

METHODS AND APPARATUSES FOR CSI REPORTING

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to methods and apparatuses for channel state information (CSI) reporting based on CSI reference signal (CSI-RS) with more than 32 CSI-RS ports.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations (BSs), which 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, or the like). 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)).

SUMMARY

[0003] 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.

[0004] Some implementations of the methods and apparatuses described herein may include a UE for wireless communication. The UE may include: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: receive CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and perform CSI reporting based on the CSI-RS and a CSI reference resource.

[0005] In some implementations of the UE described herein, the first CSI-RS resource includes at least two second CSI-RS resources. To perform CSI reporting, the at least one processor is configured to cause the UE to: transmit a first CSI report only after receiving at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI interference measurement (CSI-IM) occasion for interference measurement no later than the CSI reference resource; or when discontinuous reception (DRX) is configured, transmit the first CSI report only if receiving at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource.

[0006] In some implementations of the UE described herein, to perform CSI reporting, the at least one processor is configured to cause the UE to: transmit a second CSI report only after receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured, transmit the second CSI report only if receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and the second CSI report includes CSI determined based on a first one of the at least one second CSI-RS resource or determined based on a second CSI-RS resource selected from the at least one second CSI-RS resource by the UE.

[0007] In some implementations of the UE described herein, the at least one processor is further configured to cause the UE to receive configuration information for a codebook associated with the at least two second CSI-RS resources, wherein the second CSI report is based on the codebook.

[0008] In some implementations of the UE described herein, the at least one processor is further configured to cause the UE to transmit an indicator to indicate the selected second CSI-RS resource in the case that the second CSI report includes CSI determined based on the selected second CSI-RS resource.

[0009] In some implementations of the UE described herein, the first CSI-RS resource includes at least two second CSI-RS resources, and the at least one processor is further configured to cause the UE to transmit capability information indicating whether the UE supports a CSI report based on at least one second CSI-RS resource but not all of the at least two second CSI-RS resources.

[0010] In some implementations of the UE described herein, to perform CSI reporting, the at least one processor is configured to cause the UE to: transmit a third CSI report only after receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured, transmit the third CSI report only if receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and the third CSI report includes CSI using all of the first number of CSI-RS ports derived based on received CSI-RS.

[0011] In some implementations of the UE described herein, the at least one processor is further configured to cause the UE to transmit capability information indicating whether the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource.

[0012] In some implementations of the UE described herein, the CSI reference resource is determined based on a reference slot number, and for periodic CSI reporting or semi-persistent CSI reporting, the at least one processor is further configured to cause the UE to transmit capability information indicating a capability level which corresponds to a value of the reference slot number.

[0013] In some implementations of the UE described herein, the CSI reference resource is determined based on a reference slot number. For periodic CSI reporting or semi-persistent CSI reporting, the reference slot number is a smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, wherein K is an integer larger than or equal to 0, and μ_{DL} is a subcarrier spacing configuration for downlink.

[0014] In some implementations of the UE described herein, K is a predefined value, or the at least one processor is further configured to cause the UE to transmit capability information explicitly or implicitly indicating a value of K.

[0015] In some implementations of the UE described herein, for aperiodic CSI reporting, the at least one processor is further configured to cause the UE to perform CSI reporting further based on a first time Z or a second time Z', wherein Z includes a first additional time relative to a third time Z_2 for no more than 32 CSI-RS ports, or Z' includes a second additional time relative to a fourth time Z'_2 for no more than 32 CSI-RS ports.

[0016] In some implementations of the UE described herein, the at least one processor is further configured to cause the UE to transmit capability information indicating whether to support the first additional time or the second additional time.

[0017] In some implementations of the UE described herein, the first additional time is determined based on $k_1 Z_2$ or $k_1 Z'_2$, or the second additional time is determined based on $k_1 Z'_2$, and $0 \leq k_1 \leq 1$.

[0018] In some implementations of the UE described herein, the at least one processor is further configured to cause the UE to transmit capability information indicating a value of k_1 .

[0019] In some implementations of the UE described herein, the first CSI-RS resource includes at least two second CSI-RS resources, and the first additional time or the second

additional time is determined based on a maximum orthogonal frequency division multiplexing (OFDM) symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources.

[0020] In some implementations of the UE described herein, the first additional time or the second additional time is 14 or 28 OFDM symbols.

[0021] In some implementations of the UE described herein, the first CSI-RS resource includes at least two second CSI-RS resources, wherein: the first additional time is determined based on $k_{11}Z_2 + k_{12}$ or $k_{21}Z'_2 + k_{22}$, wherein $0 \leq k_{11} \leq 1$, k_{12} is based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources, $0 \leq k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources; or the second additional time is determined based on $k_{21}Z'_2 + k_{22}$.

[0022] In some implementations of the UE described herein, the at least one processor is further configured to cause the UE to transmit capability information indicating: value(s) of at least one of k_{11} or k_{12} ; or value(s) of at least one of k_{21} or k_{22} .

[0023] Some implementations of the methods and apparatuses described herein may include a processor for wireless communication. The processor may include: at least one controller coupled with at least one memory and configured to cause the processor to: receive CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and perform CSI reporting based on the CSI-RS and a CSI reference resource.

[0024] Some implementations of the methods and apparatuses described herein may include a BS for wireless communication. The BS may include: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the BS to: transmit CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and receive, from a UE, a CSI report based on the CSI-RS and a CSI reference resource.

[0025] In some implementations of the BS described herein, the first CSI-RS resource includes at least two second CSI-RS resources, and the at least one processor is configured to cause the BS to: receive a first CSI report only after transmitting at least one CSI-RS

transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource; or when DRX is configured for the UE, receive the first CSI report only if transmitting at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource.

[0026] In some implementations of the BS described herein, the at least one processor is configured to cause the BS to: receive a second CSI report only after transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured for the UE, receive the second CSI report only if transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and the second CSI report includes CSI determined based on a first one of the at least one second CSI-RS resource or determined based on a second CSI-RS resource selected from the at least one second CSI-RS resource by the UE.

[0027] In some implementations of the BS described herein, the at least one processor is further configured to cause the BS to transmit configuration information for a codebook associated with the at least two second CSI-RS resources, wherein the second CSI report is based on the codebook.

[0028] In some implementations of the BS described herein, the at least one processor is further configured to cause the BS to receive an indicator to indicate the selected second CSI-RS resource in the case that the second CSI report includes CSI determined based on the selected second CSI-RS resource.

[0029] In some implementations of the BS described herein, the first CSI-RS resource includes at least two second CSI-RS resources, and the at least one processor is further configured to cause the BS to receive capability information indicating whether the UE supports

a CSI report based on at least one second CSI-RS resource but not all of the at least two second CSI-RS resources.

[0030] In some implementations of the BS described herein, the at least one processor is configured to cause the BS to: receive a third CSI report only after transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured for the UE, receive the third CSI report only if transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and the third CSI report includes CSI using all of the first number of CSI-RS ports derived based on CSI-RS received by the UE.

[0031] In some implementations of the BS described herein, the at least one processor is further configured to cause the BS to receive capability information indicating whether the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource.

[0032] In some implementations of the BS described herein, the CSI reference resource is determined based on a reference slot number, and for periodic CSI reporting or semi-persistent CSI reporting, the at least one processor is further configured to cause the BS to receive capability information indicating a capability level which corresponds to a value of the reference slot number.

[0033] In some implementations of the BS described herein, the CSI reference resource is determined based on a reference slot number. For periodic CSI reporting or semi-persistent CSI reporting, the reference slot number is a smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, wherein K is an integer larger than or equal to 0, and μ_{DL} is a subcarrier spacing configuration for downlink.

[0034] In some implementations of the BS described herein, K is a predefined value, or the at least one processor is further configured to cause the BS to receive capability information explicitly or implicitly indicating a value of K.

[0035] In some implementations of the BS described herein, for aperiodic CSI reporting, the at least one processor is further configured to cause the BS to receive the CSI report further based on a first time Z or a second time Z' , wherein Z includes a first additional time relative to a third time Z_2 for no more than 32 CSI-RS ports, or Z' includes a second additional time relative to a fourth time Z'_2 for no more than 32 CSI-RS ports.

[0036] In some implementations of the BS described herein, the at least one processor is further configured to cause the BS to receive capability information indicating whether to support the first additional time or the second additional time.

[0037] In some implementations of the BS described herein, the first additional time is determined based on $k_1 Z_2$ or $k_1 Z'_2$, or the second additional time is determined based on $k_1 Z'_2$, and $0 \leq k_1 \leq 1$.

[0038] In some implementations of the BS described herein, the at least one processor is further configured to cause the BS to receive capability information indicating a value of k_1 .

[0039] In some implementations of the BS described herein, the first CSI-RS resource includes at least two second CSI-RS resources, and the first additional time or the second additional time is determined based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources.

[0040] In some implementations of the BS described herein, the first additional time or the second additional time is 14 or 28 OFDM symbols.

[0041] In some implementations of the BS described herein, the first CSI-RS resource includes at least two second CSI-RS resources, wherein: the first additional time is determined based on $k_{11} Z_2 + k_{12}$ or $k_{21} Z'_2 + k_{22}$, wherein $0 \leq k_{11} \leq 1$, k_{12} is based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources, $0 \leq k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between

two second CSI-RS resources of the at least two second CSI-RS resources; or the second additional time is determined based on $k_{21}Z'_2+k_{22}$.

[0042] In some implementations of the BS described herein, the at least one processor is further configured to cause the BS to receive capability information indicating: value(s) of at least one of k_{11} or k_{12} ; or value(s) of at least one of k_{21} or k_{22} .

[0043] Some implementations of the methods and apparatuses described herein may include a method performed by a UE. The method may include: receiving CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and performing CSI reporting based on the CSI-RS and a CSI reference resource.

[0044] Some implementations of the methods and apparatuses described herein may include a method performed by a BS. The method may include: transmitting CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and receiving, from a UE, a CSI report based on the CSI-RS and a CSI reference resource.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] In order to describe the manner in which advantages and features of the application can be obtained, a description of the application is rendered by reference to specific embodiments thereof, which are illustrated in the appended drawings. These drawings depict only example embodiments of the application and are not therefore to be considered limiting of its scope.

[0046] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0047] Figure 2 illustrates a flowchart of an exemplary method performed by a UE in accordance with aspects of the present disclosure.

[0048] Figure 3 illustrates a flowchart of an exemplary method performed by a BS in accordance with aspects of the present disclosure.

[0049] Figure 4 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0050] Figure 5 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0051] Figure 6 illustrates an example of a BS in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0052] The detailed description of the appended drawings is intended as a description of preferred embodiments of the present application and is not intended to represent the only form in which the present application may be practiced. It should be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the present application.

[0053] While operations are depicted in the drawings in a particular order, persons skilled in the art will readily recognize that such operations need not be performed in the particular order as shown or in a sequential order, or that all illustrated operations need be performed, to achieve desirable results; sometimes one or more operations can be skipped. Further, the drawings can schematically depict one or more example processes in the form of a flow diagram. However, other operations that are not depicted can be incorporated in the example processes that are schematically illustrated. For example, one or more additional operations can be performed before, after, simultaneously, or between any of the illustrated operations. In certain circumstances, multitasking and parallel processing can be advantageous.

[0054] Reference will now be made in detail to some embodiments of the present application, examples of which are illustrated in the accompanying drawings. To facilitate understanding, embodiments are provided under specific network architecture and new service scenarios, such as 3rd generation partnership project (3GPP) long-term evolution (LTE) and LTE advanced, 3GPP 5G new radio (NR), 5G-Advanced, 6G, and so on. It is contemplated that along with developments of network architectures and new service scenarios, all embodiments in the present application are also applicable to similar technical problems; and moreover, the terminologies recited in the present application may change, which should not affect the principle of the present application.

[0055] Aspects of the present disclosure are described in the context of a wireless communications system.

[0056] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network equipments (NEs) (e.g., BSs) 102, one or more UEs 104, and a core network (CN) 106. 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 NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) 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, for example, 6G. 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.

[0057] The one or more NEs 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NEs 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0058] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 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, an NE 102 may be moveable, for example, a

satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NEs 102.

[0059] 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 remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver 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.

[0060] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. 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 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.

[0061] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N2, or network interface). In some implementations, the NEs 102 may communicate with each other directly. In some other implementations, the NEs 102 may communicate with each other indirectly (e.g., via the CN 106). In some implementations, one or more NEs 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 radio heads, smart radio heads, or transmission-reception points (TRPs).

[0062] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 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 function (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 NEs 102 associated with the CN 106.

[0063] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N2, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 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 CN 106 (e.g., one or more network functions of the CN 106).

[0064] In the wireless communications system 100, the NEs 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 NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 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 NEs 102 and the UEs 104 may support various frame structures (e.g., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0065] 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., $\mu=0$) 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., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) 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., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0066] 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.

[0067] 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 (e.g., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) 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., orthogonal frequency division multiplexing (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., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0068] 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 NEs 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 NEs 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 NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0069] 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., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), 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., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0070] With the development of communication technology, enhancements on downlink multiple input multiple output (MIMO) that facilitate the use of large antenna array, for both FR1 and FR2, are proposed to fulfil the demand for evolution of NR deployments, especially for 7GHz frequency band(s). In existing 5G system, the CSI-RS port is designed based on a maximum port number of 32. However, for the large antenna array, a larger number of CSI-RS

ports (e.g., more than 32 ports) may be used to further increase beamforming gain, thereby improving the cell coverage and cell average/edge throughput, especially for the case that the CSI-RS ports are implemented with full digital ports. Herein, the terms "port," "CSI-RS port," "antenna port" and "CSI-RS antenna port" may be used interchangeably.

[0071] In existing 5G system, CSI-RS is designed based on a maximum port number of 32. According to 3GPP specifications (e.g., TS 38.214), after the CSI report (re)configuration, serving cell activation, bandwidth part (BWP) change, or activation of semi-persistent CSI (SP-CSI), the UE may transmit a CSI report only after receiving at least one CSI-RS transmission occasion for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than a CSI reference resource and may drop the CSI report otherwise; when DRX is configured for the UE, the UE may transmit a CSI report only if receiving at least one CSI-RS transmission occasion for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than a CSI reference resource and may drop the CSI report otherwise.

[0072] For CSI-RS with more than 32 ports, there may exist the following issues.

[0073] One issue is that, in some cases, the UE may receive CSI-RS with partial CSI-RS ports of the more than 32 CSI-RS ports before a CSI reference resource. Then, the UE behaviour for CSI reporting in such cases needs to be defined.

[0074] Another issue is that, for CSI-RS with more than 32 ports, the definition for the CSI reference resource may need to be changed. Then, how to determine the CSI reference resource for periodic CSI reporting and semi-persistent CSI reporting needs to be solved.

[0075] Yet another issue is that, for aperiodic CSI reporting based on CSI-RS with more than 32 ports, more computation time may be needed. Accordingly, the CSI computation delay requirement may be changed. Then, how to determine the CSI computation delay requirement for CSI-RS with more than 32 ports needs to be solved.

[0076] Embodiments of the present disclosure provide solutions for CSI reporting based on CSI-RS with more than 32 antenna ports, which can at least solve the aforementioned issues. In some embodiments of the present application, CSI-RS with more than 32 antenna ports may

refer to CSI-RS on a CSI-RS resource with more than 32 antenna ports. More details will be described in the following text in combination with the appended drawings.

[0077] In existing 5G system, CSI-RS may be transmitted on a CSI-RS resource with no more than 32 CSI-RS ports. In the time domain, the CSI-RS resource may be within a slot and include no more than 4 OFDM symbols of the slot. If CSI-RS with more than 32 CSI-RS ports are introduced for a large antenna array, additional time-frequency resources may be needed. Such time-frequency resources may include at least one of: OFDM symbols, slots, or physical resource blocks (PRBs).

[0078] According to some embodiments of the present application, CSI-RS may be transmitted on a CSI-RS resource with more than 32 ports. Such resource may be referred to as a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is larger than 32.

[0079] In some embodiments of the present disclosure, the first resource may be generated by aggregating at least two second CSI-RS resources (e.g., legacy CSI-RS resources with no more than 32 ports). Accordingly, the first resource may be referred to as an aggregated CSI-RS resource. Each of the at least two second CSI-RS resources may be referred to as a component CSI-RS resource.

[0080] In some examples, each component CSI-RS resource may have no more than 32 CSI-RS ports. In some other examples, at least one of the at least two component CSI-RS resources may have more than 32 ports. In some examples, the at least two component CSI-RS resources may have different numbers of antenna ports.

[0081] As an example, in the case of the aggregated CSI-RS resource with 48 ports, the at least two component CSI-RS resources may include two component CSI-RS resources with 24 ports or three component CSI-RS resources with 16 ports.

[0082] As another example, in the case of the aggregated CSI-RS resource with 64 ports, the at least two component CSI-RS resources may include two component CSI-RS resources with 32 ports or four component CSI-RS resources with 16 ports.

[0083] As yet another example, in the case of the aggregated CSI-RS resource with 72 ports, the at least two component CSI-RS resources may include three component CSI-RS resources with 24 ports.

[0084] As yet another example, in the case of the aggregated CSI-RS resource with 96 ports, the at least two component CSI-RS resources may include three component CSI-RS resources with 32 ports.

[0085] As yet another example, in the case of the aggregated CSI-RS resource with 128 ports, the at least two component CSI-RS resources may include two component CSI-RS resources with 64 ports or four component CSI-RS resources with 32 ports.

[0086] In some examples, the time spacing between component CSI-RS resources may guarantee CSI estimation performance. For example, the at least two component CSI-RS resources may be within the same slot or adjacent slots.

[0087] In some cases, e.g., in DRX operation, or after the CSI report (re)configuration, serving cell activation, BWP change, or activation of semi-persistent CSI (SP-CSI), etc., it may happen that CSI-RS is transmitted or received on only part (not all) of the first number of CSI-RS ports of the aggregated CSI-RS resource before a CSI reference resource. In other words, the CSI-RS is transmitted or received on at least one but not all of the at least two component CSI-RS resources before a CSI reference resource. Such case may be referred to as partial CSI-RS port transmission. However, partial CSI-RS port transmission may not include the case that CSI-RS is transmitted or received on part of one component CSI-RS resource. Then, how to perform CSI reporting in the case of partial CSI-RS port transmission needs to be defined.

[0088] The following Embodiments 1-3 provide exemplary UE behaviors that may be specified for CSI reporting with respect to partial CSI-RS port transmission.

[0089] **Embodiment 1**

[0090] In Embodiment 1, a UE may report CSI based on CSI-RS with full CSI-RS port transmission, i.e., based on CSI-RS received on all of the first number of CSI-RS ports of the aggregated CSI-RS resource or based on CSI-RS received on all of the at least two component

CSI-RS resources. The UE does not report CSI based on CSI-RS with partial CSI-RS port transmission.

[0091] As an example, to perform CSI reporting, the UE may:

- transmit a CSI report only after receiving at least one CSI-RS transmission occasion for each of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than a CSI reference resource; and
- otherwise, drop the CSI report.

[0092] As another example, to perform CSI reporting when DRX is configured, the UE may:

- transmit a CSI report only if receiving at least one CSI-RS transmission occasion for each of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than a CSI reference resource; and
- otherwise, drop the CSI report.

[0093] Herein, receiving a CSI-RS transmission occasion for a component CSI-RS resource means receiving CSI-RS on all time-frequency resources included in the component CSI-RS resource or receiving CSI-RS on all ports of the component CSI-RS resource.

[0094] **Embodiment 2**

[0095] In Embodiment 2, a UE may report CSI based on CSI-RS with full CSI-RS port transmission or based on CSI-RS with partial CSI-RS port transmission.

[0096] As an example, to perform CSI reporting, the UE may:

- transmit a first CSI report only after receiving at least one CSI-RS transmission occasion for each of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than a CSI reference resource;
- otherwise:

- transmit a second CSI report only after receiving at least one CSI-RS transmission occasion for at least one component CSI-RS resource but not all of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource; and
- otherwise, drop the CSI report.

[0097] As another example, to perform CSI reporting when DRX is configured, the UE may:

- transmit a first CSI report only if receiving at least one CSI-RS transmission occasion for each of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than a CSI reference resource;
- otherwise:
 - transmit a second CSI report only if receiving at least one CSI-RS transmission occasion for at least one component CSI-RS resource but not all of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and
 - otherwise, drop the CSI report.

[0098] In the above two examples of Embodiment 2, the first CSI report refers to a CSI report based on CSI-RS with full CSI-RS port transmission, and the second CSI report refers to a CSI report based on CSI-RS with partial CSI-RS port transmission. The first CSI report and the second CSI report will not be transmitted simultaneously. That is, when the aforementioned condition for transmitting the first CSI report is satisfied, the UE may transmit the first CSI report; when the aforementioned condition for transmitting the second CSI report is satisfied, the UE may transmit the second CSI report.

[0099] The second CSI report may include CSI determined based on a first one (the "first" here means "received earliest") of the at least one component CSI-RS resource (for which at least one CSI-RS transmission occasion is received) or determined based on a component CSI-RS resource selected from the at least one component CSI-RS resource by the UE.

[0100] In some examples of Embodiment 2, in the case that the second CSI report includes CSI determined based on the selected component CSI-RS resource, the UE may transmit, to a BS, an indicator to indicate the selected component CSI-RS resource. For example, the indicator may indicate an index of the selected component CSI-RS resource.

[0101] In Embodiment 2, the CSI-RS port number of the first one of the at least one component CSI-RS resource or the selected component CSI-RS resource may be used for generating a precoding matrix indicator (PMI) in the second CSI report. In some examples, the UE may receive configuration information (e.g., via radio resource control (RRC) signaling) for a codebook associated with the at least two component CSI-RS resources. The second CSI report may be determined based on the codebook. For example, the configuration information may include an array size of an antenna array, codebook subset restriction and/or rank restriction for the codebook. The array size may be defined by $n1$ and $n2$, wherein $n1$ is a number of antenna ports per polarization direction in a horizontal direction of the antenna array, and $n2$ is a number of antenna ports per polarization direction in a vertical direction of the antenna array.

[0102] In some embodiments of the present application, the UE may transmit capability information indicating whether the UE supports a CSI report based on at least one but not all of the at least two component CSI-RS resources (in other words, based on part of the first number of CSI-RS ports of the aggregated CSI-RS resource, based on partial CSI-RS port transmission, or based on CSI-RS received on at least one but not all of the at least two component CSI-RS resources), such that the BS may know or configure the UE behaviour for CSI reporting.

[0103] For example, in the case that the capability information transmitted by the UE indicating that the UE supports a CSI report based on partial CSI-RS port transmission, the UE may perform (or the BS may configure the UE to perform) the operations provided in Embodiment 2 for reporting CSI. In the case that the capability information transmitted by the UE indicating that the UE does not support a CSI report based on partial CSI-RS port transmission, the UE may perform (or the BS may configure the UE to perform) the operations provided in Embodiment 1 for reporting CSI.

[0104] **Embodiment 3**

[0105] In Embodiment 3, a UE may have an enhanced capability for CSI reporting. This kind of UE may derive (or predict) CSI for all of the first number of CSI-RS ports of the aggregated CSI-RS resource by using received CSI-RS (e.g., using statistics information based on previously received CSI-RS and newly received CSI-RS (e.g., received after the CSI reference resource), or using a specific algorithm for reducing computation time).

[0106] As an example, to perform CSI reporting, the UE may:

- transmit a first CSI report only after receiving at least one CSI-RS transmission occasion for each of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than a CSI reference resource;
- otherwise:
 - transmit a third CSI report only after receiving at least one CSI-RS transmission occasion for at least one component CSI-RS resource but not all of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource; and
 - otherwise, drop the CSI report.

[0107] As another example, to perform CSI reporting when DRX is configured, the UE may:

- transmit a first CSI report only if receiving at least one CSI-RS transmission occasion for each of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than a CSI reference resource;
- otherwise:
 - transmit a third CSI report only if receiving at least one CSI-RS transmission occasion for at least one component CSI-RS resource but not all of the at least two component CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and

- otherwise, drop the CSI report.

[0108] In the above two examples of Embodiment 3, the first CSI report refers to a CSI report based on CSI-RS with full CSI-RS port transmission, and the third CSI report refers to a CSI report for all CSI-RS ports based on prediction or implementation. The first CSI report and the third CSI report will not be transmitted simultaneously. That is, when the aforementioned condition for transmitting the first CSI report is satisfied, the UE may transmit the first CSI report; when the aforementioned condition for transmitting the third CSI report is satisfied, the UE may transmit the third CSI report. The third CSI report may include CSI using all of the first number of CSI-RS ports of the aggregated CSI-RS resource derived based on received CSI-RS.

[0109] As an example, in addition to CSI-RS received on component CSI-RS resource(s) no later than the CSI reference resource, CSI-RS received on component CSI-RS resource(s) later than the CSI reference resource may also be used to derive the CSI included in the third CSI report. For example, a reduced CSI computation time may be applied to determine the CSI (e.g., with a conservative value) by, e.g., searching within limited beams/codewords for determining PMI.

[0110] As another example, the CSI using all of the first number of CSI-RS ports may be predicted or derived based on CSI-RS received on component CSI-RS resource(s) no later than the CSI reference resource by using an algorithm for prediction, e.g., by using a Doppler spectrum.

[0111] In some embodiments of the present application, the UE may transmit capability information indicating whether the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource, such that the BS may know or configure the UE behaviour for CSI reporting.

[0112] For example, in the case that the capability information transmitted by the UE indicating that the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource, the UE may perform (or the BS may configure the UE to perform) the operations

provided in Embodiment 3 for reporting CSI. Otherwise, the UE may perform (or the BS may configure the UE to perform) the operations provided in Embodiment 1 for reporting CSI.

[0113] As discussed above, CSI reporting may be based on a CSI reference resource. According to some embodiments of the present application, in the time domain, the CSI reference resource for CSI reporting in uplink slot n' may be defined by a single downlink slot $n - n_{CSI_ref} - K_{offset} \cdot \frac{2^{\mu_{DL}}}{2^{\mu_{K_{offset}}}}$, wherein $n = \left\lfloor n' \cdot \frac{2^{\mu_{DL}}}{2^{\mu_{UL}}} \right\rfloor + \left\lfloor \left(\frac{N_{slot,offset,UL}^{CA}}{2^{\mu_{offset,UL}}} - \frac{N_{slot,offset,DL}^{CA}}{2^{\mu_{offset,DL}}} \right) \cdot 2^{\mu_{DL}} \right\rfloor$, μ_{DL} and μ_{UL} are subcarrier spacing configurations for downlink and uplink, respectively, $N_{slot,offset,UL}^{CA}$, $N_{slot,offset,DL}^{CA}$, $\mu_{offset,UL}$ and $\mu_{offset,DL}$ are determined by a higher-layer configured parameter (e.g., ca-SlotOffset) for the cells transmitting the uplink and downlink as defined in 3GPP standard documents (e.g., TS 38.211), K_{offset} is a parameter configured by higher layer as specified in 3GPP standard documents (e.g., TS 38.213), $\mu_{K_{offset}}$ is a subcarrier spacing configuration for K_{offset} with a value of 0 for frequency range 1 as specified in 3GPP standard documents, and n_{CSI_ref} is a reference slot number.

[0114] For periodic and semi-persistent CSI reporting based on CSI-RS with no more than 32 ports:

- if a single CSI-RS/synchronization signal block (SSB) resource is configured for channel measurement, n_{CSI_ref} is the smallest value greater than or equal to $4 \cdot 2^{\mu_{DL}}$, such that it corresponds to a valid downlink slot, or
- if multiple CSI-RS/SSB resources are configured for channel measurement, n_{CSI_ref} is the smallest value greater than or equal to $5 \cdot 2^{\mu_{DL}}$, such that it corresponds to a valid downlink slot.

[0115] In the case of CSI-RS with more than 32 CSI-RS ports, for periodic and semi-persistent CSI reporting, the value of n_{CSI_ref} may be redefined.

[0116] In some embodiments, the UE may transmit capability information for defining CSI reference resource for periodic and semi-persistent CSI-RS reporting. For example, the capability information may indicate (e.g., include one or more bits which indicate) a capability level, which corresponds to a value of n_{CSI_ref} .

[0117] For example, one of two capability levels (e.g., a high capability and a low capability) may be indicated in the capability information. The high capability may correspond to " n_{CSI_ref} being the smallest value greater than or equal to $4 \cdot 2^{\mu_{DL}}$," while the low capability may correspond to " n_{CSI_ref} being the smallest value greater than or equal to $5 \cdot 2^{\mu_{DL}}$." In such example, the capability information transmitted by the UE may include one bit indicating a capability level of the UE. The bit being "1" may indicate that the UE has the high capability, which implies that the corresponding n_{CSI_ref} is the smallest value greater than or equal to $4 \cdot 2^{\mu_{DL}}$. The bit being "0" may indicate that the UE has the low capability, which implies that the corresponding n_{CSI_ref} is the smallest value greater than or equal to $5 \cdot 2^{\mu_{DL}}$.

[0118] In some embodiments, for periodic CSI reporting or semi-persistent CSI reporting based on CSI-RS with more than 32 CSI-RS ports, n_{CSI_ref} may be a smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, wherein K is an integer larger than or equal to 0.

[0119] In some examples, K is a predefined value.

[0120] For example, a CSI-RS resource with more than 32 CSI-RS ports may be considered as a single CSI-RS resource. In such example, K equals 0. That is, n_{CSI_ref} is the smallest value greater than or equal to $4 \cdot 2^{\mu_{DL}}$.

[0121] As another example, a CSI-RS resource with more than 32 CSI-RS ports may be considered as multiple CSI-RS resources since it includes at least two component CSI-RS resources. In such example, K is larger than 0, e.g., $K = 1$ and thus n_{CSI_ref} is the smallest value greater than or equal to $5 \cdot 2^{\mu_{DL}}$.

[0122] In some other examples, the UE may transmit capability information for defining CSI reference resource for periodic and semi-persistent CSI-RS by explicitly or implicitly indicating a value of K by the capability information.

[0123] As an example, the capability information may include one or more bits explicitly indicating a value of K.

[0124] As another example, the capability information may include one or more bits indicating a capability level, which corresponds to a value of K.

[0125] For example, the capability information may include one bit indicating a capability level of the UE. The bit being "1" may indicate that the UE has high capability, which may correspond to $K = 0$, i.e., n_{CSI_ref} is the smallest value greater than or equal to $4 \cdot 2^{\mu_{DL}}$, which means that the UE can finish CSI computation using CSI-RS with more than 32 ports for periodic and semi-persistent CSI reporting in 4 downlink slots. The bit being "0" may indicate that the UE has low capability, which may correspond to a value of K larger than 0, i.e., n_{CSI_ref} is the smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, which means that the UE can finish CSI computation using CSI-RS with more than 32 ports for periodic and semi-persistent CSI reporting in $(4 + K)$ downlink slots. In such example, K may be a predefined value (e.g., $K = 1$). Alternatively, in addition to the bit indicating the capability level of the UE, the capability information transmitted by the UE may also include the value of K .

[0126] According to some embodiments of the present disclosure, for aperiodic CSI reporting triggered by downlink control information (DCI), a time requirement may be defined for preparing CSI report. The time requirement for preparing CSI report may be defined by Z_{ref} or $Z'_{ref}(n)$. For example, as specified in 3GPP TS 38.214:

- When a CSI request field on a DCI triggers a CSI report(s) on a physical uplink shared channel (PUSCH), the UE shall provide a valid CSI report for the n -th triggered report,
 - if the first uplink symbol to carry the corresponding CSI report(s) including the effect of the timing advance, starts no earlier than at symbol Z_{ref} , and
 - if the first uplink symbol to carry the n -th CSI report including the effect of the timing advance, starts no earlier than at symbol $Z'_{ref}(n)$.
- When the CSI request field on a DCI triggers a CSI report(s) on PUSCH, if the first uplink symbol to carry the corresponding CSI report(s) including the effect of the timing advance, starts earlier than at symbol Z_{ref} ,
 - the UE may ignore the scheduling DCI if no HARQ-ACK or transport block is multiplexed on the PUSCH.

- When the CSI request field on a DCI triggers a CSI report(s) on PUSCH, if the first uplink symbol to carry the n -th CSI report including the effect of the timing advance, starts earlier than at symbol $Z'_{ref}(n)$,
 - the UE may ignore the scheduling DCI if the number of triggered reports is one and no HARQ-ACK or transport block is multiplexed on the PUSCH, and
 - otherwise, the UE is not required to update the CSI for the n -th triggered CSI report.

As specified in TS 38.214, Z_{ref} may be defined as the next uplink symbol with its cyclic prefix (CP) starting $T_{proc,CSI} = (Z)(2048+144) \cdot \kappa 2^{-\mu} \cdot T_c + T_{switch}$ after the end of the last symbol of the physical downlink control channel (PDCCH) triggering the CSI report(s); $Z'_{ref}(n)$ may be defined as the next uplink symbol with its CP starting $T'_{proc,CSI} = (Z')(2048+144) \cdot \kappa 2^{-\mu} \cdot T_c$ after the end of the last symbol in time of the latest of: aperiodic CSI-RS resource for channel measurement, aperiodic CSI-IM used for interference measurements, and aperiodic non-zero-power (NZP) CSI-RS for interference measurement, when aperiodic CSI-RS is used for channel measurement for the n -th triggered CSI report, and definitions for the parameters in the above formulae can be found in 3GPP standard documents.

[0127] According to the above formulae, Z_{ref} and $Z'_{ref}(n)$ may be determined based on a first time Z and a second time Z' , respectively. Each of Z and Z' may represent a CSI computation time or CSI computation delay requirement. For CSI report based on CSI-RS with more than 4 CSI-RS ports but no more than 32 CSI-RS ports, (Z, Z') may be defined by (Z_2, Z'_2) in the following Table 1, which is the same as Table 5.4-2 in TS 38.214.

Table 1: CSI computation delay requirement 2

μ	Z_1 [symbols]		Z_2 [symbols]		Z_3 [symbols]	
	Z_1	Z'_1	Z_2	Z'_2	Z_3	Z'_3
0	22	16	40	37	22	X_0
1	33	30	72	69	33	X_1
2	44	42	141	140	$\min(44, X_2 + \text{KB}_1)$	X_2
3	97	85	152	140	$\min(97, X_3 + \text{KB}_2)$	X_3
5	388	340	608	560	$\min(388, X_5 + \text{KB}_3)$	X_5
6	776	680	1216	1120	$\min(776, X_6 + \text{KB}_4)$	X_6

[0128] For CSI report based on CSI-RS with more than 32 CSI-RS ports, the values of (Z, Z') may need to be redefined. The reasons are as follows.

[0129] In one aspect, for the larger number of antenna ports, the computation time for PMI may be increased due to processing a matrix with a high dimension. In another aspect, when the CSI-RS resource with more than 32 CSI-RS ports is aggregated by at least two component CSI-RS resources, these component CSI-RS resources may have different transmission times, e.g., different slots or OFDM symbols.

[0130] According to some embodiments of the present application, in case of CSI-RS with more than 32 CSI-RS ports, for aperiodic CSI reporting, the UE may perform CSI reporting based on a first time Z or a second time Z' . Z may include a first additional time relative to a third time Z_2 (e.g., Z_2 specified in Table 1) for no more than 32 CSI-RS ports (e.g., Z is Z_2 plus the first additional time). Z' may include a second additional time relative to a fourth time Z'_2 (e.g., Z'_2 specified in Table 1) for no more than 32 CSI-RS ports (e.g., Z' is Z'_2 plus the second additional time). The following embodiments provide several solutions for determining the first additional time and the second additional time.

[0131] **Embodiment 1'**

[0132] In some cases of Embodiment 1', the first additional time may be determined based on $k_1 Z_2$, or the second additional time may be determined based on $k_1 Z'_2$, wherein $0 \leq k_1 \leq 1$.

[0133] As an example, $k_1 = 1$, the first additional time may be equal to Z_2 , and the second additional time may be equal to Z'_2 . As another example, $k_1 = 0.5$, the first additional time may be equal to $\text{ceil}(0.5Z_2)$, and the second additional time may be equal to $\text{ceil}(0.5Z'_2)$.

[0134] In some cases of Embodiment 1', the first additional time and the second additional time may be the same, for example, both based on $k_1 Z'_2$, wherein $0 \leq k_1 \leq 1$.

[0135] As an example, $k_1 = 1$, and the first additional time and the second additional time may be equal to Z'_2 . As an example, $k_1 = 0.5$, and the first additional time and the second additional time may be equal to $\text{ceil}(0.5Z'_2)$.

[0136] In some examples of Embodiment 1', k_1 is a predefined value.

[0137] In some other examples of Embodiment 1', the UE may transmit capability information indicating a value of k_1 to a BS, such that the BS may determine the time for receiving the CSI report based on the time requirement Z_{ref} or $Z'_{ref}(n)$, which is determined based on the value of k_1 .

[0138] **Embodiment 2'**

[0139] In Embodiment 2', the first additional time or the second additional time may be determined based on a maximum OFDM symbol spacing (e.g., denoted as k_2) between two component CSI-RS resources of the aggregated CSI-RS resource with more than 32 ports.

[0140] For example, the first additional time or the second additional time may be equal to k_2 . As an example, k_2 may be 14 or 28 OFDM symbols. In such example, additional CSI processing time may be assumed to be included in newly introduced additional OFDM symbols.

[0141] **Embodiment 3'**

[0142] In embodiment 3', the first additional time or the second additional time may be defined based on a combination of Embodiment 1' and Embodiment 2'.

[0143] In some cases of Embodiment 3', the first additional time may be determined based on $k_{11}Z_2 + k_{12}$, or the second additional time may be determined based on $k_{21}Z'_2 + k_{22}$, wherein $0 \leq k_{11} \leq 1$, k_{12} is based on a maximum OFDM symbol spacing between two component CSI-RS resources of the aggregated CSI-RS resource with more than 32 ports, $0 \leq$

$k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between two component CSI-RS resources of the aggregated CSI-RS resource with more than 32 ports.

[0144] As an example, the first additional time may be $\text{ceil}(0.5Z_2 + 14)$, or the second additional time may be $\text{ceil}(0.5Z'_2 + 14)$.

[0145] In some cases of Embodiment 3', the first additional time and the second additional time may be the same, for example, both based on $k_{21}Z'_2 + k_{22}$, wherein $0 \leq k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between two component CSI-RS resources of the aggregated CSI-RS resource with more than 32 ports .

[0146] As an example, the first additional time and the second additional time may be equal to $\text{ceil}(0.5Z'_2 + 14)$.

[0147] In some embodiments of the present disclosure, for a UE with a higher processing capability, legacy values of (Z, Z') (e.g., the values of (Z_2, Z'_2) in Table 1) may be reused. For a UE with a lower processing capability, larger values for (Z, Z') may be used, for example, (Z, Z') may be determined based on the first additional time and the second additional time according to the aforementioned Embodiment 1', Embodiment 2' or Embodiment 3'.

[0148] In some embodiments of the present disclosure, the UE may transmit, to a BS, capability information (e.g., including one bit) indicating whether to support the first additional time and/or the second additional time (or indicating a higher processing capability or a lower processing capability). In the case that the capability information indicates not to support the first additional time and/or the second additional time (or indicating a higher processing capability), legacy values of (Z, Z') may be reused. In the case that the capability information indicates to support the first additional time and/or the second additional time (or indicating a lower processing capability), (Z, Z') may be determined based on the first additional time and the second additional time according to the aforementioned Embodiment 1', Embodiment 2' or Embodiment 3'. Then, based on the capability information, the BS may determine the time for receiving the CSI report.

[0149] Figure 2 illustrates a flowchart of an exemplary method in accordance with aspects of the present disclosure. The operations of the method illustrated in Figure 2 may be performed by a UE (e.g., UE 104 in Figure 1) as described herein or other apparatus with the like functions.

In some implementations, the UE may execute a set of instructions to control functional elements of the UE to perform the described operations or functions.

[0150] As shown in Figure 2, in step 202, the UE may receive CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32.

[0151] In step 204, the UE may perform CSI reporting based on the CSI-RS and a CSI reference resource.

[0152] According to some embodiments of the present disclosure, the first CSI-RS resource includes at least two second CSI-RS resources. To perform CSI reporting, the UE may: transmit a first CSI report only after receiving at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource; or when DRX is configured, transmit the first CSI report only if receiving at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource.

[0153] According to some embodiments of the present disclosure, to perform CSI reporting, the UE may: transmit a second CSI report only after receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured, transmit the second CSI report only if receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource. The second CSI report includes CSI determined based on a first one of the at least one second CSI-RS resource or determined based on a second CSI-RS resource selected from the at least one second CSI-RS resource by the UE.

[0154] In some embodiments, the UE may receive configuration information for a codebook associated with the at least two second CSI-RS resources, wherein the second CSI report is based on the codebook.

[0155] In some embodiments, the UE may transmit an indicator to indicate the selected second CSI-RS resource in the case that the second CSI report includes CSI determined based on the selected second CSI-RS resource.

[0156] According to some embodiments of the present disclosure, the UE may transmit capability information indicating whether the UE supports a CSI report based on at least one second CSI-RS resource but not all of the at least two second CSI-RS resources.

[0157] According to some embodiments of the present disclosure, to perform CSI reporting, the UE may: transmit a third CSI report only after receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured, transmit the third CSI report only if receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource. The third CSI report includes CSI using all of the first number of CSI-RS ports derived based on received CSI-RS.

[0158] According to some embodiments of the present disclosure, the UE may transmit capability information indicating whether the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource.

[0159] According to some embodiments of the present disclosure, the CSI reference resource may be determined based on a reference slot number. For periodic CSI reporting or semi-persistent CSI reporting, the UE may transmit capability information indicating a capability level which corresponds to a value of the reference slot number.

[0160] According to some embodiments of the present disclosure, the CSI reference resource may be determined based on a reference slot number. For periodic CSI reporting or semi-persistent CSI reporting, the reference slot number may be a smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, wherein K is an integer larger than or equal to 0, and μ_{DL} is a subcarrier spacing configuration for downlink.

[0161] In some embodiments, K may be a predefined value. Alternatively, the UE may transmit capability information explicitly or implicitly indicating a value of K .

[0162] According to some embodiments of the present disclosure, for aperiodic CSI reporting, the UE may perform CSI reporting further based on a first time Z or a second time Z' , wherein Z includes a first additional time relative to a third time Z_2 for no more than 32 CSI-RS ports, or Z' includes a second additional time relative to a fourth time Z'_2 for no more than 32 CSI-RS ports.

[0163] In some embodiments, the UE may transmit capability information indicating whether to support the first additional time or the second additional time.

[0164] In some embodiments, the first additional time may be determined based on $k_1 Z_2$ or $k_1 Z'_2$, or the second additional time may be determined based on $k_1 Z'_2$, and $0 \leq k_1 \leq 1$. In an embodiment, the UE may transmit capability information indicating a value of k_1 .

[0165] In some embodiments, the first CSI-RS resource may include at least two second CSI-RS resources, and the first additional time or the second additional time may be determined based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources. In an embodiment, the first additional time or the second additional time is 14 or 28 OFDM symbols.

[0166] In some embodiments, the first CSI-RS resource may include at least two second CSI-RS resources. The first additional time may be determined based on $k_{11} Z_2 + k_{12}$ or $k_{21} Z'_2 + k_{22}$, wherein $0 \leq k_{11} \leq 1$, k_{12} is based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources, $0 \leq k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources. The second additional time may be determined based on $k_{21} Z'_2 + k_{22}$.

[0167] In an embodiment, the UE may transmit capability information indicating: value(s) of at least one of k_{11} or k_{12} ; or value(s) of at least one of k_{21} or k_{22} .

[0168] Figure 3 illustrates a flowchart of an exemplary method in accordance with aspects of the present disclosure. The operations of the method illustrated in Figure 3 may be performed

by a BS (e.g., NE 102 in Figure 1) as described herein or other apparatus with the like functions. In some implementations, the BS may execute a set of instructions to control functional elements of the BS to perform the described operations or functions.

[0169] As shown in Figure 3, in step 302, the BS may transmit CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32.

[0170] In step 304, the BS may receive, from a UE, a CSI report based on the CSI-RS and a CSI reference resource.

[0171] According to some embodiments of the present disclosure, the first CSI-RS resource includes at least two second CSI-RS resources. The BS may: receive a first CSI report only after transmitting at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource; or when DRX is configured for the UE, receive the first CSI report only if transmitting at least one CSI-RS transmission occasion for each of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource.

[0172] According to some embodiments of the present disclosure, the BS may: receive a second CSI report only after transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured for the UE, receive the second CSI report only if transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource. The second CSI report includes CSI determined based on a first one of the at least one second CSI-RS resource or determined based on a second CSI-RS resource selected from the at least one second CSI-RS resource by the UE.

[0173] In some embodiments, the BS may transmit configuration information for a codebook associated with the at least two second CSI-RS resources, wherein the second CSI report is based on the codebook.

[0174] In some embodiments, the BS may receive an indicator to indicate the selected second CSI-RS resource in the case that the second CSI report includes CSI determined based on the selected second CSI-RS resource.

[0175] According to some embodiments of the present disclosure, the BS may receive capability information indicating whether the UE supports a CSI report based on at least one second CSI-RS resource but not all of the at least two second CSI-RS resources.

[0176] According to some embodiments of the present disclosure, the BS may: receive a third CSI report only after transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or when DRX is configured for the UE, receive the third CSI report only if transmitting at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource. The third CSI report includes CSI using all of the first number of CSI-RS ports derived based on CSI-RS received by the UE.

[0177] According to some embodiments of the present disclosure, the BS may receive capability information indicating whether the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource.

[0178] According to some embodiments of the present disclosure, the CSI reference resource may be determined based on a reference slot number. For periodic CSI reporting or semi-persistent CSI reporting, the BS may receive capability information indicating a capability level which corresponds to a value of the reference slot number.

[0179] According to some embodiments of the present disclosure, the CSI reference resource may be determined based on a reference slot number. For periodic CSI reporting or

semi-persistent CSI reporting, the reference slot number may be a smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, wherein K is an integer larger than or equal to 0, and μ_{DL} is a subcarrier spacing configuration for downlink.

[0180] In some embodiments, K may be a predefined value. Alternatively, the BS may receive, from the UE, capability information explicitly or implicitly indicating a value of K .

[0181] According to some embodiments of the present disclosure, for aperiodic CSI reporting, the BS may receive the CSI report further based on a first time Z or a second time Z' , wherein Z includes a first additional time relative to a third time Z_2 for no more than 32 CSI-RS ports, or Z' includes a second additional time relative to a fourth time Z'_2 for no more than 32 CSI-RS ports.

[0182] In some embodiments, the BS may receive, from the UE, capability information indicating whether to support the first additional time or the second additional time.

[0183] In some embodiments, the first additional time may be determined based on $k_1 Z_2$ or $k_1 Z'_2$, or the second additional time may be determined based on $k_1 Z'_2$, and $0 \leq k_1 \leq 1$. In an embodiment, the BS may receive, from the UE, capability information indicating a value of k_1 .

[0184] In some embodiments, the first CSI-RS resource may include at least two second CSI-RS resources, and the first additional time or the second additional time may be determined based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources. In an embodiment, the first additional time or the second additional time is 14 or 28 OFDM symbols.

[0185] In some embodiments, the first CSI-RS resource may include at least two second CSI-RS resources. The first additional time may be determined based on $k_{11} Z_2 + k_{12}$ or $k_{21} Z'_2 + k_{22}$, wherein $0 \leq k_{11} \leq 1$, k_{12} is based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources, $0 \leq k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources. The second additional time may be determined based on $k_{21} Z'_2 + k_{22}$.

[0186] In an embodiment, the BS may receive, from the UE, capability information indicating: value(s) of at least one of k_{11} or k_{12} ; or value(s) of at least one of k_{21} or k_{22} .

[0187] Figure 4 illustrates an example of a UE 400 in accordance with aspects of the present disclosure. The UE 400 may include at least one processor 402 and at least one memory 404. Additionally, the UE 400 may also include one or more of at least one controller 406 or at least one transceiver 408. The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0188] The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0189] The processor 402 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 402 may be configured to operate the memory 404. In some other implementations, the memory 404 may be integrated into the processor 402. The processor 402 may be configured to execute computer-readable instructions stored in the memory 404 to cause the UE 400 to perform various functions of the present disclosure.

[0190] The memory 404 may include volatile or non-volatile memory. The memory 404 may store computer-readable, computer-executable code including instructions when executed by the processor 402 cause the UE 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 404 or another type of memory. 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.

[0191] In some implementations, the processor 402 and the memory 404 coupled with the processor 402 may be configured to cause the UE 400 to perform one or more of the functions described herein (e.g., executing, by the processor 402, instructions stored in the memory 404). For example, the processor 402 may support wireless communication at the UE 400 in accordance with examples as disclosed herein. The UE 400 may be configured to support a means for performing the operations of the methods described in the embodiments of the present disclosure. In an embodiment, the processor 402 may be configured to cause the UE 400 to: receive CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and perform CSI reporting based on the CSI-RS and a CSI reference resource.

[0192] The controller 406 may manage input and output signals for the UE 400. The controller 406 may also manage peripherals not integrated into the UE 400. In some implementations, the controller 406 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 406 may be implemented as part of the processor 402.

[0193] In some implementations, the UE 400 may include at least one transceiver 408. In some other implementations, the UE 400 may have more than one transceiver 408. The transceiver 408 may represent a wireless transceiver. The transceiver 408 may include one or more receiver chains 410, one or more transmitter chains 412, or a combination thereof.

[0194] A receiver chain 410 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 410 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 410 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 410 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 receiver chain 410 may include at least one decoder for decoding the demodulated signal to receive the transmitted data.

[0195] A transmitter chain 412 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 412 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 transmitter chain 412 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 transmitter chain 412 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0196] Figure 5 illustrates an example of a processor 500 in accordance with aspects of the present disclosure. The processor 500 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 500 may include a controller 502 configured to perform various operations in accordance with examples as described herein. The processor 500 may optionally include at least one memory 504, which may be, for example, a layer 1 (L1), layer 2 (L2), or layer 3 (L3) cache. Additionally, or alternatively, the processor 500 may optionally include one or more arithmetic-logic units (ALUs) 506. 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).

[0197] The processor 500 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 500) 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).

[0198] The controller 502 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 500 to cause the processor 500 to support various operations in accordance with examples as described herein. For example, the controller 502 may operate as a control unit of the processor 500, generating control signals that manage the operation of various components of the processor 500. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0199] The controller 502 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 504 and determine subsequent instruction(s) to be executed to cause the processor 500 to support various operations in accordance with examples as described herein. The controller 502 may be configured to track memory address of instructions associated with the memory 504. The controller 502 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 502 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 500 to cause the processor 500 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 502 may be configured to manage flow of data within the processor 500. The controller 502 may be configured to control transfer of data between registers, ALUs, and other functional units of the processor 500.

[0200] The memory 504 may include one or more caches (e.g., memory local to or included in the processor 500 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc.). In some implementations, the memory 504 may reside within or on a processor chipset (e.g., local to the processor 500). In some other implementations, the memory 504 may reside external to the processor chipset (e.g., remote to the processor 500).

[0201] The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 500, cause the processor 500 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 502 and/or the processor 500 may be configured to execute computer-readable instructions stored in the

memory 504 to cause the processor 500 to perform various functions. For example, the processor 500 and/or the controller 502 may be coupled with or to the memory 504, the processor 500, the controller 502, and the memory 504 may be configured to perform various functions described herein. In some examples, the processor 500 may include multiple processors and the memory 504 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.

[0202] The one or more ALUs 506 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 506 may reside within or on a processor chipset (e.g., the processor 500). In some other implementations, the one or more ALUs 506 may reside external to the processor chipset (e.g., the processor 500). One or more ALUs 506 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 506 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 506 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 506 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 506 to handle conditional operations, comparisons, and bitwise operations.

[0203] The processor 500 may support wireless communication in accordance with examples as disclosed herein. The processor 500 may be configured to or operable to support a means for performing the operations of the methods described in the embodiments of the present disclosure. In an embodiment, the controller 502 may cause the processor 500 to: receive CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and perform CSI reporting based on the CSI-RS and a CSI reference resource.

[0204] Figure 11 illustrates an example of a BS 600 in accordance with aspects of the present disclosure. The BS 600 may include at least one processor 602 and at least one memory 604. Additionally, the BS 600 may also include one or more of at least one controller 606 or at least one transceiver 608. The processor 602, the memory 604, the controller 606, or the transceiver

608, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0205] The processor 602, the memory 604, the controller 606, or the transceiver 608, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0206] The processor 602 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 602 may be configured to operate the memory 604. In some other implementations, the memory 604 may be integrated into the processor 602. The processor 602 may be configured to execute computer-readable instructions stored in the memory 604 to cause the BS 600 to perform various functions of the present disclosure.

[0207] The memory 604 may include volatile or non-volatile memory. The memory 604 may store computer-readable, computer-executable code including instructions when executed by the processor 602 cause the BS 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 604 or another type of memory. 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.

[0208] In some implementations, the processor 602 and the memory 604 coupled with the processor 602 may be configured to cause the BS 600 to perform one or more of the functions described herein (e.g., executing, by the processor 602, instructions stored in the memory 604). For example, the processor 602 may support wireless communication at the BS 600 in accordance with examples as disclosed herein. The BS 600 may be configured to support a

means for performing the operations of the methods described in the embodiments of the present disclosure. In an embodiment, the processor 602 may be configured to cause the BS 600 to: transmit CSI-RS on a first CSI-RS resource with a first number of CSI-RS ports, wherein the first number is more than 32; and receive, from a UE, a CSI report based on the CSI-RS and a CSI reference resource.

[0209] The controller 606 may manage input and output signals for the BS 600. The controller 606 may also manage peripherals not integrated into the BS 600. In some implementations, the controller 606 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 606 may be implemented as part of the processor 602.

[0210] In some implementations, the BS 600 may include at least one transceiver 608. In some other implementations, the BS 600 may have more than one transceiver 608. The transceiver 608 may represent a wireless transceiver. The transceiver 608 may include one or more receiver chains 610, one or more transmitter chains 612, or a combination thereof.

[0211] A receiver chain 600 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 610 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 610 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 610 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 receiver chain 610 may include at least one decoder for decoding the demodulated signal to receive the transmitted data.

[0212] A transmitter chain 612 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 612 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 transmitter chain 612 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 transmitter chain 612 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0213] 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

What is claimed is:

1. A user equipment (UE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and
configured to cause the UE to:
receive channel state information reference signal (CSI-RS)
on a first CSI-RS resource with a first number of CSI-RS ports, wherein the
first number is more than 32; and
perform CSI reporting based on the CSI-RS and a channel
state information (CSI) reference resource.
2. The UE of Claim 1, wherein the first CSI-RS resource includes at
least two second CSI-RS resources, and to perform CSI reporting, the at least one processor
is configured to cause the UE to:
transmit a first CSI report only after receiving at least one CSI-RS
transmission occasion for each of the at least two second CSI-RS resources
for channel measurement and CSI-RS and/or CSI interference measurement
(CSI-IM) occasion for interference measurement no later than the CSI
reference resource; or
when discontinuous reception (DRX) is configured, transmit the first
CSI report only if receiving at least one CSI-RS transmission occasion for
each of the at least two second CSI-RS resources for channel measurement
and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX
active time no later than the CSI reference resource.
3. The UE of Claim 2, wherein to perform CSI reporting, the at least
one processor is configured to cause the UE to:
transmit a second CSI report only after receiving at least one CSI-RS
transmission occasion for at least one second CSI-RS resource but not all of
the at least two second CSI-RS resources for channel measurement and CSI-

RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or

when DRX is configured, transmit the second CSI report only if receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and

wherein the second CSI report includes CSI determined based on a first one of the at least one second CSI-RS resource or determined based on a second CSI-RS resource selected from the at least one second CSI-RS resource by the UE.

4. The UE of Claim 3, wherein the at least one processor is further configured to cause the UE to receive configuration information for a codebook associated with the at least two second CSI-RS resources, wherein the second CSI report is based on the codebook.

5. The UE of Claim 1, wherein the first CSI-RS resource includes at least two second CSI-RS resources, and the at least one processor is further configured to cause the UE to transmit capability information indicating whether the UE supports a CSI report based on at least one second CSI-RS resource but not all of the at least two second CSI-RS resources.

6. The UE of Claim 2, wherein to perform CSI reporting, the at least one processor is configured to cause the UE to:

transmit a third CSI report only after receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement no later than the CSI reference resource, or

when DRX is configured, transmit the third CSI report only if receiving at least one CSI-RS transmission occasion for at least one second CSI-RS resource but not all of the at least two second CSI-RS resources for channel measurement and CSI-RS and/or CSI-IM occasion for interference measurement in a DRX active time no later than the CSI reference resource; and

wherein the third CSI report includes CSI using all of the first number of CSI-RS ports derived based on received CSI-RS.

7. The UE of Claim 1, wherein the at least one processor is further configured to cause the UE to transmit capability information indicating whether the UE supports a CSI report using all of the first number of CSI-RS ports derived based on CSI-RS with part of the first number of CSI-RS ports received before the CSI reference resource.

8. The UE of Claim 1, wherein the CSI reference resource is determined based on a reference slot number, and wherein for periodic CSI reporting or semi-persistent CSI reporting, the at least one processor is further configured to cause the UE to transmit capability information indicating a capability level which corresponds to a value of the reference slot number.

9. The UE of Claim 1, wherein the CSI reference resource is determined based on a reference slot number, and wherein for periodic CSI reporting or semi-persistent CSI reporting, the reference slot number is a smallest value greater than or equal to $(4 + K) \cdot 2^{\mu_{DL}}$, wherein K is an integer larger than or equal to 0, and μ_{DL} is a subcarrier spacing configuration for downlink.

10. The UE of Claim 9, wherein K is a predefined value, or the at least one processor is further configured to cause the UE to transmit capability information explicitly or implicitly indicating a value of K.

11. The UE of Claim 1, wherein for aperiodic CSI reporting, the at least one processor is further configured to cause the UE to perform CSI reporting further based

on a first time Z or a second time Z' , wherein Z includes a first additional time relative to a third time Z_2 for no more than 32 CSI-RS ports, or Z' includes a second additional time relative to a fourth time Z'_2 for no more than 32 CSI-RS ports.

12. The UE of Claim 11, wherein the at least one processor is further configured to cause the UE to transmit capability information indicating whether to support the first additional time or the second additional time.

13. The UE of Claim 11, wherein the first additional time is determined based on $k_1 Z_2$ or $k_1 Z'_2$, or the second additional time is determined based on $k_1 Z'_2$, and $0 \leq k_1 \leq 1$.

14. The UE of Claim 13, wherein the at least one processor is further configured to cause the UE to transmit capability information indicating a value of k_1 .

15. The UE of Claim 11, wherein the first CSI-RS resource includes at least two second CSI-RS resources, and the first additional time or the second additional time is determined based on a maximum orthogonal frequency division multiplexing (OFDM) symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources.

16. The UE of Claim 15, wherein the first additional time or the second additional time is 14 or 28 OFDM symbols.

17. The UE of Claim 11, wherein the first CSI-RS resource includes at least two second CSI-RS resources, and wherein:

the first additional time is determined based on $k_{11} Z_2 + k_{12}$ or $k_{21} Z'_2 + k_{22}$, wherein $0 \leq k_{11} \leq 1$, k_{12} is based on a maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources, $0 \leq k_{21} \leq 1$, and k_{22} is based on the maximum OFDM symbol spacing between two second CSI-RS resources of the at least two second CSI-RS resources; or

the second additional time is determined based on $k_{21} Z'_2 + k_{22}$.

18. A processor for wireless communication, comprising:
at least one controller coupled with at least one memory and
configured to cause the processor to:
receive channel state information reference signal (CSI-RS)
on a first CSI-RS resource with a first number of CSI-RS ports, wherein the
first number is more than 32; and
perform CSI reporting based on the CSI-RS and a channel
state information (CSI) reference resource.
19. A base station (BS) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and
configured to cause the BS to:
transmit channel state information reference signal (CSI-RS)
on a first CSI-RS resource with a first number of CSI-RS ports, wherein the
first number is more than 32; and
receive, from a user equipment (UE), a CSI report based on
the CSI-RS and a channel state information (CSI) reference resource.
20. A method performed by a user equipment (UE), the method
comprising:
receiving channel state information reference signal (CSI-RS) on a
first CSI-RS resource with a first number of CSI-RS ports, wherein the first
number is more than 32; and
performing CSI reporting based on the CSI-RS and a channel state
information (CSI) reference resource.