a length of the joint CRI indicator field is based on the first number and the maximum of the second number, and wherein a codepoint of the joint CRI indicator field is mapped with a set of CRI values based on an order of combinations of CRS-RS resources, no more than the maximum of the second number, chosen from the first number of CRS-RS resources for channel measurement.

[0019] In some implementations of the methods, the UE and the network entity described herein, the joint CRI indicator field comprises a bitmap with a length of the first number of bits, a bit of the bitmap indicating whether a corresponding CSI-RS resource for channel measurement is reported in the CSI report.

[0020] In some implementations of the methods, the UE and the network entity described herein, the second number is selected by the UE from a set of candidate numbers configured by the network entity.

[0021] In some implementations of the methods, the UE and the network entity described herein, a length of the joint CRI indicator field is based on the first number and the candidate numbers, and wherein a codepoint of the joint CRI indicator field is mapped with a set of CRI value based on an order of combinations of CSI-RS resources, with the candidate numbers chosen from the first number of CRS-RS resources for channel measurement.

[0022] In some implementations of the methods, the UE and the network entity described herein, for the second number equal to or less than 2, in case that the CSI report configuration indicates wideband (WB) PMI reporting and WB CQI reporting, the CSI report is transmitted in one part.

[0023] In some implementations of the methods, the UE and the network entity described herein, for the second number equal to 1, a mapping order for the CSI report is in an order of a CRI followed by an RI followed by a layer indicator (LI) followed by a WB PMI followed by a WB CQI.

[0024] In some implementations of the methods, the UE and the network entity described herein, for the second number equal to 2, a mapping order for the CSI report is in an order of a joint CRI indicating a first CRI and a second CRI, followed by a first RI of the first CRI, followed by a second RI of the second CRI, followed by a first LI of the first CRI, followed by a second LI of the second CRI, followed by a first WB PMI of the first CRI, followed by a second WB PMI of the second CRI, followed by a first WB CQI of the first CRI, followed by a second WB CQI of the second CRI.

[0025] In some implementations of the methods, the UE and the network entity described herein, the CSI report comprises zero padding after the LI or after at least one of the first LI and the second LI.

[0026] In some implementations of the methods, the UE and the network entity described herein, for M equal to or greater than 2, for the second number equal to or greater than 2, the CSI report is transmitted in two parts, and a first part of the CSI report comprises a joint CRI indicating the second number of CRIs, RIs of the indicated CRIs,

and a CQI for the first transmission block (TB) of the first CRI of the indicated CRIs; and a second part of the CSI report comprises PMIs of the indicated CRIs, a CQI for the second TB the first CRI of the indicated CRIs, and CQI for the indicated CRIs other than the first CRI.

[0027] In some implementations of the methods, the UE and the network entity described herein, in case that the CSI report configuration indicates subband (SB) CQI reporting, a mapping order the first part of the CSI report is in an order of the joint CRI, followed by the second number of groups of CSI fields that are ordered by the indicated CRIs, wherein each group of CSI fields include an RI of a corresponding CRI of the indicated CRIs, a WB CQI for the first TB of the corresponding CRI, and at least one SB CQI for the first TB of the corresponding CRI as ordered.

[0028] In some implementations of the methods, the UE and the network entity described herein, in case that the CSI report configuration indicates WB PMI reporting and WB CQI reporting, a mapping order of the second part of the CSI report is in an order of the second number of groups of CSI fields, wherein each group of CSI fields includes a WB CQI for the second TB of a corresponding CRI of the indicated CRIs, a layer indicator (LI) of the corresponding CRI, and WB PMI of the corresponding CRI as ordered.

[0029] In some implementations of the methods, the UE and the network entity described herein, wherein in case that the CSI report configuration indicates SB PMI reporting and SB CQI reporting, a mapping order of the second part of the CSI report is in an order of following: a first groups of CSI fields for even subbands reporting followed by a second groups of CSI fields for odd subbands reporting, or alternatively, the second groups of CSI fields for odd subbands reporting followed by the first groups of CSI fields for even subbands reporting, wherein each of the first groups of CSI fields comprises SB CQI for the second TB of all even subbands of a corresponding CRI of the indicated CRIs, and PMI of all even subbands of the corresponding CRI, and wherein each of the second groups of CSI fields comprises SB CQI for the second TB of all odd subbands of a corresponding CRI of the indicated CRIs, and PMI of all odd subbands of the corresponding CRI.

[0030] In some implementations of the methods, the UE and the network entity described herein, in case that the CSI report configuration indicates SB PMI reporting

and SB CQI reporting, a mapping order of the second part of the CSI report is in an order of the second number of groups of CSI fields, wherein each group of CSI fields includes SB CQI for the second TB of all even subbands of a corresponding CRI of the indicated CRIs, PMI of all even subbands of the corresponding CRI, SB CQI for the second TB of all odd subbands of the corresponding CRI, and PMI of all odd subbands of the corresponding CRI.

[0031] In some implementations of the methods, the UE and the network entity described herein, the second number is determined by the UE, a first part of the CSI report comprises a joint CRI indicating the second number of CRIs, at least one RI of the indicated CRIs, a CQI for the first TB of the first CRI of the indicated CRIs, and wherein the second part of the CSI report comprise PMI of the indicated CRIs, a CQI for the second TB of the first CRI, and CQI for the indicated CRIs other than the first CRI.

[0032] In some implementations of the methods, the UE and the network entity described herein, the first part comprises zero padding after the at least one RI of the indicated CRIs.

[0033] In some implementations of the methods, the UE and the network entity described, the second number is determined by the UE, a first part of the CSI report comprises a joint CRI indicating the second number of CRIs, an RI of the first CRI of the indicated CRIs, a CQI for the first TB of the first CRI of the indicated CRIs, and wherein the second part of the CSI report comprises PMI of the indicated CRIs, at least one RI of the indicated CRIs other than the first CRI, a CQI for the second TB of the first CRI, and CQI for the indicated CRIs other than the first CRI.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] FIG. 1 illustrates an example of a wireless communications system in which some embodiments of the present disclosure can be implemented.

[0035] FIG. 2 illustrates an example of a process flow of CSI reporting in accordance with some example embodiments of the present disclosure.

[0036] FIG. 3 illustrates an example of a device that is suitable for implementing some embodiments of the present disclosure.

[0037] FIG. 4 illustrates an example of a processor that is suitable for implementing some embodiments of the present disclosure.

[0038] FIG. 5 illustrates a flowchart of a method that performed by a user equipment in accordance with aspects of the present disclosure.

[0039] FIG. 6 illustrates a flowchart of a method that performed by a network entity in accordance with aspects of the present disclosure.

[0040] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0041] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below. In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0042] References in the present disclosure to "one embodiment," "an example embodiment," "an embodiment," "some embodiments," and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0043] It shall be understood that although the terms "first" and "second" or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope

of embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms. In some examples, values, procedures, or apparatuses are referred to as "best," "lowest," "highest," "minimum," "maximum," or the like. It will be appreciated that such descriptions are intended to indicate that a selection among many used functional alternatives can be made, and such selections need not be better, smaller, higher, or otherwise preferable to other selections.

[0044] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of embodiments. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "has," "having," "includes" and/or "including," when used herein, specify the presence of stated features, elements, components and/or the like, but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof. For example, the term "includes" and its variants are to be read as open terms that mean "includes, but is not limited to." The term "based on" is to be read as "based at least in part on." The term "one embodiment" and "an embodiment" are to be read as "at least one embodiment." The term "another embodiment" is to be read as "at least one other embodiment." The use of an expression such as "A and/or B" can mean either "only A" or "only B" or "both A and B." Other definitions, explicit and implicit, may be included below.

[0045] It is suggested to enhance hybrid beamforming to multi-beam reporting (extended up to 32 ports per reported beam) with PMI/CQI/RI per beam in order to extend hybrid beamforming to larger antenna arrays (e.g., with up to 128 CSI-RS ports) and increased MU-MIMO scheduling opportunities. To support such enhancement, a UE shall be enabled to report M "quadruplets" $\{(CRI_n, RI_n, PMI_n, CQI_n), n=0, \ldots, M-1\}$ in a CSI report based on the measurement on multiple analog beams with multiple antenna ports per beam. In other words, the UE can report the CSI information corresponding to multiple analog beams to increase the multi-use scheduling opportunities with different analog beams.

[0046] In some implementations, for CRI-based CSI refinement for up to 128 CSI-RS ports, A UE may be configured to measure $K_S>1$ NZP (non-zero power) CSI-RS resources with equal number of ports, with up to 32 ports per NZP CSI-RS resource. The

UE may contain the information of M "quadruplets" {(CRI_n, RI_n, PMI_n, CQI_n), n=0, …, M–1} in one CSI reporting instance where the value range of M ($\leq K_S$) is {1, …, min(X, K_S)}. However, detailed uplink control information design (UCI) and optimization need to be further studied. Restriction(s) on channel measurement resource (CMR) configuration including relation with interference measurement resource (IMR) has not been studied yet either.

[0047] In view of this, embodiments of the present disclosure target the enhancements on the resource configuration for channel measurement and interference measurement, and the related configuration restriction as well as the UCI design for such CSI reporting.

[0048] Aspects of the present disclosure are described in the context of a wireless communications system. FIG. 1 illustrates an example of a wireless communications system 100 in which some embodiments of the present disclosure can be implemented. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as an NR network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0049] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a

communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface. In a 3GPP non-terrestrial network (NTN), a network entity 102 in form of a satellite can directly communicate to UE 104 using NR/LTE Uu interface. The satellite may be a transparent satellite or a regenerative satellite. For NTN with a transparent satellite, a base station on earth may communicate with a UE via the satellite. For NTN with a regenerative satellite, the base station may be on board and directly communicate with the UE.

[0050] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0051] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0052] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0053] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0054] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0055] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated

access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0056] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0057] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaption protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0058] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and

an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0059] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0060] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0061] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0062] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0063] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0064] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0065] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0066] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0067] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which

includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0068] Embodiments of the present disclosure provide CRI-based CSI refinement, allowing a UE to report CSIs associated with different analog beams in a CSI report, where each analog beam is represented by a CSI-RS resource. As each analog beam may serve different UEs, the interference levels for these beams may vary. Therefore, it's advantageous to assign independent CSI-IM resources used as interference measurement resources for independent interference measurement for each analog beam. Moreover, different analog beam may be configured with a common max rank indication (RI) restriction and common codebook subset restriction (CBSR) or be configured with beam-specific RI restriction and CBSR based on a same codebook configuration. Details of the embodiments of the present disclosure will be described below.

[0069] FIG. 2 illustrates an example of a process flow 200 of CSI reporting in accordance with some example embodiments of the present disclosure. The process flow 200 may involve a UE 201 and a network entity (e.g. a base station, such as gNB) 202. The process flow 200 may be applied to the wireless communications system 100 with reference to FIG. 1, for example, the UE 201 may be any of UEs 104, and the network entity 202 may be any of the network entities 102. It would be appreciated that the process flow 200 may be applied to other communication scenarios.

[0070] At 210, the network entity 202 may transmit a channel state information (CSI) report configuration 215 to the UE 201. Accordingly, at 220, the UE 201 may receive the CSI report configuration 215 from the network entity 202. The CSI report configuration 315 may be associated with Ks of CSI-reference signal (CSI-RS) resources for channel measurement and Ks of CSI-interference measurement (CSI-IM) resources for interference measurement, where Ks is a positive integer. Each of the Ks CSI-RS resources may be configured with an independent maximum rank indicator (RI) restriction, which refers to a limitation imposed on the value of RIs that can be reported by the UE 201. Additionally or alternatively, it may be configured with an independent codebook subset restriction (CBSR) which is used to restrict the set of PMIs that the 201

can select from for reporting. The CBSRs for the CSI-RS resources may be based on a common codebook configuration. The codebook is used for the UE to quantize the downlink channel matrix by defining a set of precoding matrix indicators.

[0071] In some embodiments, a CSI-RS resource set consisting of the Ks CSI-RS resources may be configured for channel measurement, where CSI-RS resources may have a same number of antenna ports. For example, for a network entity with 128 CSI-RS ports and Ks = 4, each CSI-RS resource may have 32 antenna ports.

[0072] The CSI-RS resource set consisting of the Ks non-zero power(NZP) CSI-RS resources or the CSI-IM resource set consisting of the Ks CSI-IM resources may be configured for interference measurement. Each CSI-RS resource for channel measurement is associated with a NZP CSI-RS resource or CSI-IM resource for interference measurement by the ordering of the NZP CSI-RS resource for channel measurement and NZP CSI-RS resource or CSI-IM resource for interference measurement in the corresponding resource set.

[0073] Since the analog beams corresponding to the CSI-RS resources may serve different number of UEs, the analog beams may have different interferences. If NZP CSI-RS resources are configured for interference measurement, the NZP CSI-RS resources may have different numbers of antenna ports, each antenna port corresponding to an interference layer.

[0074] The UE 201 may perform channel measurement and interference measurement using the same receiving beam. In some embodiments, the UE 201 may apply '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. When a DL signal or a DL channel is configured with a DL RS with *qcl-Type* set to 'typeD', the UE shall apply the same spatial Rx filter parameters used for the reception of the DL RS for the reception of the DL signal or DL channel.

[0075] After CSI-RS transmission and measurement between the UE 201 and the network entity 202, at 230, the UE 201 may transmit a CSI report 235 including M quadruplets in one part or two parts to the network entity 202, where M is a positive integer equal to or less than Ks. This means the UE 201 may report measurements for a

selected or configured subset of the Ks CSI-RS resources. Accordingly, at 240, the network entity 202 receives the CSI report 235 from the UE 201. In some embodiments, the CSI report 235 may be a CRI-based report which comprise a CRI indicating reported CSI-RS resource(s) and corresponding measurements on those CSI-RS resource(s). The M quadruplets in the CSI report may comprise at least one CRI indicating M CSI-RS resources of the Ks CSI-RS resources for channel measurement, and at least one RI, at least one PMI and at least one CQI corresponding to each of the indicated M CSI-RS resources.

[0076] In some embodiments, the network entity 202 may configure a CRI restriction to the UE 201. The UE 201 can be configured with one or more indications (for example, a bitmap with a length of Ks) to indicate which CRIs are expected to be reported or are not expected to be reported in a CSI report corresponding to a CSI report configuration. In some embodiments, the UE 201 may receive a first indication indicating a first subset of the Ks CSI-RS resources that should be included in the CSI report. Additionally or alternatively, the UE 201 may receive a second indication indicating a second subset of the Ks CSI-RS resources that should be excluded in the CSI report.

[0077] To support CRI selection at UE side, all the NZP CSI-RS resources for channel measurement may have the same powerControlOffset and powerControlOffsetSS to have a same EPRE (Effective Radiated Power Enhancement) for fair comparison.

[0078] The CRI reporting in the CSI report 235 will be described in detail. The UE 201 may report M "quadruplets" $\{(CRI_n, RI_n, PMI_n, CQIn), n=0, \ldots, M-1\}$ in one CSI reporting instance, where the value of $M \in \{1,2,\ldots,\min(X, K_s)\}$ may be indicated by network (NW) configuration in the CSI report configuration 215 or be determined and reported by the UE as part of the CSI report. X indicates the UE capability on the maximum number of "quadruplets" for a CSI report. A joint CRI indicator field may be included in the CSI report to indicate the M CSI-RS resources among the Ks CSI-RS resources for channel measurement that are reported in the CSI report. Other information could be included in the CSI report, such as Layer Indicator (LI). The following UE behaviors can be considered.

[0079] In some embodiments, the UE may report a fixed number of M "quadruplets" $\{(CRI_n, RI_n, PMI_n, CQI_n), n=0, \ldots, M-1\}$ according to the NW indication or configuration.

The number of CSI-RS resources (i.e., M) that can be reported in the CSI report is fixed and therefore the maximum number of CRI candidates that can be reported is determined by $C_{K_s}^{M}$, the bitwidth of the CRI indicator field is $\lceil \log_2(C_{K_s}^{M}) \rceil$, where $C_{K_s}^{M}$ denotes combinations of M CSI-RS resources chosen from all the Ks CSI-RS resources, and $\lceil * \rceil$ denotes the ceiling operator. An example on the candidate CRI values for various (Ks, M) values are provided in Table 1.

Table 1: CRI indication for CRI-based CSI report

Ks	M	Candidate CRI value	Bitwidth of CRI
2	1	{0}, {1}	$\lceil \log_2(C_2^1) \rceil = 1$
	2	{0,1}	0
3	1	{0}, {1}, {2}	$\lceil \log_2(C_3^1) \rceil = 2$
	2	{0,1}, {0,2}, {1,2}	$\lceil \log_2(C_3^2) \rceil = 2$
	3	{0,1,2}	0
4	1	{0}, {1}, {2}, {3}	$\lceil \log_2(C_4^1) \rceil = 2$
	2	{0,1}, {0,2}, {0,3}, {1,2}, {1,3}, {2,3}	$\lceil \log_2(C_4^2) \rceil = 3$
	3	{0,1,2}, {0,1,3},{0,2,3},{1,2,3}	$\lceil \log_2(C_4^3) \rceil = 2$
	4	{0,1,2,3}	0
5	1	{0}, {1}, {2}, {3}, {4}	$\lceil \log_2(C_5^1) \rceil = 3$
	2	{0,1}, {0,2}, {0,3}, {0,4}, {1,2}, {1,3}, {1,4}, {2,3}, {2,4}, {3,4}	$\lceil \log_2(C_5^2) \rceil = 4$
	3	{0,1,2}, {0,1,3}, {0,1,4}, {0,2,3}, {0,2,4}, {0,3,4}, {1,2,3}, {1,2,4}, {1,3,4}, {2,3,4}	$\lceil \log_2(C_5^3) \rceil = 4$
	4	{0,1,2,3}, {0,1,2,4}, {0,1,3,4}, {0,2,3,4}, {1,2,3,4}	$\lceil \log_2(C_5^4) \rceil = 3$
6	1	{0}, {1}, {2}, {3}, {4}, {5}	$\lceil \log_2(C_6^1) \rceil = 3$
	2	{0,1}, {0,2}, {0,3}, {0,4}, {0,5}, {1,2}, {1,3}, {1,4}, {1,5}, {2,3}, {2,4}, {2,5}, {3,4}, {3,5}, {4,5}	$\lceil \log_2(C_6^2) \rceil = 4$
	3	{0,1,2}, {0,1,3}, {0,1,4}, {0,1,5}, {0,2,3}, {0,2,4}, {0,2,5}, {0,3,4}, {0,3,5}, {0,4,5}, {1,2,3}, {1,2,4}, {1,2,5}, {1,3,4}, {1,3,5}, {1,4,5}, {2,3,4}, {2,3,5}, {2,4,5}, {3,4,5}	$\lceil \log_2(C_6^3) \rceil = 5$
	4	{0,1,2,3}, {0,1,2,4}, {0,1,2,5}, {0,1,3,4}, {0,1,3,5}, {0,1,4,5}, {0,2,3,4}, {0,2,3,5}, {0,2,4,5}, {0,3,4,5}, {1,2,3,4}, {1,2,3,5}, {1,2,4,5}, {1,3,4,5}, {2,3,4,5}	$\lceil \log_2(C_6^4) \rceil = 4$
7	1	{0}, {1}, {2}, {3}, {4}, {5}, {6}	$\lceil \log_2(C_7^1) \rceil = 3$
	2	{0,1}, {0,2}, {0,3}, {0,4}, {0,5}, {0,6},{1,2}, {1,3}, {1,4}, {1,5}, {1,6},{2,3}, {2,4}, {2,5}, {2,6},{3,4},{3,5}, {3,6},{4,5}, {4,6},{5,6}	$\lceil \log_2(C_7^2) \rceil = 5$

	3	{0,1,2}, {0,1,3}, {0,1,4}, {0,1,5}, {0,1,6}, {0,2,3}, {0,2,4}, {0,2,5}, {0,2,6}, {0,3,4}, {0,3,5}, {0,3,6}, {0,4,5}, {0,4,6}, {0,5,6}, {1,2,3}, {1,2,4}, {1,2,5}, {1,2,6}, {1,3,4}, {1,3,5}, {1,3,6}, {1,4,5}, {1,4,6}, {1,5,6}, {2,3,4}, {2,3,5}, {2,3,6}, {2,4,5}, {2,4,6}, {2,5,6}, {3,4,5}, {3,4,6}, {3,5,6}, {4,5,6}	$\lceil \log_2(C_7^3) \rceil = 6$
	4	{0,1,2,3}, {0,1,2,4}, {0,1,2,5}, {0,1,2,6}, {0,1,3,4}, {0,1,3,5}, {0,1,3,6}, {0,1,4,5}, {0,1,4,6}, {0,1,5,6}, {0,2,3,4}, {0,2,3,5}, {0,2,3,6}, {0,2,4,5}, {0,2,4,6}, {0,2,5,6}, {0,3,4,5}, {0,3,4,6}, {0,3,5,6}, {0,4,5,6}, {1,2,3,4}, {1,2,3,5}, {1,2,3,6}, {1,2,4,5}, {1,2,4,6}, {1,2,5,6}, {1,3,4,5}, {1,3,4,6}, {1,3,5,6}, {1,4,5,6}, {2,3,4,5}, {2,3,4,6}, {2,3,5,6}, {2,4,5,6}, {3,4,5,6},	$\lceil \log_2(C_7^4) \rceil = 6$
8	1	{0}, {1}, {2}, {3}, {4}, {5}, {6}, {7}	3
	2	{0,1}, {0,2}, {0,3}, {0,4}, {0,5}, {0,6}, {0,7}, {1,2}, {1,3}, {1,4}, {1,5}, {1,6}, {1,7}, {2,3}, {2,4}, {2,5}, {2,6}, {2,7},{3,4}, {3,5}, {3,6}, {3,7}, {4,5}, {4,6}, {4,7}, {5,6}, {5,7}, {6,7},	$\lceil \log_2(C_8^2) \rceil = 5$
	3	{0,1,2}, {0,1,3}, {0,1,4}, {0,1,5}, {0,1,6}, {0,1,7}, {0,2,3}, {0,2,4}, {0,2,5}, {0,2,6}, {0,2,7}, {0,3,4}, {0,3,5}, {0,3,6}, {0,3,7}, {0,4,5}, {0,4,6}, {0,4,7}, {0,5,6}, {0,5,7}, {0,6,7}, {1,2,3}, {1,2,4}, {1,2,5}, {1,2,6}, {1,2,7}, {1,3,4}, {1,3,5}, {1,3,6}, {1,3,7}, {1,4,5}, {1,4,6}, {1,4,7}, {1,5,6}, {1,5,7}, {1,6,7}, {2,3,4}, {2,3,5}, {2,3,6}, {2,3,7}, {2,4,5}, {2,4,6}, {2,4,7}, {2,5,6}, {2,5,7}, {2,6,7}, {3,4,5}, {3,4,6}, {3,4,7}, {3,5,6}, {3,5,7}, {3,6,7}, {4,5,6}, {4,5,7}, {4,6,7}, {5,6,7}	$\lceil \log_2(C_8^3) \rceil = 6$
	4	{0,1,2,3}, {0,1,2,4}, {0,1,2,5}, {0,1,2,6}, {0,1,2,7}, {0,1,3,4}, {0,1,3,5}, {0,1,3,6}, {0,1,3,7}, {0,1,4,5}, {0,1,4,6}, {0,1,4,7}, {0,1,5,6}, {0,1,5,7}, {0,1,6,7}, {0,2,3,4}, {0,2,3,5}, {0,2,3,6}, {0,2,3,7}, {0,2,4,5}, {0,2,4,6}, {0,2,4,7}, {0,2,5,6}, {0,2,5,7}, {0,2,6,7}, {0,3,4,5}, {0,3,4,6}, {0,3,4,7}, {0,3,5,6}, {0,3,5,7}, {0,3,6,7}, {0,4,5,6}, {0,4,5,7}, {0,4,6,7}, {0,5,6,7}, {1,2,3,4}, {1,2,3,5}, {1,2,3,6}, {1,2,3,7}, {1,2,4,5}, {1,2,4,6}, {1,2,4,7}, {1,2,5,6}, {1,2,5,7}, {1,2,6,7}, {1,3,4,5}, {1,3,4,6}, {1,3,4,7}, {1,3,5,6}, {1,3,5,7}, {1,3,6,7}, {1,4,5,6}, {1,4,5,7}, {1,4,6,7}, {1,5,6,7}, {2,3,4,5}, {2,3,4,6}, {2,3,4,7}, {2,3,5,6}, {2,3,5,7}, {2,3,6,7}, {2,4,5,6}, {2,4,5,7}, {2,4,6,7}, {2,5,6,7}, {3,4,5,6}, {3,4,5,7}, {3,4,6,7}, {3,5,6,7}, {4,5,6,7},	$\lceil \log_2(C_8^4) \rceil = 7$

[0080] Each codepoint of the CRI field contained in the CSI report is mapped to M CRI values. The mapping between the CRI field codepoint values and the indicated CRI valued for the cases with Ks=3,4,5 and M=2 are provided in Table 2 as an example.

Table 2: Mapping between CRI field codepoint and the CRI values for option 1 with M=2

Codepoint value of CRI field	CRI(s), K_s=3	Codepoint value of CRI field	CRI (s), K_s=4	Codepoint value of CRI field	CRI(s), K_s=5
0	0,1	0	0,1	0	0,1
1	0,2	1	0,2	1	0,2
2	1,2	2	0,3	2	0,3
3	Reserved	3	1,2	3	0,4
		4	1,3	4	1,2
		5	2,3	5	1,3
		6,7	Reserved	6	1,4
				7	2,3
				8	2,4
				9	3,4
				10-15	Reserved

[0081] In some embodiments, instead of a fixed number of reported CSI-RS resources, the UE may report up to M_{max} "quadruplets" in a CSI report, where M_{max} may be indicated or configured by the network entity. The UE may report 1, 2,…, or M CRIs in a CSI report, $1 \leqslant M \leqslant M_{max}$. In this embodiment, The number of CRI candidates is $\sum_{m=1}^{Mmax}(C_{K_s}^m)$, thus the bitwidth of the CRI field is determined by $\lceil \log_2(\sum_{m=1}^{Mmax}(C_{K_s}^m)) \rceil$. The first $C_{K_s}^1$ CRI indicator field codepoints are mapped with single CRI, the second $C_{K_s}^2$ CRI indicator field codepoints are mapped with two CRI values and so on. The mapping between the CRI indicator field codepoint values and the indicated CRI values for the case that Ks=2, 3, 4 and M_{max}=2 are provided in Table 3 as an example.

Table 3: Mapping between CRI field codepoint and the CRI values for option 2 with M_{max}=2

Codepoint value of CRI field	CRI(s), K_s=2	Codepoint value of CRI field	CRI(s), K_s=3	Codepoint value of CRI field	CRI(s), K_s=4
0	0	0	0	0	0
1	1	1	1	1	1
2	0,1	2	2	2	2
3	reserved	3	0,1	3	3
		4	0,2	4	0,1
		5	1,2	5	0,2
		6-7	reserved	6	0,3
				7	1,2
				8	1,3
				9	2,3
				10-15	reserved

[0082] Alternatively, the UE may determine the number of CSI-RS resources to be included in the CSI report. The UE may report M "quadruplets" {(CRI_n, RI_n, PMI_n, CQI_n),

n=0, …, M–1} in a CSI report and the value of M is determined by the UE. That is, the UE may report 1 up to Ks CRIs in the CSI report. In this embodiment, the CRI field designed for embodiments with Mmax configuration can be reused. Because up to Ks CRI can be reported and $\sum_{m=1}^{Ks}\left(C_{K_s}^{m}\right) = 2^{K_s} - 1$, Ks bits may always be needed. One simple way is to indicate the CRIs by a Ks-bits bitmap, $B_0B_1\ldots B_{Ks-1}$, where B_m indicates that whether CRI m is included in the CSI report. CRI $k(k \geqslant 0)$ corresponds to the configured $(k+1)$-th entry of associated nzp-CSI-RS-Resources in the corresponding NZP-CSI-RS-ResourceSet for channel measurement, and $(k+1)$-th entry of associated csi-IM-Resource in the corresponding csi-IM-ResourceSet (if configured) or $(k+1)$-th entry of associated nzp-CSI-RS-Resources in the corresponding NZP-CSI-RS-ResourceSet for interference measurement.

[0083] In some embodiments, the network entity may configure a set of candidate values for M, and the UE may select one of the candidate values to determine the number of CSI-RS resources to be included in the CSI report. The UE may be indicated to report M_1, M_2 or Ms quadruplets in a CSI report, where M_1, M_2 and Ms are configured by the NW and the UE shall selected one of them for the CSI report. In this embodiment, The number of CRI candidates is $C_{K_s}^{M_1} + C_{K_s}^{M_2} + \cdots + C_{K_s}^{M_s}$, thus the bitwidth of the CRI field is determined by $\left\lceil \log_2\left(C_{K_s}^{M_1} + C_{K_s}^{M_2} + \cdots + C_{K_s}^{M_s}\right)\right\rceil$. Accordingly, the codepoint of the joint CRI indicator field may be mapped with a set of CRI value based on an order of combinations of CSI-RS resources, with the candidate values (M_1, M_2, …, Ms) chosen from the Ks CRS-RS resources for channel measurement. The mapping between CRI field and the CRI values is similar to Table 2, except that only rows corresponding to the candidate values are kept.

[0084] In general, the CSI report could be transmitted in one part or two part, depending on the size of the CSI report. The UCI design of the CSI report will be described in the following.

[0085] If the UE is indicated to report M<=2 "quadruplets" {(CRI_n, RI_n, PMI_n, CQI_n), n=0, …, M–1} in one CSI report with wideband (WB) PMI and wideband CQI (which could be configured in the CSI report configuration), for all the CSI-RS resources, it means the size of the report would not be too large and has a fixed size, and thus all the CSI information can be reported with single part. The mapping order of CSI fields of the CSI report for such case is provided in Table 4 for M=1 and in Table 5 for M=2. For

example, for M=1, the mapping order of CSI fields may be in an order of CRI→RI→LI→ WB PMI→WB CQI, and for M=2, the mapping order may be in an order of CRI (joint indication of CRI#1 and CRI#2) → RI#1→RI#2→LI#1→ LI#2→WB PMI#1→WB PMI#2→WB CQI #1 → WB CQI#2. Note that the bitwidth of LI field $\lceil \log_2(v) \rceil$ is determined by the reported value of RI (v), O_p bits zeros may be padded after the Layer Indicator field for a fixed size of UCI.

Table 4: Mapping order of CSI fields of one CSI report, wideband PMI, CQI, M=1

CSI report number	**CSI fields**
CSI report#n	CRI
	Rank indicator
	Layer indicator, if reported
	Zero padding bits O_p, if needed.
	PMI wideband information fields $X_1(i_{1,1}, i_{1,2}, i_{1,3})$
	PMI wideband information fields $X_2(i_2)$
	Wideband CQI for the 1st TB
	Wideband CQI for the 2nd TB

Table 5: Mapping order of CSI fields of one CSI report, wideband PMI, CQI, M=2

CSI report number	**CSI fields**
CSI report#n	CRIs
	RI corresponding to the first CRI
	RI corresponding to the second CRI
	Layer indicator for the CSI-RS resource corresponding to the 1st indicated CRI
	Layer indicator for the CSI-RS resource corresponding to the 2nd indicated CRI
	Zero padding bits O_p, if needed.
	PMI wideband information fields $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ associated with the CSI-RS resource corresponding to the 1st indicated CRI
	PMI wideband information fields $X_2(i_2)$ associated with the CSI-RS resource corresponding to the 1st indicated CRI
	PMI wideband information fields $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ associated with the CSI-RS resource corresponding to the 2nd indicated CRI

	PMI wideband information fields $X_2(i_2)$ associated with the CSI-RS resource corresponding to the 2nd indicated CRI
	Wideband CQI for the 1st TB, if reported, corresponding to the 1st indicated CRI
	Wideband CQI for the 1st TB, if reported, corresponding to the 2nd indicated CRI
	Wideband CQI for the 2nd TB, if reported, corresponding to the 1st indicated CRI
	Wideband CQI for the 2nd TB, if reported, corresponding to the 2nd indicated CRI

[0086] When M≥2, the CSI corresponding to CRI-based CSI report may have two parts. Different partition schemes are proposed for different options on the M selection.

[0087] The first partition scheme is directed to a fixed number M of the CSI-RS resources to be included in the CSI report, for example, when the NW configures UE with the value of M. The first part of the CSI report (Part 1 CSI) should have a fixed size and further indicate the size of the second part of the CSI report (Part 2 CSI). At least for the case that M is fixed in the CSI report, e.g., the NW indicates the UE to report M CRIs is the CSI report, the following scheme can be considered, where Part 1 CSI includes the joint CRI indication indicating M CRIs, RI corresponding to M CRIs, CQI for the 1st TB corresponding to M CRIs, and Part 2 CSI includes PMI for M CRIs, CQI for the 2nd TB corresponding to M CRIs, and LIs for M CRIs. Each CRI may have 1 or 2 TBs depends on the reported RI value, when the report RI equals to or less than 4, the CRI only has CQI for one TB; when the report RI larger than 4, the CRI only has CQIs for two TBs.

[0088] In some embodiments, the mapping order of CSI fields for Part 1 when subband (SB) CQI report is configured is illustrated in Table 6. The mapping order of CSI fields in Part 1 may be in an order of the joint CRI indicating M CRIs, followed by M groups of CSI fields ordered by the indicated M CRIs (for example, in increasing order of indexes), where each group of CSI fields corresponds to one CRI, and may comprise RI of a the CRI, a WB CQI for the 1st transmission block (TB) of the CRI, and at least one SB CQI for the 1st TB of the CRI as ordered. For example, the mapping order could in the order of: CRI (joint CRI indication)→RI for the 1st CRI→WB CQI for the 1st TB of the first CRI→SB CQI of the 1st TB of the first CRI (with the increasing order of subband number) →RI for the second CRI→WB CQI for the 1st TB of the second CRI →SB CQI of the 1st TB of the second CRI (with the increasing order of subband number) →··· →RI for the M-th CRI→WB CQI for the 1st TB of the M-th CRI→SB CQI of the

1st TB of the M-th CRI (with the increasing order of subband number). If wideband CQI is configured, subband CQI field for the 1st TB corresponding to each CRI is not included.

Table 6: Mapping order of CSI fields of one CSI report, CSI part 1, subband CQI

CSI report number	CSI fields
CSI report#n CSI Part 1 Subband CQI	CRIs
	RI corresponding to the 1st indicated CRI
	Wideband CQI for the 1st TB, if reported, corresponding to the 1st indicated CRI
	Subband CQI for the 1st TB with increasing order of subband number, if reported, corresponding to the 1st indicated CRI, if reported
	…
	RI corresponding to the M-th indicated CRI
	Wideband CQI for the 1st TB, if reported, corresponding to the M-th indicated CRI
	Subband CQI for the 1st TB with increasing order of subband number, if reported, corresponding to the M-th indicated CRI, if reported

[0089] The mapping order of CSI fields for part 2 when wideband CQI and wideband PMI reporting is configured is illustrated in Table 7. The mapping order of CSI fields may be in an order of M groups of CSI fields, where each group corresponds to one CRI and may include a WB CQI for the 2nd TB of the CRI, an LI of the CRI, and WB PMI of the CRI as ordered. For example, the mapping order may be in an order of: wideband CQI for the 2nd TB corresponding to the first CRI→LI for the first CRI→wideband PMI associated with the CSI-RS resource corresponding to the first indicated CRI →wideband CQI for the 2nd TB corresponding to the second CRI→LI for the second CRI→wideband PMI associated with the CSI-RS resource corresponding to the second indicated CRI →… →wideband CQI for the 2nd TB corresponding to the M-th CRI→LI for the M-th CRI→ wideband PMI associated with the CSI-RS resource corresponding to the M-th indicated CRI. The PMI comprises two parts $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ and $X_2(i_2)$ and only $X_2(i_2)$ can be report for different subband. $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ and $X_2(i_2)$ are jointly used to determine a precoding matrix indicator.

Table 7: Mapping order of CSI fields of one CSI report, CSI part 2, wideband PMI, CQI

CSI report number	CSI fields
CSI report#n CSI Part 2 Wideband	Wideband CQI for the 2nd TB, if reported, corresponding to the first indicated CRI
	Layer indicator for the CSI-RS resource corresponding to the first indicated CRI
	Wideband PMI $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ associated with the CSI-RS resource corresponding to the first indicated CRI
	Wideband PMI $X_2(i_2)$ associated with the CSI-RS resource corresponding to the first indicated CRI
	...
	Wideband CQI for the 2nd TB, if reported, corresponding to the M-th indicated CRI
	Layer indicator for the CSI-RS resource corresponding to the M-th indicated CRI
	Wideband PMI $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ associated with the CSI-RS resource corresponding to the M-th indicated CRI
	Wideband PMI $X_2(i_2)$ associated with the CSI-RS resource corresponding to the M-th indicated CRI

[0090] The mapping order of CSI fields for Part 2 when subband CQI and subband PMI reporting is configured is illustrated in Table 8. The mapping order of CSI fields of Part 2 may be in an order of first M groups of CSI fields for even subbands reporting followed by a second M groups of CSI fields for odd subbands reporting, or alternatively, the second M groups of CSI fields for odd subbands reporting followed by the first M groups of CSI fields for even subbands reporting. Each of the first M groups of CSI fields corresponds to one CRI and may comprise SB CQI for the 2nd TB of all even subbands of the corresponding CRI, and PMI of all even subbands of the corresponding CRI. Each of the second M groups of CSI fields correspond to one CRI and may comprise SB CQI for the 2nd TB of all odd subbands of the corresponding CRI, and PMI of all odd subbands of the corresponding CRI.

[0091] For example, the mapping order of Part 2 may be in the order of: subband CQI for the 2nd TB of all even subbands for the first CRI→PMI of all even subbands for the first CRI→Subband CQI for the 2nd TB of all even subbands for the second CRI→PMI of all even subbands for the second CRI→··· →Subband CQI for the 2nd TB of all even subbands for the M-th CRI→PMI of all even subbands for the M-th CRI→··· →Subband CQI for the 2nd TB of all odd subbands for the first CRI→PMI of all odd subbands for the first CRI→Subband CQI for the 2nd TB of all odd subbands for the second CRI→

PMI of all odd subbands for the second CRI→… →Subband CQI for the 2nd TB of all odd subbands for the M-th CRI→PMI of all odd subbands for the M-th CRI.

Table 8: Mapping order of CSI fields of one CSI report, CSI part 2, suband PMI, CQI

CSI report number	CSI fields
CSI report#n CSI Part 2 Suband	Subband CQI for the 2nd TB of all even subbands with increasing order of subband number corresponding to the first indicated CRI
	PMI $X_2(i_2)$ of all even subbands with increasing order of subband number associated with the first CRI in CSI part 1
	…
	Subband CQI for the 2nd TB of all even subbands with increasing order of subband number corresponding to the M-th indicated CRI
	PMI $X_2(i_2)$ of all even subbands with increasing order of subband number associated with the M-th CRI in CSI part 1
	…
	Subband CQI for the 2nd TB of all odd subbands with increasing order of subband number corresponding to the first indicated CRI
	PMI $X_2(i_2)$ of all odd subbands with increasing order of subband number associated with the first CRI in CSI part 1
	…
	Subband CQI for the 2nd TB of all odd subbands with increasing order of subband number corresponding to the M-th indicated CRI
	PMI $X_2(i_2)$ of all odd subbands with increasing order of subband number associated with the M-th CRI in CSI part 1

[0092] Alternatively, the mapping order of CSI fields for Part 2 when subband CQI and subband PMI reporting is configured is illustrated in Table 9. The mapping order may be in an order of M groups of CSI fields, wherein each group corresponds to one CRI and may include SB CQI for the 2nd TB of all even subbands of the corresponding CRI, PMI of all even subbands of the corresponding CRI, SB CQI for the 2nd TB of all odd subbands of the corresponding CRI, and PMI of all odd subbands of the corresponding CRI.

[0093] For example, the mapping order of CSI fields may be in the order of: Subband CQI for the 2nd TB of all even subbands for the first CRI→PMI of all even subbands for the first CRI→Subband CQI for the 2nd TB of all odd subbands for the first CRI→PMI of all odd subbands for the first CRI→Subband CQI for the 2nd TB of all even subbands

for the second CRI→PMI of all even subbands for the second CRI→Subband CQI for the 2nd TB of all odd subbands for the second CRI→PMI of all odd subbands for the second CRI… →Subband CQI for the 2nd TB of all even subbands for the M-th CRI→ PMI of all even subbands for the M-th CRI→Subband CQI for the 2nd TB of all odd subbands for the M-th CRI→PMI of all odd subbands for the the M-th CRI.

Table 9: Mapping order of CSI fields of one CSI report, CSI part 2, subband PMI, CQI

CSI report number	**CSI fields**
CSI report#n CSI Part 2 Suband	Subband CQI for the 2nd TB of all even subbands with increasing order of subband number corresponding to the first indicated CRI
	PMI $X_2(i_2)$ of all even subbands with increasing order of subband number associated with the first CRI in CSI part 1
	Subband CQI for the 2nd TB of all odd subbands with increasing order of subband number corresponding to the first indicated CRI
	PMI $X_2(i_2)$ of all odd subbands with increasing order of subband number associated with the first CRI in CSI part 1
	…
	Subband CQI for the 2nd TB of all even subbands with increasing order of subband number corresponding to the M-th indicated CRI
	PMI $X_2(i_2)$ of all even subbands with increasing order of subband number associated with the M-th CRI in CSI part 1
	Subband CQI for the 2nd TB of all odd subbands with increasing order of subband number corresponding to the M-th indicated CRI
	PMI $X_2(i_2)$ of all odd subbands with increasing order of subband number associated with the M-th CRI in CSI part 1

[0094] Another case is that the number of reported CRIs is determined by the UE and is reported as part of the CSI report. The CSI partition scheme as discussed above may be adjusted, such that Part 1 CSI includes the joint CRI indication indicating M CRIs, RI corresponding to each CRI, (zero padding if needed), CQI for the 1st TB corresponding the first CRIs, and Part 2 CSI includes PMI for M CRIs, CQI for the 2nd TB corresponding to the first CRI and all the CQI for other CRIs.

[0095] In some embodiments, the mapping order of the Part 1 may be in the order of RI for the 1st CRI→…→RI for the M-th CRI→zero padding→WB CQI for the 1st TB of the first CRI→SB CQI of the 1st TB of the first CRI (with the increasing order of

subband number). Because Part 1 CSI should have a fixed size, the RI field should be reserved by the maximum number of reported CRIs. Zero bits may needed to be padded after the RI field for field alignment. The detailed mapping order is illustrated in Table 10. If wideband CQI is configured, the subband CQI field for the 1st TB corresponding to each CRI is not included.

Table 10: Mapping order of CSI fields of one CSI report, CSI part 1, subband CQI

CSI report number	CSI fields
CSI report#n CSI Part 1 Subband CQI	CRIs
	RI corresponding to the 1st indicated CRI
	…
	RI corresponding to the 1st indicated CRI
	Zero padding bits O_p, if needed.
	Wideband CQI for the 1st TB, if reported, corresponding to the 1st indicated CRI
	Subband CQI for the 1st TB with increasing order of subband number, if reported, corresponding to the 1st indicated CRI, if reported

[0096] Compared with scheme for which M is fixed, the CQIs corresponding to the CRIs other than the first CRI are reported in Part 2 CSI. The mapping order of Part 2 CSI fields are in the order of: wideband CQI for the 2nd TB corresponding to the first CRI→ LI for the first CRI→wideband PMI associated with the CSI-RS resource corresponding to the first indicated CRI →wideband CQI for the 1st TB corresponding to the second CRI→wideband CQI for the 2nd TB corresponding to the second CRI→LI for the second CRI→wideband PMI associated with the CSI-RS resource corresponding to the second indicated CRI →… →wideband CQI for the 1st TB corresponding to the M-th CRI→ wideband CQI for the 2nd TB corresponding to the M-th CRI→LI for the M-th CRI→ wideband PMI associated with the CSI-RS resource corresponding to the M-th indicated CRI. The detailed mapping order is shown in Table 11 below.

Table 11: Mapping order of CSI fields of one CSI report, CSI part 2, wideband PMI, CQI

CSI report number	CSI fields

CSI report#n CSI Part 2 Wideband	Wideband CQI for the 2nd TB, if reported, corresponding to the first indicated CRI
	Layer indicator for the CSI-RS resource corresponding to the first indicated CRI
	Wideband PMI $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ associated with the CSI-RS resource corresponding to the first indicated CRI
	Wideband PMI $X_2(i_2)$ associated with the CSI-RS resource corresponding to the first indicated CRI
	...
	Wideband CQI for the 1st TB, if reported, corresponding to the M-th indicated CRI
	Wideband CQI for the 2nd TB, if reported, corresponding to the M-th indicated CRI
	Layer indicator for the CSI-RS resource corresponding to the M-th indicated CRI
	Wideband PMI $X_1(i_{1,1}, i_{1,2}, i_{1,3})$ associated with the CSI-RS resource corresponding to the M-th indicated CRI
	Wideband PMI $X_2(i_2)$ associated with the CSI-RS resource corresponding to the M-th indicated CRI

[0097] When subband PMI and/or subband CQI is configured, the mapping order of CSI fields of Part 2 may be in the order of: Subband CQI for the 2nd TB of all even subbands for the first CRI → PMI of all even subbands for the first CRI → wideband/subband CQI for the 1st TB of all even subbands for the second CRI→Subband CQI for the 2nd TB of all even subbands for the second CRI→PMI of all even subbands for the second CRI→··· →wideband/subband CQI for the 1st TB of all even subbands for the M-th CRI→Subband CQI for the 2nd TB of all even subbands for the M-th CRI→ PMI of all even subbands for the M-th CRI→··· →Subband CQI for the 2nd TB of all odd subbands for the first CRI → PMI of all odd subbands for the first CRI → wideband/subband CQI for the 1st TB of all odd subbands for the second CRI→Subband CQI for the 2nd TB of all odd subbands for the second CRI→PMI of all odd subbands for the second CRI→··· →wideband/subband CQI for the 1st TB of all odd subbands for the M-th CRI→Subband CQI for the 2nd TB of all odd subbands for the M-th CRI→PMI of all odd subbands for the M-th CRI.

[0098] Another embodiment is provided targeting the case is that the number of reported CRIs is determined by the UE and is reported as part of the CSI report. In this embodiment, Part 1 CSI may include the joint CRI indication indicating the reported M

CRIs, RI corresponding to the first CRI, CQI for the 1st TB corresponding the first CRI, and Part 2 CSI may include PMI for the M CRIs, RI corresponding to the CRI other than the first CRI, CQI for the 2nd TB corresponding to the first CRI and all the CQI for other CRIs. Compared with the scheme discussed wither reference to Table 10 and Table 11, zero padding after RI field is not needed since only RI corresponding to the first CRI is reported in the Part 1 CSI.

[0099] In this embodiment, the mapping order of CSI fields may be in the order of CRI (joint CRI indication)→RI for the 1st CRI→WB CQI for the 1st TB of the first CRI →SB CQI of the 1st TB of the first CRI (with the increasing order of subband number).

[0100] When wideband PMI and wideband CQI are configured, the mapping order of Part 2 CSI fields are in the order of: wideband CQI for the 2nd TB corresponding to the first CRI→LI for the first CRI→wideband PMI associated with the CSI-RS resource corresponding to the first indicated CRI →wideband CQI for the 1st TB corresponding to the second CRI→wideband CQI for the 2nd TB corresponding to the second CRI→RI for the second CRI→LI for the second CRI→wideband PMI associated with the CSI-RS resource corresponding to the second indicated CRI →… →wideband CQI for the 1st TB corresponding to the M-th CRI→wideband CQI for the 2nd TB corresponding to the M-th CRI→RI for the M-th CRI→LI for the M-th CRI→wideband PMI associated with the CSI-RS resource corresponding to the M-th indicated CRI.

[0101] When subband PMI and subband CQI are configured, the mapping order of Part 2 CSI fields may be in the order of: subband CQI for the 2nd TB of all even subbands for the first CRI→PMI of all even subbands for the first CRI→wideband/subband CQI for the 1st TB of all even subbands for the second CRI→Subband CQI for the 2nd TB of all even subbands for the second CRI→RI for the second CRI→PMI of all even subbands for the second CRI→… →wideband/subband CQI for the 1st TB of all even subbands for the M-th CRI→Subband CQI for the 2nd TB of all even subbands for the M-th CRI →RI for the second CRI→ PMI of all even subbands for the M-th CRI→… →Subband CQI for the 2nd TB of all odd subbands for the first CRI→PMI of all odd subbands for the first CRI→wideband/subband CQI for the 1st TB of all odd subbands for the second

CRI→Subband CQI for the 2nd TB of all odd subbands for the second CRI→PMI of all odd subbands for the second CRI→… →wideband/subband CQI for the 1st TB of all odd subbands for the M-th CRI→Subband CQI for the 2nd TB of all odd subbands for the M-th CRI→PMI of all odd subbands for the M-th CRI.

[0102] FIG. 3 illustrates an example of a device that is suitable for implementing some embodiments of the present disclosure. The device 300 may be an example of a UE 104 or network entity 102 as described herein. The device 300 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 300 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 302, a memory 304, a transceiver 306, and, optionally, an I/O controller 308. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0103] The processor 302, the memory 304, the transceiver 306, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 302, the memory 304, the transceiver 306, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0104] In some implementations, the processor 302, the memory 304, the transceiver 306, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 302 and the memory 304 coupled with the processor 302 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 302, instructions stored in the memory 304).

[0105] For example, the processor 302 may support wireless communication at the device 300 in accordance with examples as disclosed herein. The device 300 may be an example of a UE 104. In this case, the processor 302 may be configured to operable to support means for receiving, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and means for transmitting, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0106] The device 300 may be an example of a network entity 102, e.g. a network entity. In this case, the processor 302 may be configured to operable to support means for transmitting, to a user equipment (UE), a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and means for receiving, from the UE, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0107] The processor 302 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable

logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 302 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 302. The processor 302 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 304) to cause the device 300 to perform various functions of the present disclosure.

[0108] The memory 304 may include random access memory (RAM) and read-only memory (ROM). The memory 304 may store computer-readable, computer-executable code including instructions that, when executed by the processor 302 cause the device 300 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 302 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 304 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0109] The I/O controller 308 may manage input and output signals for the device 300. The I/O controller 308 may also manage peripherals not integrated into the device 300. In some implementations, the I/O controller 308 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 308 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 308 may be implemented as part of a processor, such as the processor 302. In some implementations, a user may interact with the device 300 via the I/O controller 308 or via hardware components controlled by the I/O controller 308.

[0110] In some implementations, the device 300 may include a single antenna 310. However, in some other implementations, the device 300 may have more than one antenna 310 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 306 may communicate bi-directionally, via the one or more antennas 310, wired, or wireless links as described herein. For example, the

transceiver 306 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 306 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 310 for transmission, and to demodulate packets received from the one or more antennas 310. The transceiver 306 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0111] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 310 for transmitting the amplified signal into the air or wireless medium.

[0112] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 310 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0113] FIG. 4 illustrates an example of a processor 400 is suitable for implementing some embodiments of the present disclosure. The processor 400 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 400 may include a controller 402 configured to perform various operations in accordance with examples as described herein. The processor 400 may optionally include at least one memory 404. Additionally, or alternatively, the processor 400 may optionally include one or more arithmetic-logic units (ALUs) 406.

One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0114] The processor 400 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 400) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0115] The controller 402 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 400 to cause the processor 400 to support various operations in accordance with examples as described herein. For example, the controller 402 may operate as a control unit of the processor 400, generating control signals that manage the operation of various components of the processor 400. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0116] The controller 402 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 404 and determine subsequent instruction(s) to be executed to cause the processor 400 to support various operations in accordance with examples as described herein. The controller 402 may be configured to track memory address of instructions associated with the memory 404. The controller 402 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 402 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 400 to cause the processor 400 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 402 may be configured to manage

flow of data within the processor 400. The controller 402 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 400.

[0117] The memory 404 may include one or more caches (e.g., memory local to or included in the processor 400 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 404 may reside within or on a processor chipset (e.g., local to the processor 400). In some other implementations, the memory 404 may reside external to the processor chipset (e.g., remote to the processor 400).

[0118] The memory 404 may store computer-readable, computer-executable code including instructions that, when executed by the processor 400, cause the processor 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 402 and/or the processor 400 may be configured to execute computer-readable instructions stored in the memory 404 to cause the processor 400 to perform various functions (e.g., functions or tasks supporting transmit power prioritization). For example, the processor 400 and/or the controller 402 may be coupled with or to the memory 404, the processor 400, the controller 402, and the memory 404 may be configured to perform various functions described herein. In some examples, the processor 400 may include multiple processors and the memory 404 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0119] The one or more ALUs 406 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 406 may reside within or on a processor chipset (e.g., the processor 400). In some other implementations, the one or more ALUs 406 may reside external to the processor chipset (e.g., the processor 400). One or more ALUs 406 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 406 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 406 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and

logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 406 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 406 to handle conditional operations, comparisons, and bitwise operations.

[0120] The processor 400 may support wireless communication in accordance with examples as disclosed herein. The processor 400 may implemented at a UE 104. In this case, the processor 400 may be configured to operable to support means for receiving, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction. The processor 400 may be configured to operable to support means for transmitting, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0121] The processor 400 may implemented at a network entity 102, e.g. a base station. In this case, the processor 400 may be configured to operable to support means for transmitting, to a user equipment (UE), a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction. The processor 400 may be configured to operable to support means for receiving, from the UE, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least

one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

[0122] FIG. 5 illustrates a flowchart of a method 500 performed by a UE in accordance with aspects of the present disclosure. The operations of the method 500 may be implemented by a device or its components as described herein. For example, the operations of the method 500 may be performed by a UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0123] At 510, the method may include receiving, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction. The operations of 510 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 510 may be performed by a UE 104 as described with reference to FIG. 1.

[0124] At 520, the method may include transmitting, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources. The operations of 520 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 520 may be performed by a UE 104 as described with reference to FIG. 1.

[0125] FIG. 6 illustrates a flowchart of a method 600 performed by a network entity in accordance with aspects of the present disclosure. The operations of the method 600 may be implemented by a device or its components as described herein. For example, the

operations of the method 600 may be performed by a network entity 102 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0126] At 610, the method may include transmitting, to a user equipment (UE), a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction. The operations of 610 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 610 may be performed by a network entity 102 as described with reference to FIG. 1.

[0127] At 620, the method may include receiving, from the UE, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources. The operations of 620 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 620 may be performed by a network entity 102 as described with reference to FIG. 1.

[0128] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0129] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to

perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0130] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0131] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[0132] As used herein, including in the claims, an article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one

or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on. Further, as used herein, including in the claims, a "set" may include one or more elements.

[0133] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

1. A user equipment (UE) comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

receive, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and

transmit, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

2. The UE of claim 1, wherein the processor is further configured to receive, from the network entity, at least one of the following:

a first indication indicating a first subset of the first number of CSI-RS resources to be included in the CSI report; or

a second indication indicating a second subset of the first number of CSI-RS resources that to be excluded from the CSI report.

3. The UE of claim 1, wherein the CSI report comprises a joint CRI indicator field indicating the second number of CSI-RS resources that are reported in the CSI report.

4. The UE of claim 3, wherein the second number is configured by the network entity, and a length of the joint CRI indicator field is based on the first number and the second number,

and wherein each codepoint of the joint CRI indicator field is mapped with a set

of CRI values comprising the second number of CRI values.

5. The UE of claim 3, wherein the second number is determined by the UE and a maximum of the second number is configured by the network entity, and a length of the joint CRI indicator field is based on the first number and the maximum of the second number,

and wherein a codepoint of the joint CRI indicator field is mapped with a set of CRI values based on an order of combinations of CRS-RS resources, no more than the maximum of the second number, chosen from the first number of CRS-RS resources for channel measurement.

6. The UE of claim 1, wherein the second number is selected by the UE from a set of candidate numbers configured by the network entity.

7. The UE of claim 6, wherein a length of the joint CRI indicator field is based on the first number and the candidate numbers, and wherein a codepoint of the joint CRI indicator field is mapped with a set of CRI value based on an order of combinations of CSI-RS resources, with the candidate numbers chosen from the first number of CRS-RS resources for channel measurement.

8. The UE of claim 1, wherein, for the second number equal to or less than 2,

in case that the CSI report configuration indicates wideband (WB) PMI reporting and WB CQI reporting, the CSI report is transmitted in one part.

9. The UE of claim 8, wherein, for the second number equal to 1,

a mapping order for the CSI report is in an order of a CRI followed by an RI followed by a layer indicator (LI) followed by a WB PMI followed by a WB CQI.

10. The UE of claim 8, wherein, for the second number equal to 2,

a mapping order for the CSI report is in an order of a joint CRI indicating a first CRI and a second CRI, followed by a first RI of the first CRI, followed by a second RI of the second CRI, followed by a first LI of the first CRI, followed by a second LI of the

second CRI, followed by a first WB PMI of the first CRI, followed by a second WB PMI of the second CRI, followed by a first WB CQI of the first CRI, followed by a second WB CQI of the second CRI.

11. The UE of claim 9 or 10, wherein the CSI report comprises zero padding after the LI or after at least one of the first LI and the second LI.

12. The UE of claim 1, wherein, for the second number equal to or greater than 2, the CSI report is transmitted in two parts, and

a first part of the CSI report comprises a joint CRI indicating the second number of CRIs, RIs of the indicated CRIs, and a CQI for the first transmission block (TB) of the first CRI of the indicated CRIs; and

a second part of the CSI report comprises PMIs of the indicated CRIs, a CQI for the second TB the first CRI of the indicated CRIs, and CQI for the indicated CRIs other than the first CRI.

13. The UE of claim 12, wherein in case that the CSI report configuration indicates subband (SB) CQI reporting,

a mapping order the first part of the CSI report is in an order of the joint CRI, followed by the second number of groups of CSI fields that are ordered by the indicated CRIs, wherein each group of CSI fields include an RI of a corresponding CRI of the indicated CRIs, a WB CQI for the first TB of the corresponding CRI, and at least one SB CQI for the first TB of the corresponding CRI as ordered.

14. The UE of claim 12, wherein in case that the CSI report configuration indicates WB PMI reporting and WB CQI reporting,

a mapping order of the second part of the CSI report is in an order of the second number of groups of CSI fields, wherein each group of CSI fields includes a WB CQI for the second TB of a corresponding CRI of the indicated CRIs, a layer indicator (LI) of the corresponding CRI, and WB PMI of the corresponding CRI as ordered.

15. The UE of claim 12, wherein in case that the CSI report configuration indicates SB PMI reporting and SB CQI reporting, a mapping order of the second part of

the CSI report is in an order of following:

a first groups of CSI fields for even subbands reporting followed by a second groups of CSI fields for odd subbands reporting, or alternatively,

the second groups of CSI fields for odd subbands reporting followed by the first groups of CSI fields for even subbands reporting,

wherein each of the first groups of CSI fields comprises SB CQI for the second TB of all even subbands of a corresponding CRI of the indicated CRIs, and PMI of all even subbands of the corresponding CRI, and

wherein each of the second groups of CSI fields comprises SB CQI for the second TB of all odd subbands of a corresponding CRI of the indicated CRIs, and PMI of all odd subbands of the corresponding CRI.

16. The UE of claim 12, wherein in case that the CSI report configuration indicates SB PMI reporting and SB CQI reporting,

a mapping order of the second part of the CSI report is in an order of the second number of groups of CSI fields, wherein each group of CSI fields includes SB CQI for the second TB of all even subbands of a corresponding CRI of the indicated CRIs, PMI of all even subbands of the corresponding CRI, SB CQI for the second TB of all odd subbands of the corresponding CRI, and PMI of all odd subbands of the corresponding CRI.

17. The UE of claim 1, wherein the second number is determined by the UE,

a first part of the CSI report comprises a joint CRI indicating the second number of CRIs, at least one RI of the indicated CRIs, a CQI for the first TB of the first CRI of the indicated CRIs, and

wherein the second part of the CSI report comprise PMI of the indicated CRIs, a CQI for the second TB of the first CRI, and CQI for the indicated CRIs other than the first CRI.

18. A network entity comprising:

a processor; and

a transceiver coupled to the processor,

wherein the processor is configured to:

transmit, to a user equipment (UE), a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and

receive, from the UE, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

19. A processor for wireless communication, comprising:

at least one memory; and

a controller coupled with the at least one memory and configured to cause the controller to:

receive, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and

transmit, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.

20. A method performed by a user equipment (UE), the method comprising:

receiving, from a network entity, a channel state information (CSI) report configuration associated with a first number of CSI-reference signal (CSI-RS) resources for channel measurement and the first number of CSI-interference measurement (CSI-IM) resources for interference measurement, wherein each of the CSI-RS resources is configured with at least one of an independent maximum rank indicator (RI) restriction or an independent codebook subset restriction; and

transmitting, to the network entity, a CSI report including a second number of quadruplets in one part or two parts, the second number being equal to or less than the first number, wherein the second number of quadruplets comprise at least one CSI resource indicator (CRI) indicating the second number of CSI-RS resources of the first number of CSI-RS resources for channel measurement, and at least one RI, at least one precoding matrix indicator (PMI) and at least one channel quality indicator (CQI) corresponding to the indicated second number of CSI-RS resources.