

EVENT DRIVEN BEAM REPORTING FOR UNIFIED TCI

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a user equipment (UE), a base station (BS), methods, apparatuses, and computer readable
5 medium for event driven beam reporting for unified transmission configuration indicator (TCI).

BACKGROUND

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

[0003] The network (NW) controlled beam measurement and beam reporting has been specified, however, the network needs to configure or activate frequent periodic or semi-persistent beam reporting or triggers frequent periodic beam reporting, which results in larger
25 overhead.

SUMMARY

[0004] The present disclosure relates to a base station, user equipment, methods, apparatuses, processors, and computer readable medium for event driven beam reporting for unified TCI. According to the proposed solution, a beam report may be transmitted in case
30 an event associated with an indicated joint or downlink (DL) TCI state is satisfied, thus the

UE behavior for beam reporting is defined and the overhead is saved.

[0005] In some implementations, there is provided a UE. The UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: determine that an event associated with an indicated joint or DL TCI state is satisfied; and in accordance with a determination that a trigger condition associated with the event is met, transmit, to a base station, a beam report indicating one of: the event, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

[0006] In some implementations, there is provided a base station. The base station comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the base station to: transmit, to a UE, downlink control information (DCI) indicating an indicated joint or DL TCI state; and receive, from the UE, a beam report indicating one of: an event associated with the indicated joint or DL TCI state, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

[0007] In some implementations, there is provided a method performed by the UE. The method comprises: determining that an event associated with an indicated joint or DL TCI state is satisfied; and in accordance with a determination that a trigger condition associated with the event is met, transmitting, to a base station, a beam report indicating one of: the event, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

[0008] In some implementations, there is provided a method performed by the base station. The method comprises: transmitting, to a UE, downlink control information (DCI) indicating an indicated joint or DL TCI state; and receiving, from the UE, a beam report indicating one of: an event associated with the indicated joint or DL TCI state, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

[0009] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: determine that an event associated with an indicated joint or DL TCI state is satisfied; and in accordance with a determination that a trigger condition associated with the event is met, transmit, to a base station, a beam report indicating one of: the event, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

[0010] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and

configured to cause the processor to: transmit, to a UE, a DCI indicating an indicated joint or DL TCI state; and receive, from the UE, a beam report indicating one of: an event associated with the indicated joint or DL TCI state, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

5 **[0011]** In some implementations of the methods and the UE described herein, further comprising: transmitting, to the base station, a dedicated scheduling request (SR) for requesting a transmission resource of a medium access control (MAC) control element (CE); and receiving, from the base station, a first DCI scheduling a physical uplink shared channel (PUSCH) transmission carrying the MAC CE.

10 **[0012]** In some implementations of the methods and the UE described herein, the event comprises the first event or the second event, further comprising: receiving, from the base station, a second DCI indicating a further indicated joint or DL TCI state, wherein the further indicated joint or DL TCI state is the same as or different from the activated joint or DL TCI state in the beam report; and applying the further indicated joint or DL TCI state for further
15 transmission or reception.

[0013] In some implementations of the methods and the UE described herein, the event comprises the third event or the fourth event, further comprising: applying the activated joint or DL TCI state after a specific time point, wherein the specific time point is 28 symbols from a last symbol of a physical downlink control channel (PDCCH) reception with a third DCI
20 scheduling a PUSCH transmission with a same hybrid automatic repeat request (HARQ) process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled new data indicator (NDI) field value.

[0014] In some implementations of the methods and the UE described herein, further comprising: in accordance with a determination that there is an uplink (UL) TCI state paired
25 with the activated DL TCI state, applying the UL TCI state for further transmission; or in accordance with a determination that there is no UL TCI state paired with the activated DL TCI state, continuing applying a current UL TCI state for further transmission.

[0015] In some implementations of the methods and the UE described herein, further comprising: receiving, from the base station, a second DCI indicating a further indicated joint
30 or DL TCI state before a third DCI, wherein the third DCI is scheduling a PUSCH transmission with a same HARQ process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled NDI field value; and applying the further

indicated joint or DL TCI state for further transmission or reception.

[0016] In some implementations of the methods and the BS described herein, further comprising: receiving, from the UE, a dedicated SR for requesting a transmission resource of the MAC CE; and transmitting, to the UE, a first DCI scheduling a PUSCH transmission
5 carrying the MAC CE.

[0017] In some implementations of the methods and the BS described herein, the event comprises the first event or the second event, further comprising: transmitting, to the UE, a second DCI indicating a further indicated joint or DL TCI state, wherein the further indicated joint or DL TCI state is the same as or different from the activated joint or DL TCI state in
10 the beam report; and applying the further indicated joint or DL TCI state for further transmission or reception with the UE.

[0018] In some implementations of the methods and the BS described herein, the event comprises the third event or the fourth event, further comprising: applying the activated joint or DL TCI state after a specific time point, wherein the specific time point is 28 symbols from
15 a last symbol of a PDCCH reception with a third DCI scheduling a PUSCH transmission with a same HARQ process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled NDI field value.

[0019] In some implementations of the methods and the BS described herein, further comprising: in accordance with a determination that there is a UL TCI state paired with the
20 activated DL TCI state, applying the UL TCI state for further transmission; or in accordance with a determination that there is no UL TCI state paired with the activated DL TCI state, continuing applying a current UL TCI state for further transmission.

[0020] In some implementations of the methods and the BS described herein, further comprising: transmitting, to the UE, a second DCI indicating a further indicated joint or DL
25 TCI state before a third DCI, wherein the third DCI is scheduling a PUSCH transmission with a same HARQ process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled NDI field value; and applying the further indicated joint or DL TCI state for further transmission or reception with the UE.

[0021] In some implementations of the methods, the UE, and the BS described herein, the trigger condition comprises one of: the event is satisfied, or the event has been satisfied for a
30 plurality of continuous times within a time window, wherein a number of the plurality of continuous times is predefined or preconfigured.

- 5 [0022] In some implementations of the methods, the UE, and the BS described herein, the event comprises one of: a first event indicating that a quality of the indicated joint or DL TCI state is less than or not greater than a first threshold, a second event indicating that a quality of one of activated joint or DL TCI states exceeds or not less than a second threshold, a third event indicating that a difference between a quality of one of activated joint or DL TCI states and a quality of the indicated joint or DL TCI state exceeds or not less than a third threshold, or a fourth event indicating that a quality of the indicated joint or DL TCI state is less than or not greater than a fourth threshold and a quality of one of activated joint or DL TCI states exceeds or not less than a fifth threshold.
- 10 [0023] In some implementations of the methods, the UE, and the BS described herein, at least one threshold associated with the event is at least one block error rate (BLER), and the at least one BLER is determined based on: one or more specific hypothetical PDCCH transmission parameters, or layer 1 reference signal received power (L1-RSRP) configured by radio resource control (RRC) signalling.
- 15 [0024] In some implementations of the methods, the UE, and the BS described herein, the event comprises the first event, and the beam report is comprised in an SR.
- [0025] In some implementations of the methods, the UE, and the BS described herein, the event comprises one of the second event, the third event, or the fourth event, and wherein the beam report is comprised in a MAC CE which indicates the one of activated joint or DL TCI states.
- 20 [0026] In some implementations of the methods, the UE, and the BS described herein, the MAC CE comprises a bitmap, wherein a bit in the bitmap corresponding to the one of activated joint or DL TCI states for a bandwidth part (BWP) of a serving cell of the UE is set to be a specific value.
- 25 [0027] In some implementations of the methods, the UE, and the BS described herein, the MAC CE comprises one of: an identifier (ID) of the one of activated joint or DL TCI states, a non-zero power (NZP) channel state information (CSI) reference signal (RS) resource ID which is associated with the one of activated joint or DL TCI states, or an indication of a TCI codepoint which is mapped with the one of activated joint or DL TCI states.
- 30 [0028] In some implementations of the methods, the UE, and the BS described herein, different events are associated with different logical channel identities (LCIDs), and wherein the MAC CE further comprises a LCID associated with the event.

[0029] In some implementations of the methods, the UE, and the BS described herein, different events are associated with a same LCID, and wherein the MAC CE comprises the LCID being carried in a specific position associated with the event.

BRIEF DESCRIPTION OF THE DRAWINGS

5 [0030] FIG. 1 illustrates an example of a wireless communications system in which some embodiments of the present disclosure can be implemented;

[0031] FIG. 2 illustrates an example schematic of timing relation for a transmission of PRACH preamble in accordance with some example embodiments of the present disclosure;

10 [0032] FIG. 3A illustrates an example schematic of MAC CE including a bitmap for indicating an activated joint or TCI state in accordance with some example embodiments of the present disclosure;

[0033] FIG. 3B illustrates an example schematic of MAC CE including a NZP CSI-RS resource ID associated with an activated joint or TCI state in accordance with some example embodiments of the present disclosure;

15 [0034] FIG. 3C illustrates an example schematic of MAC CE indicating a TCI codepoint mapped with an activated joint or TCI state in accordance with some example embodiments of the present disclosure;

20 [0035] FIG. 3D illustrates an example schematic of MAC CE including an ID of an activated joint or TCI state in accordance with some example embodiments of the present disclosure;

[0036] FIG. 4A illustrates an example schematic of MAC CE including an ID of an activated joint or TCI state and an event ID in accordance with some example embodiments of the present disclosure;

25 [0037] FIG. 4B illustrates an example schematic of MAC CE including a NZP CSI-RS resource ID and an event ID in accordance with some example embodiments of the present disclosure;

[0038] FIG. 4C illustrates an example schematic of MAC CE including a TCI codepoint mapped with an activated joint or TCI state and an event ID in accordance with some example embodiments of the present disclosure;

30 [0039] FIG. 5A illustrates an example schematic for TCI state switching in accordance with

some example embodiments of the present disclosure;

[0040] FIG. 5B illustrates another example schematic for TCI state switching in accordance with some example embodiments of the present disclosure;

5 [0041] FIG. 6 illustrates an example of a device that is suitable for implementing embodiments of the present disclosure;

[0042] FIG. 7 illustrates an example of a processor that is suitable for implementing some embodiments of the present disclosure;

[0043] FIG. 8 illustrates a flowchart of an example method implemented at a UE in accordance with aspects of the present disclosure; and

10 [0044] FIG. 9 illustrates a flowchart of an example method implemented at a BS in accordance with aspects of the present disclosure.

[0045] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

DETAILED DESCRIPTION

15 [0046] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones
20 described below. In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0047] References in the present disclosure to “one embodiment,” “an example embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the
25 embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to
30 affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0048] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of
5 embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms. In some examples, values, procedures, or apparatuses are referred to as “best,” “lowest,” “highest,” “minimum,” “maximum,” or the like. It will be appreciated that such descriptions are intended to indicate that a selection among many used
10 functional alternatives can be made, and such selections need not be better, smaller, higher, or otherwise preferable to other selections.

[0049] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of embodiments. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly
15 indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “has,” “having,” “includes” and/or “including,” when used herein, specify the presence of stated features, elements, components and/or the like, but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof. For example, the term “includes” and its variants are to be read as open terms that mean
20 “includes, but is not limited to.” The term “based on” is to be read as “based at least in part on.” The term “one embodiment” and “an embodiment” are to be read as “at least one embodiment.” The term “another embodiment” is to be read as “at least one other embodiment.” The use of an expression such as “A and/or B” can mean either “only A” or “only B” or “both A and B.” Other definitions, explicit and implicit, may be included below.

[0050] FIG. 1 illustrates an example of a wireless communications system 100 in which some embodiments of the present disclosure can be implemented. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network (CN) 106, and a packet data network 108. The wireless communications system 100 may support various radio
30 access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a long term evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as a new radio (NR) network. In other implementations,

the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G.

5 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.

[0051] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network

10 entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102

15 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0052] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, message, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a

20 network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or

25 different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages,

30 currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0053] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a

mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0054] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the CN 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0055] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink (SL). For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0056] A network entity 102 may support communications with the CN 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the CN 106 through one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with

the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

5 [0057] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed
10 unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0058] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or
15 more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

20 [0059] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may
25 support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaptation protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or
30 more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU.

[0060] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0061] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-C, F1-U), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[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 functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the CN 106.

[0063] The CN 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via a network entity 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the

established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0064] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[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 (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) 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 network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[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.

5 **[0070]** NW controlled beam measurement and beam reporting for beam management was specified in the first release of NR and has been enhanced from release 16 (Rel-16) to release 18 (Rel-18) for performance improvement or for signaling overhead reduction. In order to timely acquire the quality of interested beams, e.g., the qualities of the activated TCI state(s) for a BWP of a serving cell, the network needs to configure or activate frequent periodic or
10 semi-persistent beam reporting (e.g., N best beams and corresponding L1-RSRPs) or triggers frequent aperiodic beam reporting. However, such operation clear results in larger uplink (UL) report overhead. A beam in FR2 can be represented by a reference signal. For example, a DL beam can be represented by a NZP CSI-RS resource or an SSB resource. Beam ID can be represented by a NZP CSI-RS resource ID or an SSB resource ID. When
15 a beam is indicated for a DL reception, the UE can receive the DL signal with the same Rx spatial filter parameters for the reception of the NZP CSI-RS resource or an SSB resource represent the beam. The beam information for DL reception is indicated or be configured by a joint or DL TCI state by containing a DL reference signal resource in the TCI state with QCL type D. Beam measurement and beam report procedure is configured by a CSI report
20 configuration, and the beam report is carried by a CSI report.

[0071] For example, when unified TCI framework is configured for a serving cell, the NW may activate up to 8 joint or DL TCI states for a TRP and any one of them may be indicated for DL channel or RS reception. To ensure the indicated TCI state having a better performance, frequent beam reporting on the beams corresponding to the activated TCI states
25 are required. Given that UE has better and more-timely knowledge of beam quality changes for each of the activated TCI state, UE-initiated beam reporting procedure with specified event can lead to more timely beam reports yet with reduced reporting overhead. Under such a procedure, if the UE determines that the condition for one or more specified event is satisfied, UE can trigger beam reporting without the network needing to configure or trigger
30 frequent reporting. With such justification, the following objective for release 19 (Rel-19) multi-input multi-output (MIMO) evolution has been approved.

- Specify enhancement to facilitate UE-initiated/event-driven beam management for reducing overhead and/or latency, assuming the unified TCI while leveraging (as much

as possible) legacy CSI measurement and reporting configuration frameworks, targeting FR2 and TRP with intra- and inter-cell beam management.

- UL signaling content(s) (and procedure(s) as required) for UE-initiated/event-driven beam reporting facilitating fast beam switching.
- 5 - UL signaling medium/container considering the UE-initiated/event-driven nature of the UL transmission, designed primarily for the purpose of beam reporting.

[0072] Embodiments of the present disclosure provide a solution for event driven beam reporting for unified TCI. In the solution, a UE may determine whether an event associated with an indicated joint/DL TCI state is satisfied, for example, the UE may be configured with one or more events. The UE may further transmit a beam report to a base station in case the condition for an event is satisfied, as such the beam report may be used by the base station for further consideration such as TCI state switching.

[0073] In the present disclosure, a channel quality may also be referred to as a radio link quality or a beam quality, it is understood that they can be used interchangeably.

15 [0074] FIG. 2 illustrates a signalling chart illustrating communication process 200 in accordance with some example embodiments of the present disclosure. The process 200 may involve a UE 201 and a base station 202. With reference to FIG. 1, the UE 201 may be implemented as the UE 104 and the base station 202 may be implemented as the network entity 102. It would be appreciated that the process 200 may be applied to other communication scenarios, which will not be described in detail.

[0075] The UE 201 may be provided, for each BWP of a serving cell, a set $\bar{q}_0$ of periodic CSI-RS resource configuration indexes by *failureDetectionResourcesToAddModList* and a set $\bar{q}_1$ of periodic CSI-RS resource configuration indexes and/or SS/PBCH block indexes by *candidateBeamRSList* or *candidateBeamRSListExt* or *candidateBeamRSSCellList* for radio link quality measurements on the BWP of the serving cell. Instead of the sets $\bar{q}_0$ and $\bar{q}_1$, for each BWP of a serving cell, the UE 201 can be provided respective two sets $\bar{q}_{0,0}$ and $\bar{q}_{0,1}$ of periodic CSI-RS resource configuration indexes by *failureDetectionSet1* and *failureDetectionSet2* that can be activated by a MAC CE and corresponding two sets $\bar{q}_{1,0}$ and $\bar{q}_{1,1}$ of periodic CSI-RS resource configuration indexes and/or SS/PBCH block indexes by *candidateBeamRS-List* and *candidateBeamRS-List2*, respectively, for radio link quality measurements on the BWP of the serving cell. The set $\bar{q}_{0,0}$ is associated with the set $\bar{q}_{1,0}$ and the set $\bar{q}_{0,1}$ is associated with the set $\bar{q}_{1,1}$.

[0076] When unified TCI framework is configured for a serving cell, the UE 201 be configured with up to 128 joint or DL TCI states, which may be used to determine the Rx beam for DL reception, and up to 64 UL TCI state, which may be used to determine the Tx beam for UL transmission, by RRC signaling for a BWP of a serving cell according to UE capability. When joint TCI states are configured, the joint TCI state is used for the UE to determine both the Rx beam for DL reception and the Tx beam for UL transmission. The NW may further send a MAC CE to the UE 201 to activate up to 8 joint/DL/UL TCI state to a TRP for a BWP of a serving cell and each of the activated joint/DL/UL TCI state is mapped to a TCI field codepoint contained in DCI format 1_1/1_2. When a TCI field codepoint is mapped with a DL TCI state and a UL TCI state, then it is assumed that the DL TCI state is paired with the UL TCI state. The NW shall further transmit a DCI with format 1_1/1_2 to indicate a TCI field codepoint for the UE 201 to indicate one joint TCI state or a pair of DL and UL TCI state which are mapped to the indicated TCI codepoint for the DL reception and UL transmission in the BWP of the serving cell.

[0077] In the process 200, the BS 202 transmits a DCI with format 1_1/1_2 to the UE 201 which indicates a TCI codepoint for the UE 201 at 210. The indicates TCI codepoint may be used for indicating an indicated joint or DL TCI state. Specifically, the TCI codepoint may indicate one joint TCI state or a pair of DL and UL TCI state which are mapped to the indicated TCI codepoint for the DL reception and UL transmission in the BWP of the serving cell. Each of the joint/DL TCI state contains a quasi-colocation (QCL) Type-D RS for the UE to determine the spatial domain RX filter parameters for DL reception and the RS can be periodic CSI-RS for beam management or a periodic CSI-RS for tracking.

[0078] In the process 200, the UE 201 determines that an event associated with the indicated joint or DL TCI state is satisfied at 220. In some examples, the UE 201 may determine whether the event has been satisfied for multiple continuous times within a time window. In some implementations, the UE 201 may be configured with one or more events among a first event, a second event, a third event, and a fourth event.

[0079] In the present disclosure, the indicated joint or DL TCI state may be represented as a current joint/DL TCI state, for example, it refers to the current TCI state being applied by the UE 201 and the BS 202 for the BWP of the serving cell.

[0080] The first event may indicate that a quality of the indicated joint or DL TCI state is less than or not greater than a first threshold. In some implementations, the first event may

be represented as Event 1, and the first threshold may be represented as Q1. In some examples, Q1 may be a BLER which is derived based on the specific hypothetical PDCCH transmission parameters (for example the parameters illustrated in Table 1 below), or a L1-RSRP configured by RRC signalling.

5

Table 1

Attribute	Value
DCI payload size	1-0
Number of control OFDM symbols	2
Aggregation level (control channel element (CCE))	4
Ratio of hypothetical PDCCH resource element (RE) energy to average SSS RE energy	0 or 4 dB
Ratio of hypothetical PDCCH DMRS energy to average secondary synchronization signal (SSS) RE energy	0 or 4 dB
Bandwidth (physical resource blocks (PRBs))	24
Sub-carrier spacing (SCS) (kHz)	SCS of the active DL BWP
DMRS pre-coder granularity	REG bundle size
Resource element group (REG) bundle size	6
Cyclic prefix (CP) length	Normal
Mapping from REG to CCE	Distributed

[0081] In some implementations, the UE 201 may determine whether the trigger condition of the first event (Event 1) is satisfied. In some example embodiments, the UE 201 may need to monitor the quality of the indicated joint or DL TCI state. With this event, the UE 201 can timely tell the BS 202 that the current indicated TCI state is not good enough before triggering beam failure event.

[0082] In some examples, the UE 201 may assess (e.g. compare) the quality of the indicated joint or DL TCI state against the first threshold Q1. If the UE 201 has detected that the quality of the indicated joint or DL TCI state is less than Q1 for N1 continuous times (which can be controlled by a counter in MAC) within a time window W1 (which can be controlled by a Timer in MAC), it will send a beam report (refer to 230) to the BS 202 to indicate such event. For example, a dedicated SR can be configured for the beam report for the first event (Event 1). In some examples, after receiving the beam report, i.e., the dedicated SR, the BS 202 may indicate a new joint TCI state or a DL TCI state or a pair of DL and UL TCI states for the BWP of the serving cell.

[0083] The second event may indicate that a quality of one of activated joint or DL TCI states exceeds or not less than a second threshold. In some implementations, the second event may be represented as Event 2, and the second threshold may be represented as Q2. In some examples, Q2 may be a BLER which is derived based on the specific hypothetical PDCCH transmission parameters, or a L1-RSRP configured by RRC signalling.

[0084] In some implementations, the UE 201 may determine whether the trigger condition of the second event (Event 2) is satisfied. In some example embodiments, the UE 201 may monitor (e.g. measure) the qualities of all the activated joint/DL TCI states other than the indicated joint/DL TCI state. With this event, the UE 201 can timely report a better candidate TCI state which is good enough to the BS 202 for potential TCI state switching.

[0085] In some examples, the UE 201 may assess (e.g. compare) each quality of a corresponding activated joint or DL TCI state other than the indicated joint/DL TCI state against the second threshold Q2. If the UE 201 has detected that the quality of one activated joint/DL TCI state equals to or is larger than Q2 for N2 continuous times within a time window W2, it will send a beam report (refer to 230) to the BS 202 to indicate such event and report this activated joint/DL TCI state (or the CSI-RS associated with this activated joint/DL TCI state). For example, N2 may equal to N1, and the time window W2 may be the same with the time window W1. For example, a MAC CE may be configured for the beam report for the second event (Event 2). In some examples, after receiving the beam report, the BS 202 may indicate a TCI codepoint mapped with the reported joint/DL state for the BWP of the serving cell.

[0086] The third event may indicate that a difference between a quality of one of the activated joint or DL TCI states, e.g., the best activated joint or DL TCI state, and a quality of the indicated joint/DL TCI state exceeds or not less than a third threshold. In some implementations, the third event may be represented as Event 3, and the third threshold may be represented as Q3. In some examples, Q3 may be a BLER which is derived based on the specific hypothetical PDCCH transmission parameters, or a L1-RSRP configured by RRC signalling.

[0087] In some implementations, the UE 201 may determine whether the trigger condition of the third event (Event 3) is satisfied. In some example embodiments, the UE 201 may monitor (e.g. measure) the qualities of all the activated joint/DL TCI states including the indicated joint/DL TCI state. With this event, the UE 201 can timely beam report a better

candidate TCI state which is better than the current indicated joint/DL TCI state to the BS 202 for potential TCI state switching.

[0088] In some examples, the UE 201 may assess (e.g. compare) a difference between qualities of an activated joint/DL TCI state and the indicated joint/DL TCI state against the third threshold Q3. If the UE 201 detects that the quality of one activated joint/DL TCI state becomes better than the current indicated TCI state for N1 continuous times within a time window W1 with the quality offset equals to or larger than Q3, it will send a beam report to the BS 202 to indicate such event and report this activated joint/DL TCI state (or the CSI-RS associated with this joint/DL TCI state). For example, a MAC CE may be configured for the beam report for the third event (Event 3).

[0089] The fourth event may indicate that a quality of the indicated joint or DL TCI state is less than or not greater than a fourth threshold and a quality of one of the activated joint or DL TCI state exceeds or not less than a fifth threshold. In some implementations, the fourth event may be represented as Event 4, the fourth threshold may be represented as Q4, and the fifth threshold may be represented as Q5. In some examples, Q4 and/or Q5 may be a BLER which is derived based on the specific hypothetical PDCCH transmission parameters, or a L1-RSRP configured by RRC signalling.

[0090] In some implementations, the UE 201 may determine whether the trigger condition of the fourth event (Event 4) is satisfied. In some example embodiments, the fourth event may be regarded as a combination of the first event and the second event, for example, $Q4=Q1$ and $Q5=Q2$. With this event, the UE 201 can timely tell the BS 202 that the current indicated TCI state is not good enough before triggering beam failure event, and a better candidate TCI state is identified for e.g. fast TCI state switching before triggering beam failure event.

[0091] In some examples, if the UE 201 has detected that the quality of the indicated joint or DL TCI state is less than Q4 for N1 continuous times within a time window W1, and identified that the quality of one activated joint/DL TCI state is larger than Q5 for N2 continuous times within a time window W2, it will send a beam report (refer to 230) to the BS 202 to indicate such event and report this activated joint/DL TCI state (or the CSI-RS associated with this activated joint/DL TCI state). For example, a MAC CE may be configured for the beam report for the fourth event (Event 4).

5 [0092] In the process 200, the UE 201 transmits a beam report to the BS 202 at 230. In some implementations, the beam report may be triggered by occurrence of at least one of the first event, the second event, the third event, and the fourth event. In some example embodiments, the beam report may be regarded as an event driven beam report or an event triggered beam report.

10 [0093] In some implementations, the beam report may indicate the trigger condition of at least one event which is satisfied. In some implementations, if the satisfied event includes one or more of the second event, the third event, or the fourth event, the beam report may further indicate one activated joint or DL TCI state which is different from the indicated joint or DL TCI state and associated with the satisfied event.

[0094] In some implementations, if the trigger condition of first event is satisfied, the beam report may be transmitted via a dedicated SR or a MAC CE. For example, the MAC CE may include a dedicated field which may include at least one bit. For example, the MAC CE may include a specific field which includes an event ID of the first event.

15 [0095] In some other implementations, if the trigger condition of one or more of the second event, the third event, or the fourth event is satisfied, the beam report may be transmitted via a MAC CE.

20 [0096] In some example embodiments, the MAC CE may indicate one activated joint or DL TCI state associated with the satisfied event. In some examples, one of the second event, the third event, or the fourth event may be configured to the UE 201 in a BWP of a serving cell. For example, the one activated joint or DL TCI state indicated by the MAC CE may be a best joint/DL TCI state determined by the UE 201, e.g. with a highest channel quality. In some examples, the one activated joint or DL TCI state may be indicated by the MAC CE explicitly or implicitly.

25 [0097] In some embodiments, the one activated joint or DL TCI state indicated by the MAC CE may be referred to as a reported joint/DL TCI state, a suggested joint/DL TCI state, a selected joint/DL TCI state, or a recommended joint/DL TCI state, etc. the present disclosure does not limit this aspect. In some embodiments, the MAC CE may further include: a serving cell ID field, a BWP ID field, and an L1-RSRP field, for example, the serving cell ID field and the BWP ID field may indicate the serving cell and the BWP for which the MAC CE applies to, and the L1-RSRP field may indicate a measurement RSRP on the NZP CSI-RS associated with the reported joint/DL TCI state.

30

- [0098] In some examples, the MAC CE may include a bitmap which includes multiple bits corresponding to multiple activated joint or DL TCI states. FIG. 3A illustrates an example schematic of MAC CE 310 including a bitmap for indicating an activated joint or TCI state in accordance with some example embodiments of the present disclosure. As shown in FIG. 3A, the bitmap 312 may include T7 to T0 corresponding to 8 activated joint or TCI states. For example, one of T7 to T0 may be a first value, others of T7 to T0 may be a second value, in this case, an activated joint or TCI state corresponding to the first value may be indicated, e.g. as the one meets the satisfied event. For example, the first value may be 1 and the second value may be 0.
- [0099] In some examples, the MAC CE may include a NZP CSI-RS resource ID. Since each joint/DL TCI state contains a QCL Type-D RS such as a NZP CSI-RS, the NZP CSI-RS resource ID may be included in the MAC CE for indicating a corresponding activated joint/DL TCI state. FIG. 3B illustrates an example schematic of MAC CE 320 indicating a NZP CSI-RS resource ID associated with an activated joint or TCI state in accordance with some example embodiments of the present disclosure. As shown in FIG. 3B, a field 322 may include the NZP CSI-RS resource ID which is corresponding to the activated joint/DL TCI state.
- [00100] In some examples, the MAC CE may include an indication of a TCI codeword which is mapped with the activated joint or DL TCI state. FIG. 3C illustrates an example schematic of MAC CE 330 including a TCI codeword mapped with an activated joint or TCI state in accordance with some example embodiments of the present disclosure. As shown in FIG. 3C, a field 332 may include a TCI codeword i . For example, the field 332 may be with 3 bits. For example, the field 332 may indicate an activated joint/DL TCI state which is mapped with TCI codeword i .
- [00101] In some examples, the MAC CE may include an identifier or an identity (ID) of the activated or DL TCI state. FIG. 3D illustrates an example schematic of MAC CE 340 including an ID of an activated joint or TCI state in accordance with some example embodiments of the present disclosure. As shown in FIG. 3D, a field 342 may include a joint or DL TCI state ID which is associated with one activated joint/DL TCI state.
- [00102] In some other example embodiments, the MAC CE may further include an event ID. For example, if more than one event, such as two or three among the second event, the third

event, and the fourth event, are configured to the UE 201, the MAC CE may include a field indicating the event which is satisfied.

[00103] In some examples, the MAC CE corresponding to different events may be associated with different LCIDs. For example, different LCIDs may be configured for the MAC CE
5 for different events.

[00104] In some other examples, the field may include multiple sub-fields corresponding to multiple events. For example, a single event field may be configured for multiple events, such as three events: the second event, the third event, and the fourth event. For example, the sub-fields at different positions in the field may correspond to different events. In this
10 case, a sub-field with the single event field may indicate a corresponding event, while other sub-fields may be set as predefined value (e.g. all 0) or void.

[00105] FIGS. 4A-4C illustrates some examples of MAC CE which includes an event ID. It is to be understood that the examples shown in FIGS. 4A-4C are only for illustration without any limitation. For example, a MAC CE may be determined based on the MAC CE
15 in FIG. 3B/3C/3C with an event field with three sub-fields one of which is associated with the event.

[00106] As mentioned above, the beam report may be transmitted via a MAC CE. In some implementations, there may be available UL resource for the MAC CE transmission, and the MAC CE may be carried by a PUSCH.

[00107] In some other implementations, if there is no available UL resource for the MAC
20 CE transmission, the UE 201 may further transmit a regular SR or a dedicated SR to request the UL resource for sending the beam report, for example, the regular SR or the dedicated SR for beam report may be used for requesting a transmission resource of the MAC CE. In some examples, different SRs may be configured with different priorities, and a transmission
25 of the regular SR or the dedicated SR for beam report may be made by considering the priorities. For example, a priority of the dedicated SR for beam report may be higher than a priority of an SR for beam failure report (BFR), which is higher than a priority of a regular SR. In some examples, the BS 202 may transmit, in response to the regular SR or the dedicated SR for beam report from the UE 201, a first DCI scheduling a PUSCH transmission
30 which may carry the MAC CE, and accordingly, the UE 201 may transmit the MAC CE based on the first DCI.

[00108] In some implementations, if multiple events are configured to the UE 201, there may be more than one event that is satisfied. In this case, an event with a highest priority may be reported. For example, different events may be configured with different priorities. For example, a priority order of these events may be: $P(\text{Event 4}) > P(\text{Event 3}) > P(\text{Event 1}) > P(\text{Event 2})$.

[00109] In some examples, if the first event, the second event, and the fourth event are satisfied, then the fourth event may be reported. For example, the MAC CE may indicate the fourth event and an associated activated joint/DL TCI state.

[00110] Referring back to FIG. 2, in addition or alternatively, the BS 202 may determine whether to perform a TCI state switching for the UE 201 based on the beam report at 240.

[00111] In some implementations, the beam report may indicate that the first event is satisfied. In this case, there is no reported joint/DL TCI state for penitential switching included in the beam report, and the BS 202 may determine, e.g. by itself, whether to switch to another TCI state. That is, it is up to BS 202 to decide whether to switch to another TCI state.

[00112] In some implementations, the beam report may indicate that the second event is satisfied. In this case, a reported joint/DL TCI state is included in the beam report, however, the second event does not consider a channel quality of the indicated joint/DL TCI state (i.e. the current joint/DL TCI state). For example, the current joint/DL TCI state may be good enough for data transmission. Thus, the UE 201 may follow an instruction from the BS 202, e.g. as that in legacy.

[00113] In some implementations, the beam report may indicate that the third or fourth event is satisfied. In this case, a reported joint/DL TCI state is included in the beam report, which may be used for potential switching.

[00114] In some example embodiments, the UE 201 and the BS 202 may switch to the reported joint/DL TCI state (one of activated joint/DL TCI states) for further communication. For example, the UE 201 and the BS 202 may, e.g. automatically, switch to the reported joint/DL TCI state after a specific time point.

[00115] In some examples, the UE 201 may apply the reported joint/DL TCI state after 28 symbols from a last symbol of a PDCCH reception with a third DCI scheduling a PUSCH transmission with a same hybrid automatic repeat request (HARQ) process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled new data indicator

(NDI) field value. FIG. 5A illustrates an example schematic for TCI state switching 510 in accordance with some example embodiments of the present disclosure. As shown in FIG. 5A, the beam report may be transmitted by a MAC CE 512 which indicates a third event or a fourth event and a reported joint/DL TCI state. In addition, a DCI 514 may be received, which schedules a PUSCH transmission with a same HARQ process number as for a transmission of the first PUSCH carrying the MAC CE and has a toggled NDI field value. Then, the reported joint/DL TCI state may be applied after 28 symbols from the last symbol of the PDCCH carrying the DCI 514.

[00116] For example, if the reported joint/DL TCI state is an activated joint TCI state, that is, a joint TCI mode is applied, then the activated joint TCI state may be applied.

[00117] For another example, if reported joint/DL TCI state is an activated DL TCI state, then the activated DL TCI state may be applied. In addition, a UL TCI state may be further determined. In some instances, there may be a paired UL TCI state which is mapped to a same TCI codepoint with the activated DL TCI state (i.e. the reported DL TCI state), then the UE 201 may apply the activated DL TCI state and the paired UL TCI state. In some other instances, there may be no paired UL TCI state which is mapped to a same TCI codepoint with the activated DL TCI state (i.e. the reported DL TCI state), then the current UL TCI state may be continued applying; in other words, the UE 201 may apply the activated DL TCI state and maintain the current UL TCI state.

[00118] As such, the reported joint or DL TCI state may be applied and there may be no need for an additional DCI with format 1_1/1_2 indicating the reported joint or DL TCI state, therefore, a signalling overhead may be reduced and the TCI state switching may be more efficient.

[00119] In some example embodiments, the reported joint/DL TCI state may not be applied automatically. In some example embodiments, the UE 201 may expect to receive a DCI with format 1_1/1_2 indicating a TCI codepoint which is mapped with the reported joint/DL TCI state, e.g. after receiving a DCI format scheduling a PUSCH transmission with a same HARQ process number as for the transmission of the first PUSCH carrying the MAC CE and having a toggled NDI field value.

[00120] In some examples, after receiving a beam report (i.e. a MAC CE including a reported joint/DL TCI state), the BS 202 may transmit a second DCI with format 1_1/1_2 which indicates another indicated joint/DL TCI state. For example, another indicated joint/DL

TCI state is different from the current joint/DL TCI state, and another indicated joint/DL TCI state may be a new TCI state. For example, the second DCI may indicate to the UE 201 to perform a TCI state switching.

5 [00121] In some examples, if the UE 201 receives the second DCI with format 1_1/1_2 which indicates a new TCI state before receiving a DCI format scheduling a PUSCH transmission with a same HARQ process number as for the transmission of the first PUSCH carrying the MAC CE and having a toggled NDI field value, then the UE 201 may apply the new TCI state. FIG. 5B illustrates an example schematic for TCI state switching 520 in accordance with some example embodiments of the present disclosure. As shown in FIG.
10 5B, the beam report may be transmitted by a MAC CE 522 which indicates a third event or a fourth event and a reported joint/DL TCI state. In addition, a DCI 524 may be received, which indicates a new TCI state. Then, the new joint/DL TCI state may be applied after a beam application time from the last symbol of physical uplink control channel (PUCCH)/PUSCH 526.

15 [00122] For example, the PUCCH/PUSCH 526 may carry a positive HARQ-ACK corresponding to the DCI 524 indicating a new TCI state. For example, the beam application time may be N symbols from a set {1, 2, 4, 7, 14, 28, 42, 56, 70, 84, 98, 112, 224, 336} symbols.

[00123] According to some embodiments with reference to FIGS. 2-5B, an event driven
20 beam report may be transmitted by the UE 201 to the BS 202, and thus the beam report may be used by the BS 202 for consideration, e.g. for potential TCI state switching. Therefore, signalling overhead may be saved and the TCI state switching may be more efficient.

[00124] It is to be understood that the BS 202 may be implemented as a TRP, for example,
the present disclosure may be applied to a single TRP scenario. For example, the periodic
25 CSI-RS resources, which can be CSI-RSs for beam management or tracking reference signals (TRSs), associated with all the activated joint or DL TCI states are determined as the single measurement resource pool for single TRP scenario. The UE 201 may monitor the qualities of those CSI-RS resources and compare with a configured threshold or compared with the quality of the indicated joint/DL TCI state to determine whether to trigger a beam report.

30 [00125] In some other cases, the present disclosure may also be applied to a multi-TRP scenario. For example, the embodiments discussed above may be straightforwardly extent

to the multi-TRP scenario. For example, the resource pool for measurement can be determined per TRP, and the event can be triggered per TRP.

[00126] For single-DCI based multi-TRP (S-DCI MTRP), all the first joint/DL TCI states mapped to each of activated TCI codepoint are determined as a first measurement resource set for the first TRP, and all the second joint/DL TCI states mapped to each of activated TCI codepoint are determined as a second measurement resource set for the second TRP. For multi-DCI based multi-TRP (M-DCI MTRP), all the activated joint/DL TCI states specific to coresetPoolIndex value 0 are determined as a first measurement resource set for the first TRP, and all the activated joint/DL TCI states specific to coresetPoolIndex value 1 are determined as a second measurement resource set for the second TRP.

[00127] The two indicated joint/DL TCI states for S-DCI MTRP are determined as the first and the second indicated joint/DL TCI states. For M-DCI MTRP, the first and the second indicated joint/DL TCI states are the joint/DL TCI state specific to coresetPoolIndex value 0 and the joint/DL TCI state specific to coresetPoolIndex value 1, respectively. That is, a current TCI state for the first TRP is the first indicated joint/DL TCI state, and a current TCI state for the second TRP is the second indicated joint/DL TCI state.

[00128] The UE 201 may evaluate each of the events per TRP level. In some examples, an event for the first TRP may be satisfied, and/or another event for the second TRP may be satisfied; in addition the UE 201 may transmits an SR or a MAC CE which may include a beam report for the first TRP and/or the second TRP. For example, the SR or the MAC CE may include a field for indicating the first TRP and/or the second TRP.

[00129] For example, if the UE 201 identified that any one the joint/DL TCI states in the first measurement resource set becomes offset better than the first indicated TCI state, Event 3 corresponding to the first TRP will be triggered. If the UE 201 identified that the second indicated TCI state becomes worse than a threshold and at least one TCI state is identified among the second measurement resource set becomes better than a threshold, Event 4 corresponding to the second TRP will be triggered.

[00130] In this way, the event driven beam report may be transmitted to the BS 202, and the BS 202 may be aware of the channel quality associated with at least the indicated joint/DL TCI state. In some examples, the UE 201 and the BS 202 may apply a better TCI state, such as the reported joint/DL TCI state in the beam report if available, and thus signalling overhead may be reduced and TCI state switching may be more efficient. In some other examples,

the BS 202 may take the beam report into consideration and determine whether to perform a TCI state switching for the UE 201, and thus the decision made by the BS 202 will be more accurate.

[00131] FIG. 6 illustrates an example of a device 600 that is suitable for implementing
5 embodiments of the present disclosure. The device 600 may be an example of a base station or a UE as described herein. The device 600 may support wireless communication with a UE 201, a base station 202, or any combination thereof. The device 600 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 602, a memory 604, a transceiver 606, and,
10 optionally, an I/O controller 608. 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).

[00132] The processor 602, the memory 604, the transceiver 606, or various combinations thereof or various components thereof may be examples of means for performing various
15 aspects of the present disclosure as described herein. For example, the processor 602, the memory 604, the transceiver 606, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[00133] In some implementations, the processor 602, the memory 604, the transceiver 606, or various combinations or components thereof may be implemented in hardware (e.g., in
20 communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.
25 In some implementations, the processor 602 and the memory 604 coupled with the processor 602 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 602, instructions stored in the memory 604).

[00134] For example, the processor 602 may support wireless communication at the device 600 in accordance with examples as disclosed herein. The processor 602 may be configured
30 to operable to support a means for operations discussed above.

[00135] The processor 602 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable

logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 602 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 602. The processor 602 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 604) to cause the device 600 to perform various functions of the present disclosure.

[00136] The memory 604 may include random access memory (RAM) and read-only memory (ROM). The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 602 cause the device 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 602 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 604 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[00137] The I/O controller 608 may manage input and output signals for the device 600. The I/O controller 608 may also manage peripherals not integrated into the device 600. In some implementations, the I/O controller 608 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 608 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 608 may be implemented as part of a processor, such as the processor 602. In some implementations, a user may interact with the device 600 via the I/O controller 608 or via hardware components controlled by the I/O controller 608.

[00138] In some implementations, the device 600 may include a single antenna 610. However, in some other implementations, the device 600 may have more than one antenna 610 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 606 may communicate bi-directionally, via the one or more antennas 610, wired, or wireless links as described herein. For example, the transceiver 606 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver.

The transceiver 606 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 610 for transmission, and to demodulate packets received from the one or more antennas 610. The transceiver 606 may include one or more transmit chains, one or more receive chains, or a combination thereof.

5 **[00139]** A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques
10 such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 610 for transmitting the amplified signal into the air or wireless medium.

15 **[00140]** A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 610 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to
20 demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[00141] FIG. 7 illustrates an example of a processor 700 that is suitable for implementing
25 some embodiments of the present disclosure. The processor 700 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 700 may include a controller 702 configured to perform various operations in accordance with examples as described herein. The processor 700 may optionally include at least one memory 704, such as L1/L2/L3 cache. Additionally, or
30 alternatively, the processor 700 may optionally include one or more arithmetic-logic units (ALUs) 706. 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).

[00142] The processor 700 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.

5 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 700) 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
10 (PCM), and others).

[00143] The controller 702 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 700 to cause the processor 700 to support various operations in accordance with examples as described herein.

15 For example, the controller 702 may operate as a control unit of the processor 700, generating control signals that manage the operation of various components of the processor 700. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[00144] The controller 702 may be configured to fetch (e.g., obtain, retrieve, receive)
20 instructions from the memory 704 and determine subsequent instruction(s) to be executed to cause the processor 700 to support various operations in accordance with examples as described herein. The controller 702 may be configured to track memory address of instructions associated with the memory 704. The controller 702 may be configured to decode instructions to determine the operation to be performed and the operands involved.

25 For example, the controller 702 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 700 to cause the processor 700 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 702 may be configured to manage flow of data within the processor 700. The controller 702 may be configured to control transfer of data
30 between registers, arithmetic logic units (ALUs), and other functional units of the processor 700.

[00145] The memory 704 may include one or more caches (e.g., memory local to or included in the processor 700 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM,

flash memory, etc. In some implementations, the memory 704 may reside within or on a processor chipset (e.g., local to the processor 700). In some other implementations, the memory 704 may reside external to the processor chipset (e.g., remote to the processor 700).

[00146] The memory 704 may store computer-readable, computer-executable code including instructions that, when executed by the processor 700, cause the processor 700 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 702 and/or the processor 700 may be configured to execute computer-readable instructions stored in the memory 704 to cause the processor 700 to perform various functions. For example, the processor 700 and/or the controller 702 may be coupled with or to the memory 704, the processor 700, the controller 702, and the memory 704 may be configured to perform various functions described herein. In some examples, the processor 700 may include multiple processors and the memory 704 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.

[00147] The one or more ALUs 706 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 706 may reside within or on a processor chipset (e.g., the processor 700). In some other implementations, the one or more ALUs 706 may reside external to the processor chipset (e.g., the processor 700). One or more ALUs 706 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 706 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 706 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 706 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 706 to handle conditional operations, comparisons, and bitwise operations.

[00148] The processor 700 may support wireless communication in accordance with examples as disclosed herein. The processor 700 may be configured to or operable to support a means for operations described in some embodiments of the present disclosure.

[00149] FIG. 8 illustrates a flowchart of a method 800 performed by a UE in accordance with

aspects of the present disclosure. The operations of the method 800 may be implemented by a device or its components as described herein. For example, the operations of the method 800 may be performed by the UE 201 in FIG. 2. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00150] At 810, the method may include determining that an event associated with an indicated joint or DL TCI state is satisfied. The operations of 810 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 810 may be performed by the UE 201 as described with reference to FIG. 2.

[00151] At 820, the method may include in accordance with a determination that a trigger condition associated with the event is met, transmitting, to a base station, a beam report indicating one of: the event, or an activated joint or DL TCI state different from the indicated joint or DL TCI state. The operations of 820 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 820 may be performed by the UE 201 as described with reference to FIG. 2.

[00152] FIG. 9 illustrates a flowchart of a method 900 performed by a base station in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a device or its components as described herein. For example, the operations of the method 900 may be performed by the BS 202 in FIG. 2. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00153] At 910, the method may include transmitting, to a UE, downlink control information (DCI) indicating an indicated joint or DL TCI state. The operations of 910 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 910 may be performed by the BS 202 as described with reference to FIG. 2.

[00154] At 920, the method may include receiving, from the UE, a beam report indicating one of: an event associated with the indicated joint or DL TCI state, or an activated joint or DL TCI state different from the indicated joint or DL TCI state. The operations of 920 may be performed in accordance with examples as described herein. In some implementations,

aspects of the operations of 920 may be performed by the BS 202 as described with reference to FIG. 2.

[00155] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[00156] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00157] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[00158] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the

form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[00159] As used herein, including in the claims, an article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[00160] 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) comprising:
at least one memory; and
5 at least one processor coupled with the at least one memory and configured to cause the UE to:
determine that an event associated with an indicated joint or downlink (DL)
transmission configuration indicator (TCI) state is satisfied; and
in accordance with a determination that a trigger condition associated with the
10 event is met, transmit, to a base station, a beam report indicating one of: the event, or an
activated joint or DL TCI state different from the indicated joint or DL TCI state.
2. The UE of claim 1, wherein the trigger condition comprises one of:
the event is satisfied, or
15 the event has been satisfied for a plurality of continuous times within a time window,
wherein a number of the plurality of continuous times is predefined or preconfigured.
3. The UE of claim 1, wherein the event comprises one of:
a first event indicating that a quality of the indicated joint or DL TCI state is less than
20 or not greater than a first threshold,
a second event indicating that a quality of one of activated joint or DL TCI states
exceeds or not less than a second threshold,
a third event indicating that a difference between a quality of one of activated joint or
DL TCI states and a quality of the indicated joint or DL TCI state exceeds or not less than a
25 third threshold, or
a fourth event indicating that a quality of the indicated joint or DL TCI state is less
than or not greater than a fourth threshold and a quality of one of activated joint or DL TCI
states exceeds or not less than a fifth threshold.
- 30 4. The UE of claim 1, wherein at least one threshold associated with the event is
at least one block error rate (BLER), and the at least one BLER is determined based on:
one or more specific hypothetical physical downlink control channel (PDCCH)
transmission parameters, or

layer 1 reference signal received power (L1-RSRP) configured by radio resource control (RRC) signalling.

5 5. The UE of claim 3, wherein the event comprises the first event, and the beam report is comprised in a scheduling request (SR).

10 6. The UE of claim 3, wherein the event comprises one of the second event, the third event, or the fourth event, and wherein the beam report is comprised in a medium access control (MAC) control element (CE) which indicates the one of activated joint or DL TCI states.

15 7. The UE of claim 6, wherein the MAC CE comprises a bitmap, wherein a bit in the bitmap corresponding to the one of activated joint or DL TCI states for a bandwidth part (BWP) of a serving cell of the UE is set to be a specific value.

20 8. The UE of claim 6, wherein the MAC CE comprises one of:
an identifier (ID) of the one of activated joint or DL TCI states,
a non-zero power (NZP) channel state information (CSI) reference signal (RS)
resource ID which is associated with the one of activated joint or DL TCI states, or
an indication of a TCI codepoint which is mapped with the one of activated joint or
DL TCI states.

25 9. The UE of claim 6, wherein different events are associated with different logical channel identities (LCIDs), and wherein the MAC CE further comprises a LCID associated with the event.

30 10. The UE of claim 6, wherein different events are associated with a same LCID, and wherein the MAC CE comprises the LCID being carried in a specific position associated with the event.

11. The UE of claim 6, wherein the at least one processor is further configured to cause the UE to:
transmit, to the base station, a dedicated SR for requesting a transmission resource of the MAC CE; and

receive, from the base station, first downlink control information (DCI) scheduling a physical uplink shared channel (PUSCH) transmission carrying the MAC CE.

12. The UE of claim 3, wherein the event comprises the first event or the second event, and wherein the at least one processor is configured to cause the UE to:

receive, from the base station, a second DCI indicating a further indicated joint or DL TCI state, wherein the further indicated joint or DL TCI state is the same as or different from the activated joint or DL TCI state in the beam report; and

10 apply the further indicated joint or DL TCI state for further transmission or reception.

13. The UE of claim 6, wherein the event comprises the third event or the fourth event, and wherein the at least one processor is configured to cause the UE to:

15 apply the activated joint or DL TCI state after a specific time point, wherein the specific time point is 28 symbols from a last symbol of a PDCCH reception with a third DCI scheduling a PUSCH transmission with a same hybrid automatic repeat request (HARQ) process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled new data indicator (NDI) field value.

14. The UE of claim 13, wherein the at least one processor is configured to cause the UE to:

in accordance with a determination that there is an uplink (UL) TCI state paired with the activated DL TCI state, apply the UL TCI state for further transmission; or

25 in accordance with a determination that there is no UL TCI state paired with the activated DL TCI state, continue applying a current UL TCI state for further transmission.

15. The UE of claim 6, wherein the at least one processor is configured to cause the UE to:

30 receive, from the base station, a second DCI indicating a further indicated joint or DL TCI state before a third DCI, wherein the third DCI is scheduling a PUSCH transmission with a same HARQ process number as for a transmission of a first PUSCH carrying the MAC CE and having a toggled NDI field value; and

apply the further indicated joint or DL TCI state for further transmission or reception.

16. A base station comprising:

at least one memory; and

at least one processor coupled with the at least one memory and configured to cause the base station to:

transmit, to a user equipment (UE), downlink control information (DCI)
5 indicating an indicated joint or downlink (DL) transmission configuration indicator (TCI) state; and

receive, from the UE, a beam report indicating one of: an event associated with the indicated joint or DL TCI state, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

10

17. The base station of claim 16, wherein the event comprises one of:

a first event indicating that a quality of the indicated joint or DL TCI state is less than or not greater than a first threshold,

a second event indicating that a quality of one of activated joint or DL TCI states
15 exceeds or not less than a second threshold,

a third event indicating that a difference between a quality of one of activated joint or DL TCI states and a quality of the indicated joint or DL TCI state exceeds or not less than a third threshold, or

a fourth event indicating that a quality of the indicated joint or DL TCI state is less
20 than or not greater than a fourth threshold and a quality of one of activated joint or DL TCI states exceeds or not less than a fifth threshold.

18. The base station of claim 16, wherein at least one threshold associated with the event is at least one block error rate (BLER), and the at least one BLER is determined based
25 on:

one or more specific hypothetical physical downlink control channel (PDCCH) transmission parameters, or

layer 1 reference signal received power (L1-RSRP) configured by radio resource control (RRC) signalling.

30

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

determining that an event associated with an indicated joint or downlink (DL) transmission configuration indicator (TCI) state is satisfied; and

in accordance with a determination that a trigger condition associated with the event

is met, transmitting, to a base station, a beam report indicating one of: the event, or an activated joint or DL TCI state different from the indicated joint or DL TCI state.

20. A processor for wireless communication comprising at least one controller
5 coupled with at least one memory and configured to cause the processor to:
determine that an event associated with an indicated joint or downlink (DL)
transmission configuration indicator (TCI) state is satisfied; and
in accordance with a determination that a trigger condition associated with the event
is met, transmit, to a base station, a beam report indicating one of: the event, or an activated
10 joint or DL TCI state different from the indicated joint or DL TCI state.