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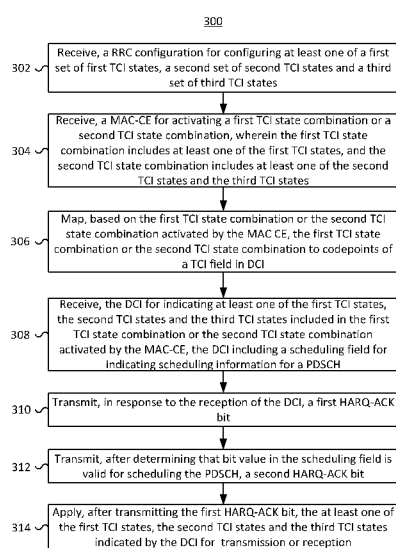


FIG. 3

(57) Abstract: A method and a user equipment for beam operation are provided. The method includes: receiving, RRC configuration for configuring first TCI states, second TCI states or third TCI states; receiving, a MAC-CE for activating a first TCI state combination including the first TCI states or a second TCI state combination including the second TCI states or the third TCI states; mapping the first TCI state combination or the second TCI state combination to codepoints of a TCI field in DCI; receiving, the DCI for indicating the first TCI states, the second TCI states or the third TCI states activated by the MAC-CE; transmitting, a first HARQ-ACK bit; transmitting, after determining that bit value in the scheduling field is valid for scheduling the PDSCH, a second HARQ-ACK bit; and applying, the first TCI states, the second TCI states or the third TCI states indicated by the DCI for transmission or reception.



METHOD AND USER EQUIPMENT FOR BEAM OPERATION

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] The present disclosure claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 63/138,164, filed on January 15, 2021, entitled “TRP-SPECIFIC BEAM FAILURE RECOVERY FOR PDCCH WITH MULTIPLE ACTIVATED TCI STATES” (“the ’164 provisional”) and U.S. Provisional Patent Application Serial No. 63/138,756, filed on January 18, 2021, entitled “INDICATION AND ACKNOWLEDGEMENT FOR BEAM-BASED OPERATION” (“the ’756 provisional”). The contents of the ’164 provisional and the ’756 provisional are hereby incorporated fully by reference into the present disclosure for all purposes.

FIELD

[0002] The present disclosure is related to wireless communication, and more particularly, to a method and a user equipment (UE) for beam operation in next generation wireless communication networks.

BACKGROUND

[0003] Various efforts have been made to improve different aspects of wireless communication for cellular wireless communication systems, such as 5G New Radio (NR), by improving data rate, latency, reliability, and mobility. The 5G NR system is designed to provide flexibility and configurability to optimize the network services and types, accommodating various use cases such as enhanced Mobile Broadband (eMBB), massive Machine-Type Communication (mMTC), and Ultra-Reliable and Low-Latency Communication (URLLC). However, as the demand for radio access continues to increase, there exists a need for further improvements in the art.

SUMMARY

[0004] The present disclosure is related to a method and a user equipment for beam operation in the next generation wireless communication networks.

[0005] In a first aspect of the present disclosure, a method performed by a user equipment (UE) for beam operation is provided. The method includes: receiving, a radio resource control (RRC) configuration for configuring at least one of a first set of first TCI states, a second set of second TCI states and a third set of third TCI states; receiving, a medium access control (MAC)-control element (CE) for activating a first TCI state combination or a second TCI state combination, wherein the first

TCI state combination includes at least one of the first TCI states, and the second TCI state combination includes at least one of the second TCI states and the third TCI states; mapping, based on the first TCI state combination or the second TCI state combination activated by the MAC CE, the first TCI state combination or the second TCI state combination to codepoints of a TCI field in downlink control information (DCI); receiving, the DCI for indicating the at least one of the first TCI states, the second TCI states and the third TCI states included in the first TCI state combination or the second TCI state combination activated by the MAC-CE, the DCI including a scheduling field for indicating scheduling information for a physical downlink shared channel (PDSCH); transmitting, in response to the reception of the DCI, a first HARQ-ACK bit; transmitting, after determining that bit value in the scheduling field is valid for scheduling the PDSCH, a second HARQ-ACK bit; and applying, after transmitting the first HARQ-ACK bit, the at least one of the first TCI states, the second TCI states and the third TCI states indicated by the DCI for transmission or reception.

[0006] In an implementation of the first aspect of the present disclosure, the bit value in the scheduling field is invalid for scheduling the PDSCH.

[0007] In an implementation of the first aspect of the present disclosure, each bit in at least one field in the DCI is set to “0” or “1”, and the at least one field is different from the TCI field and the scheduling field.

[0008] In an implementation of the first aspect of the present disclosure, the method further includes: applying, after determining that the DCI format indicates the first TCI states, receiver (RX) parameters for receiving one or more configured downlink (DL) transmissions and transmitter (TX) parameters for transmitting one or more configured uplink (UL) transmissions, wherein the first TCI states include the RX parameters and the TX parameters.

[0009] In an implementation of the first aspect of the present disclosure, the method further includes: applying, after determining that the DCI format indicates the second TCI states, transmitter (TX) parameters for transmitting one or more configured uplink (UL) transmissions, wherein the second TCI states include the TX parameters.

[0010] In an implementation of the first aspect of the present disclosure, the method further includes: applying, after determining the DCI format indicates the third TCI states, receiver (RX) parameters for receiving one or more configured downlink (DL) transmissions, wherein the third TCI states include the RX parameters.

[0011] In an implementation of the first aspect of the present disclosure, the first TCI states are referred to as joint TCI states.

[0012] In an implementation of the first aspect of the present disclosure, the second TCI states are referred to as uplink (UL)-only TCI states.

[0013] In an implementation of the first aspect of the present disclosure, the third TCI states are referred to as downlink (DL)-only TCI states.

[0014] In a second aspect of the present disclosure, a UE for beam operation is provided. The UE includes a processor; and a memory coupled to the processor. The memory stores a computer-executable program that when executed by the processor, causes the processor to: receive, RRC configuration for configuring at least one of a first set of first TCI states, a second set of second TCI states and a third set of third TCI states; receive, a MAC-CE for activating a first TCI state combination or a second TCI state combination, wherein the first TCI state combination includes the first TCI states, and the second TCI state combination includes at least one of the second TCI states and the third TCI states; map, based on the first TCI state combination or the second TCI state combination activated by the MAC CE, the first TCI state combination or the second TCI state combination to codepoints of a TCI field in DCI; receive, the DCI for indicating the at least one of the first TCI states, the second TCI states and the third TCI states included in the first TCI state combination or the second TCI state combination activated by the MAC-CE, the DCI including a scheduling field for indicating scheduling information for a PDSCH; transmit, in response to the reception of the DCI, a first HARQ-ACK bit; transmit, after determining that bit value in the scheduling field is valid for scheduling the PDSCH, a second HARQ-ACK bit; and apply, after transmitting the first HARQ-ACK bit, the at least one of the first TCI states, the second TCI states and the third TCI states indicated by the DCI for transmission or reception.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Aspects of the disclosure are best understood from the following detailed disclosure when read with the accompanying drawings. Various features are not drawn to scale. Dimensions of various features may be arbitrarily increased or reduced for clarity of discussion.

[0016] FIG. 1 is a schematic diagram illustrating an MAC-CE format with a fixed size of 16 bits that is used for activating a TCI state for a CORESET according to an example implementation of the present disclosure.

[0017] FIG. 2 is a schematic diagram illustrating an association of one TCI codepoint with two TCI states according to an example implementation of the present disclosure.

[0018] FIG. 3 is a flowchart illustrating a method performed by a UE for beam operation according to an example implementation of the present disclosure.

[0019] FIG. 4 is a block diagram illustrating a node for wireless communication according to an example implementation of the present disclosure.

DESCRIPTION

[0020] The following contains specific information related to implementations of the present disclosure. The drawings and their accompanying detailed disclosure are merely directed to implementations. However, the present disclosure is not limited to these implementations. Other variations and implementations of the present disclosure will be obvious to those skilled in the art. Unless noted otherwise, like or corresponding elements among the drawings may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present disclosure are generally not to scale and are not intended to correspond to actual relative dimensions.

[0021] For the purposes of consistency and ease of understanding, like features may be identified (although, in some examples, not illustrated) by the same numerals in the drawings. However, the features in different implementations may be different in other respects and shall not be narrowly confined to what is illustrated in the drawings.

[0022] The phrases “in one implementation,” or “in some implementations,” may each refer to one or more of the same or different implementations. The term “coupled” is defined as connected whether directly or indirectly via intervening components and is not necessarily limited to physical connections. The term “comprising” means “including, but not necessarily limited to” and specifically indicates open-ended inclusion or membership in the so-disclosed combination, group, series or equivalent. The expression “at least one of A, B and C” or “at least one of the following: A, B and C” means “only A, or only B, or only C, or any combination of A, B and C.”

[0023] For the purposes of explanation and non-limitation, specific details such as functional entities, techniques, protocols, and standards are set forth for providing an understanding of the disclosed technology. In other examples, detailed disclosure of well-known methods, technologies, systems, and architectures are omitted so as not to obscure the present disclosure with unnecessary details.

[0024] Persons skilled in the art will immediately recognize that any network function(s) or algorithm(s) disclosed may be implemented by hardware, software or a combination of software and hardware. Disclosed functions may correspond to modules which may be software, hardware, firmware, or any combination thereof. A software implementation may include computer executable instructions stored on a computer readable medium such as memory or other type of storage devices. One or more microprocessors or general-purpose computers with communication processing capability may be programmed with corresponding executable instructions and perform the disclosed network function(s) or algorithm(s). The microprocessors or general-purpose computers may include Application Specific Integrated Circuitry (ASIC), programmable logic arrays, and/or using one or more Digital Signal Processor (DSPs). Although some of the disclosed implementations are oriented

to software installed and executing on computer hardware, alternative implementations implemented as firmware or as hardware or as a combination of hardware and software are well within the scope of the present disclosure.

[0025] The computer-readable medium includes but is not limited to Random Access Memory (RAM), Read Only Memory (ROM), Erasable Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), flash memory, Compact Disc Read-Only Memory (CD-ROM), magnetic cassettes, magnetic tape, magnetic disk storage, or any other equivalent medium capable of storing computer-readable instructions.

[0026] A radio communication network architecture such as a Long-Term Evolution (LTE) system, an LTE-Advanced (LTE-A) system, an LTE-Advanced Pro system, or a 5G NR Radio Access Network (RAN) typically includes at least one base station (BS), at least one UE, and one or more optional network elements that provide connection within a network. The UE communicates with the network such as a Core Network (CN), an Evolved Packet Core (EPC) network, an Evolved Universal Terrestrial RAN (E-UTRAN), a 5G Core (5GC), or an internet via a RAN established by one or more BSs.

[0027] A UE may include but is not limited to a mobile station, a mobile terminal or device, or a user communication radio terminal. The UE may be a portable radio equipment that includes but is not limited to a mobile phone, a tablet, a wearable device, a sensor, a vehicle, or a Personal Digital Assistant (PDA) with wireless communication capability. The UE is configured to receive and transmit signals over an air interface to one or more cells in a RAN.

[0028] The BS may include but is not limited to a node B (NB) in the UMTS, an evolved node B (eNB) in LTE or LTE-A, a radio network controller (RNC) in UMTS, a BS controller (BSC) in the GSM/GERAN, an ng-eNB in an Evolved Universal Terrestrial Radio Access (E-UTRA) BS in connection with 5GC, a next generation Node B (gNB) in the 5G-RAN, or any other apparatus capable of controlling radio communication and managing radio resources within a cell. The BS may serve one or more UEs via a radio interface.

[0029] A BS may be configured to provide communication services according to at least a Radio Access Technology (RAT) such as Worldwide Interoperability for Microwave Access (WiMAX), Global System for Mobile communications (GSM) that is often referred to as 2G, GSM Enhanced Data rates for GSM Evolution (EDGE) RAN (GERAN), General Packet Radio Service (GPRS), Universal Mobile Telecommunication System (UMTS) that is often referred to as 3G based on basic wideband-code division multiple access (W-CDMA), high-speed packet access (HSPA), LTE, LTE-A, evolved LTE (eLTE) that is LTE connected to 5GC, NR (often referred to as 5G), and/or LTE-A Pro. However, the scope of the present disclosure is not limited to these protocols.

[0030] The BS is operable to provide radio coverage to a specific geographical area using a plurality of cells forming the RAN. The BS supports the operations of the cells. Each cell is operable to provide services to at least one UE within its radio coverage. Each cell (often referred to as a serving cell) may provide services to serve one or more UEs within its radio coverage such that each cell schedules the DL and optionally UL resources to at least one UE within its radio coverage for DL and optionally UL packet transmissions. The BS can communicate with one or more UEs in the radio communication system via the plurality of cells. A cell may allocate sidelink (SL) resources for supporting Proximity Service (ProSe) or Vehicle to Everything (V2X) service. Each cell may have overlapped coverage areas with other cells.

[0031] As discussed above, the frame structure for NR supports flexible configurations for accommodating various next generation (e.g., 5G) communication requirements such as Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), and Ultra-Reliable and Low-Latency Communication (URLLC), while fulfilling high reliability, high data rate and low latency requirements. The Orthogonal Frequency-Division Multiplexing (OFDM) technology in the 3rd Generation Partnership Project (3GPP) may serve as a baseline for an NR waveform. The scalable OFDM numerology such as adaptive sub-carrier spacing, channel bandwidth, and Cyclic Prefix (CP) may also be used. Additionally, two coding schemes are considered for NR, specifically Low-Density Parity-Check (LDPC) code and Polar Code. The coding scheme adaption may be configured based on channel conditions and/or service applications.

[0032] Moreover, it is also considered that in a transmission time interval TX of a single NR frame, at least downlink (DL) transmission data, a guard period, and uplink (UL) transmission data should be included, where the respective portions of the DL transmission data, the guard period, and the UL transmission data should also be configurable, for example, based on the network dynamics of NR. In addition, sidelink resources may also be provided in an NR frame to support ProSe services.

[0033] In addition, the terms “system” and “network” herein may be used interchangeably. The term “and/or” herein is only an association relationship for describing associated objects and represents that these relationships may exist. For example, A and/or B may indicate that: A exists alone, A and B exist at the same time, or B exists alone. In addition, the character “/” herein generally represents that the former and latter associated objects are in an “or” relationship.

[0034] Examples of some selected terms are provided as follows.

[0035] Beam: The term “beam” may be replaced by the term “spatial filter.” For example, when a UE reports a preferred gNB TX beam, the UE is essentially selecting a spatial filter used by the gNB. The term “beam information” is used to provide information about which beam/spatial filter is being used/selected. Individual reference signals are transmitted by applying individual beams/spatial filters.

Thus, the term “beam” or “beam information” may be represented by the term “reference signal resource index(es).”

[0036] Antenna Panel: It may be assumed that an antenna panel is an operational unit for controlling a transmit spatial filter/beam. An antenna panel is typically consisted of a plurality of antenna elements. A beam can be formed by an antenna panel and in order to form two beams simultaneously, two antenna panels are needed. Such simultaneous beamforming from multiple antenna panels is subject to UE capability. A similar definition for “antenna panel” may be possible by applying spatial receiving filtering characteristics.

[0037] Hybrid Automatic Repeat Request (HARQ): A functionality ensures delivery between peer entities at Layer 1 (i.e., Physical Layer). A single HARQ process supports one Transport Block (TB) when the physical layer is not configured for downlink/uplink spatial multiplexing, and when the physical layer is configured for downlink/uplink spatial multiplexing, a single HARQ process supports one or multiple TBs. There is one HARQ entity per serving cell. Each of HARQ entity supports a parallel of DL and UL HARQ process.

[0038] Timer: A Medium Access Control (MAC) entity may setup one or more timers for individual purposes, for example, triggering some uplink signaling retransmission or limiting some uplink signaling retransmission period. A timer is running once it is started, until it is stopped or until it expires; otherwise, it is not running. A timer may be started if it is not running, or may be restarted if it is running. A timer may be always started or restarted from an initial value. The initial value may be but not limited to be configured by the gNB via downlink Radio Resource Control (RRC) signaling.

[0039] Bandwidth Part (BWP): A subset of the total cell bandwidth of a cell is referred to as a BWP and beamwidth part adaptation is achieved by configuring the UE with BWP(s) and telling the UE which of the configured BWPs is currently the active one. To enable Bandwidth Adaptation (BA) on a Primary Cell (PCell), the gNB configures the UE with UL and DL BWP(s). To enable BA on Secondary Cells (SCells) in case of Carrier Aggregation (CA), the gNB configures the UE with DL BWP(s) at least (i.e., there may be none in the UL). For the PCell, the initial BWP is the BWP used for initial access. For the SCell(s), the initial BWP is the BWP configured for the UE to first operate at SCell activation. The UE may be configured with a first active uplink BWP by a *firstActiveUplinkBWP* Information Element (IE). If the first active uplink BWP is configured for a Special Cell (SpCell), the *firstActiveUplinkBWP* IE field contains the Identity (ID) of the UL BWP to be activated upon performing the RRC (re-)configuration. If the field is absent, the RRC (re-)configuration does not impose a BWP switch. If the first active uplink BWP is configured for an SCell, the *firstActiveUplinkBWP* IE field contains the ID of the UL BWP to be used upon MAC-activation of an SCell.

[0040] Quasi Co-Location (QCL): Two antenna ports are said to be quasi co-located if properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. The properties of the channel may include Doppler shift, Doppler spread, average delay, delay spread, and spatial RX parameters. These properties are categorized into different QCL types in NR specifications. For example, QCL-TypeD refers to spatial RX parameter. QCL-TypeD is also referred to “beam” in the present disclosure.

[0041] Transmission Configuration Indication (TCI) state: A TCI state contains parameters for configuring a QCL relationship between one or two DL reference signals and a target reference signal set. For example, a target reference signal set may be the Demodulation Reference Signal (DMRS) ports of Physical Downlink Shared Channel (PDSCH) or Physical Downlink Control Channel (PDCCH).

[0042] Beam failure recovery (BFR): The movements in the environment or other events, may lead to a currently established beam pair being rapidly blocked without sufficient time for the regular beam adjust to adapt based on beam reporting mechanism (beam reporting mechanism is similar to CSI (channel state information) reporting mechanism taken place in physical (PHY) channels. A beam failure recovery procedure is to deal with such occurrences with short reaction time.

[0043] Normal Scheduling Request (SR): The normal SR may be used for requesting Uplink Shared Channel (UL-SCH) resource (e.g., Physical Uplink Shared Channel (PUSCH) resource) for new transmission. The UE may be configured with zero, one, or more normal SR configurations. A normal SR configuration may consist of a set of Physical Uplink Control Channel (PUCCH) resources for SR across different BWPs and cells. For a logical channel, at most one PUCCH resource for SR is configured per BWP. Each normal SR configuration may correspond to one or more logical channels. Each logical channel may be mapped to zero or one normal SR configuration. The normal SR configuration of the logical channel that triggered the BSR (if such a configuration exists) is considered as corresponding normal SR configuration for the triggered SR. When a normal SR is triggered, it shall be considered as pending until it is cancelled.

[0044] For QCL assumption indication in DL, the TCI framework is introduced in 3GPP NR Release 15/16 (Rel-15/16). In 3GPP NR Rel-15/16, different QCL types have been defined for indicating different parameters for DL synchronization purpose, including timing/frequency/spatial domain synchronization. Among them, the spatial domain synchronization may be often referred to as beam or spatial filter. For UL synchronization in a spatial or beam domain, a spatial relation information parameter has been introduced since 3GPP NR Rel-15. One of the reasons for applying different principles for indicating DL/UL spatial domain filter characteristics is that the overhead on

synchronization parameters in UL direction is less than in DL direction.

[0045] The beam indication for DL channels/signals may be a TCI (which includes beam indication information) indication for the DL Channel State Information-Reference Signal (CSI-RS). For periodic CSI-RS, the TCI may be configured by RRC. For semi-persistent (SP) CSI-RS, the TCI may be provided by a MAC-CE when the SP CSI-RS is activated. For an aperiodic (AP) CSI-RS, the TCI may be configured by RRC in associated trigger states.

[0046] The beam indication for DL channels/signals may be a TCI indication for a PDSCH. A first set of TCI states may be configured by RRC. The MAC-CE signaling may activate a subset from the first set of TCI states for beam indication or reception of the PDSCH. The Downlink Control Information (DCI) signaling may dynamically indicate one TCI state for scheduled PDSCH transmission.

[0047] The beam indication for DL channels/signals may be a TCI indication for a PDCCH. A second set of TCI states may be configured by RRC for the PDCCH. The configuration for the second set of TCI states may be per-Control Resource Set (CORESET) signaling. The MAC-CE signaling may activate one from the second set of TCI states. The second set of TCI states may be a subset of the first set of TCI states.

[0048] The beam indication for UL channels/signals may be a beam indication for a UL Sounding Reference Signal (SRS). For periodic SRS, the spatial transmission property (e.g., beam indication for UL) may be configured by RRC. For an SP/aperiodic (AP) SRS, the spatial transmission property may be provided and/or updated by a MAC-CE signaling.

[0049] The beam indication for UL channels/signals may be a beam indication for a PUCCH. A set of spatial transmission properties may be configured by RRC for PUCCH resources. The MAC-CE signaling may be used to activate one spatial transmission property from the set of spatial transmission properties for transmission of a PUCCH resource.

[0050] The beam indication for UL channels/signals may be a beam indication for a PUSCH. The spatial transmission property of PUSCH transmission may refer to one or more RRC-configured SRS resources. The DCI signaling may be used to indicate one spatial transmission property, from the one or more RRC-configured SRS resources, for a scheduled PUSCH transmission. By referring to an RRC-configured SRS resource as a spatial transmission property, the PUSCH transmission may assume a same spatial transmission property as that applied for the referred RRC-configured SRS resource. The spatial transmission property of the RRC-configured SRS resource may be updated by MAC-CE signaling.

[0051] To simplify beam indication overhead, a common beam indication may be applied for a set of channels and/or signals, instead of indicating beam information individually. The common beam

operation may be considered in two aspects: joint DL/UL common beam operation and separate DL/UL common beam operation.

[0052] The joint DL/UL common beam operation may assume that a same common beam indication is applicable to the specific channels/signals in both DL and UL directions. This may be achieved by a same beam indication signaling and may require beam correspondence capability to be supported for a UE. The separate DL/UL common beam operation may assume that respective common beam is applicable to respective DL channels/signals and UL channels/signals, individually. This may be achieved by different indication signaling for the DL and UL common beam. The beam correspondence capability may not be necessary for a UE operating in the separate DL/UL common beam operation. A beam correspondent UE may not always perform the joint DL/UL common beam operation when the separate DL/UL common beam operation is, for example, enabled by the network (NW). There may be situations where different beams are preferred for DL reception and UL transmission, for example, due to Maximum Power Emission (MPE) considerations. In this situation, even though beam correspondence and the joint common beam operation are supported by the UE, the separate DL/UL common beam operation may be applied.

[0053] One method for such common beam operation is to reuse the PDSCH beam indication framework of 3GPP NR Rel-15/16. That is, the MAC-CE signaling may be used to activate a subset of TCI states from a set of TCI states configured by RRC. Then, the DCI may be used to indicate/update a common beam to be applied for a (pre-)configured/(pre-)specified channels/signals. The common beam may be a joint DL/UL common beam, or a DL or UL beam in separate DL/UL common beam. In such framework, the following issues (a)-(c) need to be addressed.

[0054] (a) Indication signaling details for the common beam indication, including the joint DL/UL common beam and the separate DL/UL common beam.

[0055] (b) Acknowledgement of successful reception of the common beam indication. It may be noted that since an indicated common beam may be applied for reception/transmission for multiple times, the penalty of not receiving the common beam indication is large compared with the PDSCH beam indication of 3GPP NR Rel-15/16.

[0056] (c) Common beam operation may be potentially applied in a multi-Transmission Reception Point (TRP) scenario, where a UE may communicate with more than one TRP. Since TRPs are not co-located in general, different common beams may need to be indicated for communicating with multiple TRPs.

[0057] For common beam indication, various DCI format(s) may be considered. In the present disclosure, existing DCI format(s) but with dedicated use for common beam indication may be considered. Field value(s) of the DCI format(s) may be set to specific values for identifying a received

DCI format as a common beam indication. Specific Field(s) of the DCI format(s) may be reused for indicating common beam(s). For acknowledgement of common beam indication, methods for adding extra HARQ-ACK bits for common beam indication(s) in a HARQ-ACK codebook is proposed. Additionally, new MAC-CE for confirming successful reception of common beam indication is also proposed. For all methods, both joint DL/UL common beam operation and separate DL/UL common beam operation are considered.

[0058] The methods proposed here may be applied for both joint DL/UL common beam operation and separate DL/UL common beam operation, if not stated otherwise. A 3-step common beam indication framework where Layer-3 RRC, Layer-2 MAC-CE and Layer-1 DCI signaling may be involved. Since one common beam indication may be applied for multiple times for reception/transmission of specific (DL and/or UL) channels/signals, making sure the indication is successfully received is of crucial. In this sense, not only indication signaling, but also acknowledgement signaling of indication reception may need to be devised.

[0059] Dependent on system design, M common beam(s) may be assumed, where $M = 1$ or $M > 1$. While $M=1$ may simplify system design, $M > 1$ may find its application in, for example, a multi-TRP scenario. $M=1$ may be restricted to a single-TRP scenario. $M>1$ may be required for an inter-cell/intra-cell multi-TRP scenario. $M>1$ may be required for a generic multi-TRP scenario. $M>1$ may be referred to that a common beam indication may (only) be applicable for some of DL channels and/or signals. It is noted that a multi-TRP scenario may be identified based on RRC parameter(s). For example, when parameter *CORESETPoolIndex* is not configured for any CORESET, or no CORESET is configured with parameter *CORESETPoolIndex* ≥ 1 , a single-TRP scenario may be assumed. For differentiating between an intra-cell multi-TRP and an inter-cell multi-TRP, additional parameter(s) may be needed.

[0060] In single-TRP (s-TRP) scenario, one DL common beam may be applied for a UE in DL and one UL common beam may be applied for the UE in UL. In joint DL/UL common beam operation, the DL common beam and the UL common beam may be the same. In separate DL/UL common beam operation, the DL common beam and the UL common beam may be different. In multi-TRP (m-TRP) scenario, M DL common beam(s) may be applied for a UE in DL and N UL common beam(s) may be applied for the UE in UL. In joint DL/UL common beam operation, the DL common beam and the UL common beam may be the same, and M may be equal to N. In separate DL/UL common beam operation, the DL common beam and the UL common beam may be different, M may or may not be equal to N. In the present disclosure, the term “gNB” may be replaced by other terms, such as a network node, or a base station (BS).

[0061] The DL DCI format(s) may be applied for the common beam indication. For example, DCI 1_0, DCI 1_1, or DCI 1_2 may be applied for the common beam indication. In some implementations, more than one of DCI 1_0, DCI 1_1 and DCI 1_2 may be applied for the common beam indication. In some implementations, the group common DCI may be applied for the common beam indication for a group of UEs. The DCI format(s) used for the common beam indication may be at least one of the following (a)-(d).

[0062] (a) A dynamic resource scheduling DCI for a PDSCH and/or a PUSCH.

[0063] (b) A Semi-persistent scheduling (SPS) PDSCH scheduling activation/release DCI (or PDCCH), as specified in e.g., the 3GPP Technical Specification (TS) 38.213 V16.2.0. The SPS scheduling activation/release DCI may be used for activation/release of at least one SPS configuration. The release of a SPS configuration may mean the de-activation of the SPS configuration. The SPS scheduling activation/release DCI may be used for activation of single or multiple SPS configurations. The single or multiple SPS configurations may be configured in an active DL BWP for a scheduled cell related to the activation/release DCI.

[0064] (c) A UL Configured Grant (CG) PUSCH scheduling activation/release DCI (or PDCCH), as specified in e.g., the 3GPP TS 38.213 V16.2.0. The UL CG may be a type 2 configured grant. The UL CG scheduling activation/release DCI may be used for activation/release of single UL CG configuration. The UL CG scheduling activation/release DCI may be used for activation of single or multiple UL CG configurations. The single or multiple UL CG configurations may be configured in an active UL BWP for a scheduled cell related to the activation/release DCI.

[0065] (d) A DCI format with Cyclic Redundancy Check (CRC)-scrambled by Cell-Radio Network Temporary Identifier (C-RNTI), Configured Scheduling (CS)-RNTI, or a new RNTI (compared to the RNTIs defined in the 3GPP TS 38.321 V16.2.0) defined for the common beam indication.

[0066] The UE may validate a common beam indication signaling in a similar manner as for validating a DL SPS or a UL CG type 2 scheduling release/deactivation when the UE is provided with a single/multiple SPS configuration(s) or UL grant type 2 configuration(s) in an active DL/UL BWP of the scheduled cell of a DCI signaling. The UE may validate a common beam indication signaling when receiving the DCI with field(s) set/indicated as at least one of the following (a)-(c).

[0067] (a) The new data indicator field in the DCI format for enabled Transport Block (TB) may be set to a specific value, e.g., "0."

[0068] (b) The Downlink Feedback Information (DFI) flag field, if present, in the DCI format may be set to a specific value, e.g., "0."

[0069] (c) The HARQ Process Number (HPN) field, the Redundancy Version (RV) field, the

Modulation and Coding Scheme (MCS) field, and/or the Frequency Domain Resource Assignment (FDRA) field may be set to specific values. The HPN field may be set to a specific codepoint, e.g., all “0”s. The HPN field may be used to indicate adaptation of one or multiple common beams. The codepoint value of the HPN field may be mapped to one or a subset of the TCI states activated by the MAC-CE for the common beam operation. The RV field may be set to a specific codepoint, e.g., all “0”s. The RV field may be used to indicate adaptation of one or multiple common beams. The codepoint value of the RV field may be mapped to one or a subset of the TCI states activated by the MAC-CE for the common beam operation. The MCS field may be set to a specific value, e.g., all “0”s. The MCS field may be used to indicate adaptation of one or multiple common beams. The codepoint value of the MCS field may be mapped to one or a subset of the TCI states activated by the MAC-CE for common beam operation. The FDRA field may be set to specific values based on the configured FDRA type e.g., all “1”s or all “0”s as specified in, for example, the 3GPP TS 38.213 V16.2.0. All “0”s may mean that each bit in the field is set to “0”, and all “1”s may mean that each bit in the field is set to “1”.

[0070] The UE may validate a common beam indication signaling in a similar manner as for validating a DL SPS or a UL CG type 2 scheduling activation when the UE is provided a single/multiple SPS configuration(s) or UL grant type 2 configuration(s) in an active DL/UL BWP of the scheduled cell of a DCI signaling. The UE may validate a common beam indication signaling when receiving the DCI with field(s) set/indicated as at least one of the following (a)-(c).

[0071] (a) The new data indicator field in the DCI format for enabled TB may be set to a specific value, e.g., “0.”

[0072] (b) The DFI flag field, if present, in the DCI format may be set to a specific value, e.g., “0.”

[0073] (c) The HPN field and/or the RV field may be set to specific values. The HPN field may be set to a specific codepoint, e.g., all “0”s. The HPN field may be used to indicate adaptation of one or multiple common beams. The codepoint value of the HPN field may be mapped to one or a subset of the TCI states activated by the MAC-CE for the common beam operation. The RV field may be set to a specific codepoint, e.g., all “0”s. The RV field may be used to indicate adaptation of one or multiple common beams. The codepoint value of the RV field may be mapped to one or a subset of the TCI states activated by the MAC-CE for the common beam operation. All “0”s may mean that each bit in the field is set to “0”, and all “1”s may mean that each bit in the field is set to “1”.

[0074] For mapping a DCI field codepoint to one or a subset of the MAC-CE activated TCI states, the codepoint may be a bit map that maps to the MAC-CE activated TCI states. Individual bits may correspond to individual activated TCI state position. More than one activated TCI states may be

indicated by the bit map. A specific TCI state position may include more than one activated TCI states. For mapping a DCI field codepoint to one or a subset of the MAC-CE indicated TCI states, the codepoint may be mapped to one or multiple TCI states. The codepoint may indicate a specific TCI state position in the MAC-CE. A specific TCI state position may include more than one activated TCI states.

[0075] The DCI format for common beam indication may indicate more than one common beam. Individual common beams may be mapped to transmissions/receptions related to individual TRPs in a (pre-)configured/(pre-)specified manner. The first (indicated/specified) common beam may be applied for transmissions/receptions related to the first TRP. The second (indicated/specified) common beam may be applied for transmissions/receptions related to the second TRP. The first/second TRP may be determined by index associated with the TRP, e.g., *CORESETPoolIndex*, or TRP index. The first TRP may be associated with a TRP with the lowest TRP index, and the second TRP may be associated with a TRP with the second lowest TRP index. Individual common beams may be mapped to transmissions/receptions related to individual UE panels in a (pre-)configured/(pre-)specified manner. The first (indicated/specified) common beam may be applied for transmissions/receptions related to the first UE panel. The second (indicated/specified) common beam may be applied for transmissions/receptions related to the second UE panel. The first/second UE panel may be determined by index associated with a panel, e.g., panel index. The first UE panel may be associated with a panel with the lowest panel index, and the second UE panel may be associated with a panel with the second lowest panel index. The panel index may be associated with the SRS resource set index.

[0076] There may be one or more (additional) field for identifying the common beam indication in the DCI format. There may be a combination of one or more (additional) field indicating one or more specific values for identifying the common beam indication in the DCI format. The DCI format(s) may be the DL DCI format(s) or the UL DCI format(s). The DL DCI format(s) may be applied for the joint DL/UL common beam indication. The DL DCI format(s) may be applied for the DL common beam indication in the separate DL/UL common beam operation. The UL DCI format(s) may be applied for the UL common beam indication in the separate DL/UL common beam operation. For separate DL/UL common beam indication, one DCI signaling may be used for indicating only one of DL and UL common beam update.

[0077] Acknowledgement of successful reception of the common beam indication may ensure common understanding on the communication means taken by the gNB and the UE. Since the indicated common beam(s) may be applied for reception/transmission for multiple times, the penalty of not receiving common beam indication correctly is larger compared with the beam indication for PDSCH in 3GPP NR Rel-15/16. Following the 3-step common beam indication framework, an

acknowledgement signaling may reuse the feedback procedure as specified in e.g., the 3GPP TS 38.213 V16.2.0 and/or the 3GPP TS 38.321 V16.2.0, but with modification.

[0078] The feedback confirmation for the DL scheduling may be performed by the HARQ-ACK feedback by the UE. While the DL reception may trigger the HARQ-ACK feedback, the motivation and thus the decisioning on ACK/NACK bits may not be the same for different types of receptions. For DG/SPS PDSCH, a HARQ-ACK bit may indicate the decoding state of the scheduled PDSCH. For SPS PDSCH release DCI, it may ensure the common understanding between the gNB and the UE by acknowledging reception of such release command. The feedback confirmation for the UL scheduling, on the other hand, may be performed by the UL MAC-CE feedback by the UE. The MAC-CE confirmation message may be included in data channel, e.g., PUSCH, based on dynamically scheduled or pre-configured UL resources.

[0079] The HARQ-ACK bit may be applied as an acknowledgement for the common beam indication. The HARQ-ACK bit may be included in a HARQ-ACK codebook, and be transmitted to the gNB via the PUSCH or the PUCCH by the UE. Both ACK and NACK may be used as an acknowledgement. The DTX may be used for indicating missed reception of the common beam indication by the UE. The HARQ-ACK bit applied for acknowledgement for the common beam indication may be associated with DCI or a PDSCH. The PDSCH may be a DG PDSCH. The PDSCH may be a SPS PDSCH. The DCI may be a modified or newly-interpreted version of the SPS PDSCH activation/release DCI or the CG type 2 PUSCH activation release DCI. The HARQ-ACK bit may correspond to successful reception of more than one common beams in one common beam indication.

[0080] The HARQ-ACK bit(s) as an acknowledgement for the common beam indication may be applied for the joint DL/UL common beam operation. The HARQ-ACK bit(s) as an acknowledgement for the common beam indication may be applied for the DL common beam indication in the separate DL/UL common beam operation. The HARQ-ACK bit(s) as an acknowledgement for common beam indication may be applied for UL common beam indication in the separate DL/UL common beam operation. The HARQ-ACK bit(s) as an acknowledgement for the common beam indication may be (extra) bits attached or inserted to existing HARQ-ACK codebook(s) (e.g., the HARQ-ACK codebook(s) as specified in the 3GPP TS 38.213 V16.3.0). The (extra) bits may be attached at a specific position of the HARQ-ACK codebook(s). For example, the (extra) bits may be attached at the ending parts of the HARQ-ACK codebook(s). That is, the (extra) bits may be the Least Significant Bit (LSB) bits of the HARQ-ACK codebook(s). The (extra) bits may be attached at a specific position of the HARQ-ACK codebook(s) corresponding to a TRP. For example, the (extra) bits may be attached at the ending parts of the HARQ-ACK codebook(s) corresponding to a TRP. That is, the (extra) bits may be the Least Significant Bit (LSB) bits of the HARQ-ACK codebook(s) corresponding to a TRP. The

HARQ-ACK bit(s) as an acknowledgement for the common beam in a HARQ-ACK codebook may be only one bit. The UE may not include/attach more than one HARQ-ACK bit as an acknowledgement for the common beam in a HARQ-ACK codebook. For a common beam indication applied for a TRP, the HARQ-ACK bit(s) as an acknowledgement for the common beam in a HARQ-ACK codebook may be only one bit. For a common beam indication applied for a TRP, the UE may not include/attach more than one HARQ-ACK bit as an acknowledgement for the common beam in a HARQ-ACK codebook.

[0081] A MAC-CE confirmation message may be used as an acknowledgement for the common beam indication. The MAC-CE confirmation message may be identified by a Logical Channel ID (LCID). The confirmation message may have a fixed size of zero bit. The confirmation message having a fixed size of zero bit may be applied for all common beam operation modes in s-TRP case. The confirmation message may have a fixed/variable size of non-zero bits. The confirmation message having a fixed/variable size of non-zero bits may be applied for the separate DL/UL common beam operation. There may be a field in the confirmation message for indicating either DL common beam or UL common beam is acknowledged. The confirmation message having a fixed/variable size of non-zero bits may be applied when more than one common beam is operating or is indicated in one indication. The confirmation message having a fixed/variable size of non-zero bits may be applicable in the joint DL/UL common beam operation or in the separate DL/UL common beam operation. The indication field in the confirmation message having a fixed/variable size of non-zero bits may simply indicate successful reception of a common beam indication, where the common beam indication may include more than one common beams. The indication field(s) in the confirmation message having a fixed/variable size of non-zero bits may indicate successful reception of more than one common beam individually in a common beam indication, where the common beam indication may include more than one common beam.

[0082] There may be only one common beam in the joint DL/UL beam operation for at least one serving cell. There may be only one common beam in the joint DL/UL beam operation for a TRP in at least one serving cell. There may be only one DL common beam in the separate DL/UL beam operation for at least one serving cell. The MAC-CE confirmation message may acknowledge the reception of the DL common beam indication for the at least one serving cell. There may be only one UL common beam in the separate DL/UL beam operation for at least one serving cell. The MAC-CE confirmation message may acknowledge the reception of the UL common beam indication for the at least one serving cell. There may be only one DL common beam in the separate DL/UL beam operation for a TRP in at least one serving cell. The MAC-CE confirmation message may acknowledge the reception of the DL common beam indication for the TRP in the at least one serving cell. There may be only one

UL common beam in the separate DL/UL beam operation for a TRP in at least one serving cell. The MAC-CE confirmation message may acknowledge the reception of the UL common beam indication for the TRP in the at least one serving cell. The DCI for common beam indication may be a modified version of the SPS PDSCH activation/release DCI and/or the CG type 2 PUSCH activation/release DCI. The MAC-CE confirmation may carry/indicate information for one or more serving cells. All or some of the one or more serving cells indicated in the MAC-CE confirmation may be configured with the CG configuration. The carried/indicated information may be at least one of the following types (a)-(c), where the type of the carried/indicated information may not be the same across all the one or more serving cells indicated in the MAC-CE. (a) Confirmation of CG activation/release; (b) Confirmation of common beam indication; and (c) Confirmation of both CG activation (or release) and common beam indication.

[0083] The UL power control for the PUCCH transmission may depend on the number of Uplink Control Information (UCI) bits carried in a PUCCH. The UCI bits may include HARQ-ACK bits (O_{ACK}), Scheduling Request (SR) bits (O_{SR}), and Channel State Information (CSI) bits (O_{CSI}). In a case that the number of the UCI bits ($O_{ACK} + O_{SR} + O_{CSI}$) ≤ 11 , the UE may determine another number of HARQ-ACK bits ($n_{HARQ-ACK}$), which may be applied for the power control purpose for the PUCCH transmission. The HARQ-ACK bits (O_{ACK}) may include the (extra) bits for the acknowledgement for the common beam indication.

[0084] If none of serving cells are configured to perform code block group (CBG)-based HARQ operation, or for PDSCH receptions scheduled by a DCI format that does not support CBG-based PDSCH receptions, or for SPS PDSCH reception, or for SPS PDSCH release, or for a DCI format that provides the common beam indication without resource allocation, and if the number of UCI bits is less than or equal to 11, the value of the HARQ-ACK bits ($n_{HARQ-ACK}$) may be determined for deriving the UL power for the PUCCH transmission. Such implementation for deriving the UL power for the PUCCH transmission may be applicable for HARQ Type1 (semi-static) and Type 2 (dynamic) codebook. For example, for dynamic codebook, the value of the HARQ-ACK bits ($n_{HARQ-ACK}$) may be determined based on Equation 1. Equation 1 is based on the formulation in 3GPP NR Rel-15/16, for example, as specified in the 3GPP TS 38.213 V16.4.0, but with the definition of the parameters modified as detailed below.

[0085]
$$n_{HARQ-ACK} = n_{HARQ-ACK,TB} = \left(\left(V_{DAI,M_{last}}^{DL} - \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} \right) \bmod 4 \right) N_{TB,max}^{DL} +$$

$$\sum_{c=0}^{N_{cells}^{DL}-1} \left(\sum_{m=0}^{M-1} N_{m,c}^{received} + N_{SPS,c} \right) \quad (\text{Equation 1}), \text{ where:}$$

[0086] N_{cells}^{DL} is the number of serving cells configured by higher layers for the UE.

[0087] M is the cardinality of a set of PDCCH monitoring occasions for PDCCH with a DCI format scheduling PDSCH receptions or SPS PDSCH release or optionally a DCI format that provides common beam indication without resource allocation across active DL BWPs of configured serving cells for which a UE transmits HARQ-ACK information in a same PUCCH in slot n . The PDCCH monitoring occasions may be ordered in ascending order of start time of the search space set associated with a PDCCH monitoring occasion.

[0088] If $N_{\text{cells}}^{DL} = 1$, $V_{DAI,M_{last}}^{DL}$ is the value of the counter Downlink Assignment Index (DAI) in the last valid DCI format scheduling PDSCH reception or indicating SPS PDSCH release or optionally indicating the common beam indication without resource allocation for any serving cell c that the UE detects within the M PDCCH monitoring occasions.

[0089] If $N_{\text{cells}}^{DL} > 1$ and the UE does not detect any DCI that includes a total DAI field in a last PDCCH monitoring occasion within the M PDCCH monitoring occasions where the UE detects at least one DCI format scheduling PDSCH reception or indicating SPS PDSCH release or optionally indicating common beam indication without resource allocation for any serving cell c , $V_{DAI,M_{last}}^{DL}$ is the value of the counter DAI in a last valid DCI format the UE detects in the last PDCCH monitoring occasion.

[0090] If $N_{\text{cells}}^{DL} > 1$, and the UE detects at least one DCI format that includes a total DAI field in a last PDCCH monitoring occasion within the M PDCCH monitoring occasions where the UE detects at least one DCI format scheduling PDSCH reception or indicating SPS PDSCH release or optionally indicating the common beam indication without resource allocation for any serving cell c , $V_{DAI,M_{last}}^{DL}$ is the value of the total DAI in the at least one DCI format that includes a total DAI field.

[0091] $V_{DAI,m_{last}}^{DL} = 0$ if the UE does not detect any DCI format scheduling PDSCH reception or indicating SPS PDSCH release or optionally indicating the common beam indication without resource allocation for any serving cell c in any of the M PDCCH monitoring occasions.

[0092] $U_{DAI,c}$ is the total number of a DCI format scheduling PDSCH receptions or indicating SPS PDSCH release or optionally indicating the common beam indication without resource allocation that the UE detects within the M PDCCH monitoring occasions for serving cell c . $U_{DAI,c} = 0$ if the UE does not detect any DCI format scheduling PDSCH reception or indicating SPS PDSCH release or optionally indicating the common beam indication without resource allocation for serving cell c in any of the M PDCCH monitoring occasions.

[0093] $N_{TB,max}^{DL} = 2$ if the value of the parameter *maxNrofCodeWordsScheduledByDCI* provided from higher layers is 2 for any serving cell c and the parameter *harq-ACK-SpatialBundlingPUCCH*

is not provided; otherwise, $N_{TB,max}^{DL} = 1$.

[0094] $N_{m,c}^{received}$ is the number of transport blocks the UE receives in a PDSCH scheduled by a DCI format that the UE detects in PDCCH monitoring occasion m for serving cell c if the parameter *harq-ACK-SpatialBundlingPUCCH* is not provided, or the number of PDSCH scheduled by a DCI format that the UE detects in PDCCH monitoring occasion m for serving cell c if the parameter *harq-ACK-SpatialBundlingPUCCH* is provided, or the number of DCI format that the UE detects and indicate SPS PDSCH release or optionally indicating the common beam indication without resource allocation in PDCCH monitoring occasion m for serving cell c .

[0095] $N_{SPS,c}$ is the number of SPS PDSCH receptions by the UE on serving cell c for which the UE transmits corresponding HARQ-ACK information in the same PUCCH as for HARQ-ACK information corresponding to PDSCH receptions within the M PDCCH monitoring occasions.

[0096] When counting the number of DCI format received, the DCI format(s) used for indicating the common beam indication without (DL and/or UL) resource allocation may be (additionally) counted. Such implementation may be applicable to semi-static codebook case, and to the case when CBG-based HARQ operation is applied/configured. Such implementation may be applicable to the m-TRP case or to the case where more than one common beam is indicated/operating. In a case that more than one TRP is considered in a serving cell, all DCI formats indicating the common beam indication without resource allocation from all TRPs may need to be counted. The acknowledge bits for the common beam indication may be considered by the UE when determining parameters or values associated with the UL power control.

[0097] In 3GPP NR Rel-15, the link recovery (e.g., Beam Failure Recovery (BFR)) for special cells (e.g., Primary Cell, Primary Secondary Cell) is supported. In 3GPP NR Rel-16, the link recovery for SCells was introduced as well. The link recovery may include the following four steps (a)-(d).

[0098] (a) Beam Failure Detection (BFD): A beam failure event of a BWP of a serving cell may be detected based on implicitly or explicitly configured BFD reference signal (RS).

[0099] (b) New beam identification (NBI): An alternative beam for recovering a link that is detected as beam failure may be identified based on configured RSs.

[00100] (c) Beam Failure Recovery reQuest (BFRQ) transmission: The information needed for recovering the link may be delivered by BFRQ transmission. The BFRQ transmission may be a Physical Random Access Channel (PRACH)-based transmission for special cells or a PUSCH-based transmission (carried in the MAC-CE) for SCells.

[00101] (d) gNB response reception for completing the link recovery by the UE: For special cells, the UE may monitor PDCCH transmission on a dedicatedly configured search space to determine if

BFRQ is successfully received by the gNB or not. For SCells, the UE may monitor an UL DCI (PDCCH) transmission which indicates the same HARQ process ID as the HARQ process ID used for the BFRQ PUSCH transmission but with a toggled NDI field.

[00102] In 3GPP NR Rel-17, the multi-TRP scenario may be extended for DL control channel, i.e., PDCCH. Details on how to derive BFD RS(s) implicitly need to be devised. In 3GPP NR Rel-15/16, the QCL assumption for a transmission may be indicated via the TCI state. For PDCCH reception, a set of candidate TCI states may be RRC configured to a CORESET, with a number constraint *maxNrofTCI-StatesPDCCH*. Among the set of candidate TCI states, one TCI state may be activated for the CORESET by the MAC-CE signaling. FIG. 1 is a schematic diagram illustrating an MAC-CE format 100 with a fixed size of 16 bits that is used for activating a TCI state for a CORESET according to an example implementation of the present disclosure. The MAC-CE format 100 may include fields of Serving Cell ID 110, CORESET ID 120 and TCI State ID 130. In the following, the fields of the Serving Cell ID 110, the CORESET ID 120 and the TCI State ID 130 are described.

[00103] Serving Cell ID 110: This field indicates the identity of the Serving Cell for which the MAC-CE applies. The length of the field is 5 bits.

[00104] CORESET ID 120: This field indicates a CORESET identified with the parameter *ControlResourceSetId* as specified in e.g., the 3GPP TS 38.331 V16.2.0, for which the TCI state is indicated. In a case that the value of the field is 0, the field may refer to the CORESET configured by the parameter *controlResourceSetZero* as specified in e.g., the 3GPP TS 38.331 V16.2.0. The length of the field is 4 bits.

[00105] TCI State ID 130: This field indicates the TCI state identified by the parameter *TCI-StateId* as specified in e.g., the 3GPP TS 38.331 V16.2.0 applicable to the CORESET identified by CORESET ID field. If the field of CORESET ID is set to 0, this field indicates a parameter *TCI-StateId* for a TCI state of the first 64 TCI-states configured by the parameters *tcI-States-ToAddModList* and *tcI-States-ToReleaseList* in the *PDSCH-Config* in the active BWP. If the field of CORESET ID is set to the other value than 0, this field indicates a parameter *TCI-StateId* configured by parameters *tcI-StatesPDCCH-ToAddList* and *tcI-StatesPDCCH-ToReleaseList* in the *controlResourceSet* identified by the indicated CORESET ID. The length of the field is 7 bits.

[00106] In 3GPP NR Rel-15/16, the BFD RS, which is used for detecting a beam failure condition, may be either explicitly configured or implicitly configured. The explicit configuration of BFD RS(s) may be based on explicit RRC signaling. The implicit configuration may take place when the BFD RS(s) is not explicitly configured. For the implicit configuration, the UE may determine the BFD RS(s) by including the RS(s) in the RS sets indicated by the TCI state for respective CORESET that the UE uses for monitoring the PDCCH. If there are two RS indexes in a TCI state, the RS with the QCL-

TypeD configuration for the corresponding TCI state may be included. Based on current 3GPP specifications (e.g., the 3GPP TS 38.213 V16.3.0), up to 2 BFD RSs may be explicitly configured for a BWP. In 3GPP NR Rel-15, up to 3 CORESETs per BWP may be configured while in 3GPP NR Rel-16 multi-PDCCH based multi-TRP transmission, up to 5 CORESETs per BWP may be configured. For implicit BFD RS selection, there may be no specified rule for selecting BFD RS(s) when the number (e.g., 3) of PDCCH TCI states (each TCI state corresponds to a CORESET within a concerned BWP) is larger than the number (e.g., 2) of BFD RS to be selected. The implicit BFD RS selection may be determined based on the UE implementation.

[00107] The implicit BFD RS configuration may be applicable to beam failure recovery for either special cell(s) or for SCell(s). The Radio Link Monitoring (RLM) RS(s) may be determined implicitly as well, when the RLM RS(s) is not explicitly configured. For the implicit RLM RS configuration, the RLM RS(s) may be selected based on PDCCH reception TCI states. When there are more PDCCH TCI states than the number of RLM RS to be selected, the following Method#A selection rule may be applied. Method#A selection rule: The UE may select the required number of the RS provided for the active TCI states for the PDCCH receptions in the CORESETs associated with the search space sets in an order from the shortest monitoring periodicity. If more than one CORESETs are associated with search space sets having same monitoring periodicity, the UE may determine the order of the CORESET from the highest CORESET index as specified in the 3GPP TS 38.213. If the active TCI state for the PDCCH reception includes two RSs, one RS may have QCL-TypeD and the UE may use the RS with QCL-TypeD for radio link monitoring.

[00108] FIG. 2 is a schematic diagram illustrating an association of one TCI codepoint 210 with two TCI states 220, 230 according to an example implementation of the present disclosure. In 3GPP NR Rel-16, the multi-TRP techniques may be applied for the PDSCH for improved reliability and robustness targeting at fulfilling URLLC requirements. As one of multi-TRP features, a codepoint in the TCI field in a DL DCI format may indicate up to 2 TCI states for the PDSCH scheduling, as illustrated in FIG. 2. When one TCI codepoint 210 is associated with 2 TCI states 220, 230, the QCL assumptions indicated by both TCI states 220, 230 may be applied for the PDSCH reception from the UE perspective. The association of TCI codepoints 210 with TCI states 220, 230 may be signaled by the MAC CE signaling.

[00109] For PDCCH reliability and robustness, the PDCCH transmission may adopt similar Spatial Division Multiplexing (SDN) or Single Frequency Network (SFN) approach, that is, the DCI transmission may be received by the UE by applying multiple QCL assumptions. The transmission from individual QCL assumptions may be performed by different TRPs. This leads to the possibility

of TRP-specific BFR, that is, (control) channel links from individual TRPs may be maintained/recovered by individual BFR procedure or two sub-procedure under a BFR procedure. From gNB perspective, as long as information provided in BFRQ may indicate which TRP is related to a degrading (control) channel link, subsequent steps in a BFR procedure may be performed to recover the link.

[00110] For TRP-specific BFR procedure, the UE may need to be able to learn which TRP is related to a degrading (control) channel link, so that a BFR procedure corresponding to the TRP can be triggered. The following two approaches (a) and (b) may be considered.

[00111] (a) Individual sets of BFD RS(s) for individual BFR procedures may be provided. That is, each TRP-specific BFR may be provided with their individual BFD RS sets. When channel quality of all or a subset of RS(s) in a BFD RS set falls below a specific threshold, a corresponding BFR procedure may be triggered. When the BFD RS is implicitly configured and a CORESET is provided with more than one activated TCI states, a rule for selecting/deciding BFD RS for each TRP-specific BFR procedure corresponding to the 2-TCI-state CORESET may be needed.

[00112] (b) Alternative approach is devised based on the observation that (control) channel quality corresponding to a 2-TCI-state CORESET degrades when links correspond to both TRPs are failing. In this situation, there may not be need for differentiating BFD RS(s) for different TRP-specific BFR procedures. Instead, a UE simply needs to have a rule to decide which TRP-specific BFR procedure(s) to trigger after deciding that beam failure associated with the channel quality of the 2-TCI-state CORESETs (optionally, and other related CORESET(s) of the beam failure detection) is detected.

[00113] The Beam failure procedure (BFR) is devised to quickly recover failed link between a UE and a Base Station (BS) node, especially for vulnerable beamformed transmission in higher frequency, e.g., Frequency Range 2 (FR2), where wireless channel characteristics is less favorable for reliable transmission. Based on the BFR procedure, a set of BFD RSs may be defined. The BFD RSs may be monitored to derive a hypothetical PDCCH channel quality. If the quality is lower than a specific threshold, the beam failure detection may be declared. Upon the BFD, the UE may indicate the BS of new beam(s) for link recovery. Such message may be termed Beam Failure Recovery request (BFRQ). The BFRQ may be transmitted based on PRACH channel and/or MAC-CE based message. Both contention-based and contention-free PRACH may be used for the BFRQ transmission, for special cells. In PRACH-based approach, new beam information may be implicitly carried in the selected PRACH resource. For MAC-CE based solution, more information may be carried, and the information may include new beam(s), failed serving cell identity etc. Upon delivery of the BFRQ, the UE may expect BS response to confirm the reception of BFRQ. Once BFRQ is confirmed properly received by BS response, the UE may apply the new beam(s) for DL reception in a pre-specific manner.

[00114] When more than 1 TRP is provided to the UE, the TRPs may be intra-cell TRPs or maybe inter-cell TRPs. Two TRPs residing within a same serving cell, thus showing a same Physical Cell Identity (PCI) may be considered intra-cell TRPs. Two TRPs residing in different serving cell, thus showing different PCI may be considered inter-cell TRPs. Specifically, the TRP-specific BFR procedure may address a scenario where $N > 1$ TRPs may be configured in a same serving cell or configured to serve a same serving cell. Among the N TRPs, $M (\leq N)$ TRPs may be provided with the BFR procedures individually. The total number of TRPs configured to a UE may be more than N . The TRP-specific BFR procedure may include at least one of the following features (a)-(c).

[00115] (a) More than one TCI state may be activated for a CORESET. In some implementations, two TCI states may be activated for a CORESET. In some implementations, the UE may be provided/configured with 2-TCI-state CORESET(s) and 1-TCI-state CORESET(s) at the same time. In some implementations, 2-TCI-state CORESET(s) and 1-TCI-state CORESET(s) may be configured to be associated with search space(s). The 1-TCI-state CORESET may stand for a CORESET with 1 activated TCI state.

[00116] (b) A UE may transmit BFRQ indicating beam failure detection of a TRP or a serving cell towards a gNB. The gNB may provide response to indicate successful reception of the BFRQ. After receiving gNB reception, a new beam (q_new) indicated by the UE in the BFRQ information may be applied for PDCCH reception by the UE before further TCI state update for configured CORESETs.

[00117] (c) A TCI state may be provided with information for identifying a cell and/or a TRP.

[00118] For beam failure detection purpose, the number of the BFD RS may be upper limited, e.g., two BFD RSs per BWP, and the number of the BFD RS may be smaller than the total number of TCI states for PDCCH monitoring over all related CORESET(s). The related CORESETs may be the CORESETs configured for a concerned active BWP. When the BFD RS is to be determined implicitly from the PDCCH reception TCI states/QCL assumption(s), down selection on the TCI states may be needed. When an active TCI state for PDCCH reception includes two reference signals, the UE may assume that one RS has QCL-TypeD and the UE may use the QCL-TypeD RS as BFD RS, if the active TCI state is selected for beam failure detection purpose. Furthermore, for TRP-specific BFR procedure, how to associate a detected beam failure with a set of BFR procedures may need to be determined, especially in implicit BFD RS configuration case. For such purpose, the following (a) and (b) may be considered.

[00119] (a) Individual sets of BFD RS(s) for individual BFR procedures may be decided. When BFD RS (set) is implicitly configured/determined and at least a CORESET is provided with more than one activated TCI states, a rule for selecting/deciding BFD RS for each TRP-specific BFR procedure

corresponding to the 2-TCI-state CORESET may be applied.

[00120] (b) The TRP-specific BFR procedure(s) which should be triggered may be decided after deciding that beam failure associated with the channel quality of a 2-TCI-state CORESETs (optionally, and other related CORESET(s) of the beam failure detection) is detected.

[00121] In 3GPP NR Rel-15/16, a BFR procedure may be configured to a UE in a per serving cell manner. When more than one TRP is provided to the UE, the TRPs may be intra-cell TRPs or maybe inter-cell TRPs. The TRP-specific BFR procedure may address a scenario where $N > 1$ TRPs are configured in a same serving cell and among the N TRPs, $M (\leq N)$ TRPs are provided with the BFR procedures individually. The total number of TRPs configured to a UE may be more than N . The quality between a UE and a TRP may be determined by performing measurements on a set of RSs. The set of RSs may be related to hypothetical PDCCH channel quality. From beam failure detection perspective, the set of RSs may be referred to as BFD RS set. The set may be explicitly configured or implicitly derived from the activated TCI state(s) for PDCCH monitoring. The TRP-specific BFR procedure may include at least one of the following features (a)-(c).

[00122] (a) More than one TCI state may be activated for receiving a CORESET. In some implementations, two TCI states may be activated for receiving a CORESET. In some implementations, the 2-TCI-state CORESET may be configured when at least one of the following conditions (a1) and (a2) is met. (a1) The UE is in a High Speed Train (HST) scenario. In some implementations, the indication of a 2-TCI-state CORESET may implicitly indicate the HST scenario. (a2) The UE is in a Single Frequency Network (SFN) scenario. In some implementations, when the 2-TCI-state CORESET is signaled to the UE, all CORESETs may be activated with the 2 TCI states. That is, all CORESETs may be 2-TCI-state CORESETs. When the 2-TCI-state CORESET is signaled/configured to the UE in a (active) DL BWP in a serving cell, all CORESETs at least in the (active) DL BWP in the serving cell may be activated with the 2 TCI states. In some implementations, the UE may be provided with 2-TCI-state CORESET(s) and 1-TCI-state CORESET(s) at the same time. The 1-TCI-state CORESET may stand for a CORESET with one activated TCI state for reception. The UE may be provided with the 2-TCI-state CORESET(s) and the 1-TCI-state CORESET(s), where both of them are associated with the monitored search space(s), in a (active) DL BWP in a serving cell.

[00123] (b) A UE may transmit BFRQ indicating beam failure detection of a TRP or a serving cell towards a gNB. The gNB may provide response to indicate successful reception of the BFRQ. After receiving the gNB reception, a new beam(s) q_new indicated by the UE in the BFRQ information may be applied for PDCCH reception by the UE before further TCI state update for configured CORESETs.

[00124] In some implementations, only 2-TCI-State CORESET(s) related to the TRP or the serving

cell may apply the new beam q_new . Only one TCI state of the 2-TCI-state CORESET(s) may be updated to the new beam q_new . Each of the two original TCI states of the 2-TCI-state CORESET(s) may correspond to respective link of a corresponding TRP. The corresponding TRP for each of the two original TCI states may be different. The TCI state corresponding to the TRP with failed link (the one with beam failure detection) may be updated by the new beam q_new . The TCI state(s) with a default position/order in the 2-TCI-state CORESET(s) may be updated to the new beam q_new . In some implementations, the default position/order may be the first/last one of the two TCI states of the 2-TCI-state CORESET(s). The position or order of TCI state for a CORESET may be observed or derived from a MAC-CE for activating TCI state(s) for receiving the CORESET. Both of the TCI states of the 2-TCI-state CORESET(s) may be updated to the new beam q_new . The new beam q_new may include two beams. When applying new beam q_new , both of the two beams may be applied for the 2-TCI-state CORESET(s).

[00125] In some implementations, only 1-TCI-state CORESET(s) related to the TRP or the serving cell may apply the new beam q_new . Only 1-TCI-state CORESET(s) associated with a TRP whose link is reported as beam failure in BFRQ may be updated to the new beam q_new . All 1-TCI-state CORESET(s) of the serving cell containing the TRP whose link is reported as beam failure in BFRQ may be updated to the new beam q_new . All 1-TCI-state CORESET(s) associated with the TRP whose link is reported as beam failure in BFRQ may be updated to the new beam q_new .

[00126] In some implementations, both 2-TCI-state CORESET(s) and 1-TCI-state CORESET(s) related to the TRP or the serving cell may apply the new beam q_new . The new beam q_new may include two beams. When applying new beam q_new , both of the two beams may be applied for the 2-TCI-state CORESET(s), and one of the two beams may be applied for the 1-TCI-state CORESET(s). When applying new beam q_new for a 2-TCI-state CORESET, the 2-TCI-state CORESET may fall back to 1-TCI-state CORESET. After fallback, there may be only one active TCI state, which is the new beam or reference signal index indicated by q_new , for the 2-TCI-state CORESET.

[00127] (c) A TCI state may be provided with information for identifying a cell and/or a TRP. The TCI state may be provided/associated with cell index and/or TRP index. For example, the PCI (physical cell index) and/or the parameter *CORESETPoolIndex* may be used as cell index and TRP index, respectively.

[00128] For multi-TRP based PDDCH reliability enhancement, a PDCCH may be monitored with multiple QCL assumptions (for reception), where individual QCL assumptions may be indicated by individual TCI states. For beam failure detection purpose, the number of BFD RS may be upper limited, e.g., two BFD RSs per BWP, and the number of BFD RS may be smaller than or equal to the total number of TCI states for PDCCH monitoring over all related CORESET(s). The related CORESETs

may be the CORESETs configured for a concerned active BWP. When the BFD RS is to be determined implicitly from the PDCCH reception TCI states, down selection on the TCI states may be needed. When an active TCI state for PDCCH reception includes two reference signals, the UE may assume that one RS has QCL-TypeD and the UE may use the QCL-TypeD RS as BFD RS, if the active TCI state is selected for beam failure detection purpose. A 2-TCI-state CORESET may be activated with two TCI states for PDCCH reception. Furthermore, for TRP-specific BFR procedure, how to associate a detected beam failure with a set of BFR procedures may need to be determined, especially in implicit BFD RS configuration case. For such down selection, the following (a) and (b) may be considered.

[00129] (a) Individual sets of BFD RS(s) for individual BFR procedures may be decided. When BFD RS is not configured or is implicitly configured, and when a CORESET is provided with more than one activated TCI states, a rule for selecting/deciding BFD RS for each TRP-specific BFR procedure corresponding to the 2-TCI-state CORESET may be applied.

[00130] (b) The TRP-specific BFR procedure(s) which should be triggered after deciding that beam failure associated with the channel quality of a 2-TCI-state CORESETs (optionally, and other related CORESET(s) of the beam failure detection) is detected.

[00131] In the following, the rules for the selection of a subset of RSs from PDCCH reception TCI states for beam failure detection purpose is described.

[00132] For a 2-TCI-state CORESET, the two active TCI states of the 2-TCI-state CORESET may be mapped to different sets of BFD RS sets. Each of the different sets of the BFD RS sets may correspond to different TRP-specific BFR procedures. Each of the TRP-specific BFR procedures may be applied for monitoring/recovering link between the UE and a corresponding TRP. For a 1-TCI-state CORESET, the active TCI state of the 1-TCI-state CORESET may be mapped to a specific set of BFD RS sets. Each of the BFD RS sets may correspond to different TRP-specific BFR procedures. Each of the TRP-specific BFR procedures may be applied for monitoring/recovering link between the UE and a corresponding TRP. The specific set may be determined based on the cell or TRP information provided in the active TCI state. The specific set may be a default set. The default set may be a first/last set among all TRP-specific BFR procedures in a serving cell. The all TRP-specific BFR procedures may not include a PRACH-based BFR procedure. The default set may be (pre-)configured or (pre-)specified.

[00133] The active TCI state(s) in CORESET(s) associated with the search space may set with shorter monitoring periodicity may be selected first. The active TCI state(s) in CORESET(s) associated with higher priority CORESET(s) may be selected first. The higher priority CORESETs may be based on the CORESET index. The lower-indexed (or higher-indexed) CORESET may have higher priority. The CORESET priority may be indicated by a base station signaling. When considering/determining

CORESET priority, the UE may (only) consider CORESET(s) associated with search space(s). The active TCI state(s) in CORESET(s) with higher or lower CORESET group ID (e.g., *CORESETPoolIndex*) may be selected first. A master CORESET group may be identified by e.g., CORESET group ID, and the active TCI state(s) associated with CORESET(s) in the master CORESET group may be selected first.

[00134] If there are multiple active TCI states in a CORESET, a default TCI state from the multiple active TCI states may be selected. The default TCI state may be preconfigured, or RRC configured, or pre-defined. The default TCI state may be as specified in the 3GPP TS 38.213 and the 3GPP TS 38.214. For example, the default TCI state may be the first (or last) one among the multiple active TCI states. The default TCI state may be the TCI state with lowest (or highest) *TCI-StateId* among the multiple active TCI states. A TCI state may be associated with a TCI state group index. The default TCI state may be the TCI state associated with a lowest (or highest) TCI state group index. In one implementation, each of the multiple active TCI states in the CORESET may be associated with different TCI state group indexes.

[00135] A TCI state may be associated with a TCI state group index. The PDCCH reception TCI state(s) associated with a lower (or higher) TCI state group index may be selected first. Each of the multiple active TCI states in a CORESET may be associated with different TCI state group indexes. An active TCI state whose QCL RS(s) corresponds to lower-indexed (or higher-indexed) serving cell(s) may be selected first. An active TCI state whose QCL RS(s) corresponds to an intra-band serving cell of the concerned serving cell may be selected first. The concerned serving cell may be the serving cell where beam failure detection is targeted for, based on the selected BFD RS. An active TCI state with lower (or higher) TCI stat ID (e.g., *TCI-StateId*) may be selected first. An active TCI state with shorter QCL RS(s) periodicity may be selected first. The active TCI states in CORESET(s) with multiple TCI states may be selected first (or last). The priority (i.e., first or last) may be configured by a base station signaling. The priority may be “first” to benefit multi-TRP case. The priority may be “last” to priority single-TRP operation. The selection of a subset of RSs from PDCCH reception TCI states for beam failure detection purpose may be based on the UE implementation.

[00136] It may be noted that when the above rules are applied, it may be further subject to an order for applying the subset of rules. In the following, some implementations are provided. It is further noted that while the rules are assumed to apply for implicit BFD RS selection, the rules may also be applied for enhancing implicit RLM RS selection.

[00137] Method#1: Two-stage BFD RS Selection

[00138] In Stage-1, for a CORESET with multiple active TCI states (e.g., a 2-TCI-state CORESET), one active TCI state may be selected from the multiple active TCI state. In Stage-2, a required number

of TCI states (which is equal to the number of BFD RS to be derived) may be selected from the remaining active TCI states (individual remaining active TCI states correspond to individual CORESETs). It may be noted that the steps of the Stage-1 and the Stage-2 may be applied for deriving a BFD RS set for a (TRP-specific) BFR procedure. In some implementations, the steps of the Stage-1 and the Stage-2 may be applied iteratively for deriving another BFD RS set for another (TRP-specific) BFR procedure. It may be noted that the remaining active TCI states may be TCI states selected in Stage-1.

[00139] Stage-1: For a CORESET with multiple active TCI states, one active TCI state for determining a BFD RS(s) (of a BFR procedure) may be selected. A default TCI state from the multiple active TCI states may be selected. The default TCI state may be preconfigured, or RRC configured, or pre-defined. The default TCI state may be as specified in the 3GPP TS 38.213 and the 3GPP TS 38.214. For example, the default TCI state may be the first (or last) one among the multiple active TCI states. The default TCI state may be the TCI state with lowest (or highest) *TCI-StateId* among the multiple active TCI states. The default TCI may be associated with a parameter *CORESETPoolIndex* of the CORESET. The parameter *CORESETPoolIndex* may be identified as master CORESET, which may further correspond to a master TRP. A TCI state may be associated with a TCI state group index. The default TCI state may be the TCI state associated with a lowest (or highest) TCI state group index. Each of the multiple active TCI states in the CORESET may be associated with different TCI state group indexes.

[00140] The Stage-1 may be performed for each one of CORESET(s) with multiple active TCI states. The Stage-1 may not be performed on each one of CORESET(s) with multiple active TCI states. The selection may be performed on CORESET(s) one-by-one if the total number of active TCI states is larger than the required number of BFD RS. When the remaining number of TCI states (including those from multiple-TCI-State CORESET(s) and from 1-TCI-State CORESET(s)) is equal or smaller than the required number of BFD RS, the selection may not be performed to remaining multiple-TCI-State CORESET(s). The selection of multiple-TCI-State CORESET(s) for down-selecting corresponding multiple TCI states may be based on CORESET index. The multiple-TCI-States CORESET with highest CORESET index may be selected for down-selection first.

[00141] Stage-2: If the total number of active TCI states in related CORESET(s) is still larger than the number of required BFD RS (e.g., the number is 2 in 3GPP NR Rel-15/16), the remaining TCI states may be down-selected to meet the required number of BFD RS. The remaining TCI states may originally correspond to multiple-TCI-State CORESET or correspond to 1-TCI-State CORESET. The down-selection may be based on the UE implementation. The remaining TCI states originally corresponding to multiple-TCI-State CORESET may be down-selected first. The remaining TCI states

originally corresponding to 1-TCI-State CORESET may be down-selected first. The Method#A selection rule when deriving RS from TCI states for PDCCH receptions may be reused for BFD RS derivation. The Method#A selection rule, with additional rule to prioritize certain CORESET group index or TCI state group index may be used for BFD RS derivation. In some implementations, the UE may select the required number of RS provided for active TCI states for PDCCH receptions in CORESETs associated with the search space sets in an order from the shortest monitoring periodicity. If more than one CORESETs are associated with search space sets having same monitoring periodicity, the UE may determine the order of the CORESETs (or TCI states) from e.g., the highest CORESET group index (or TCI state group index). A master CORESET group may be identified by e.g., CORESET group ID, and active TCI state(s) associated with the master CORESET group may be selected first. If more than one CORESETs (or TCI states) are associated with same CORESET group index (or TCI state group index), the UE may determine the order of the CORESETs (or TCI states) from e.g., the highest CORESET index (or TCI state index).

[00142] Method#2: Method#A-based rule

[00143] The Method#A selection rule when deriving RS from TCI states for PDCCH receptions may be used as baseline. On top of the Method#A selection rule, additional rules may be applied to take into account the fact that a CORESET may be activated with multiple TCI states. It may be noted that the Method#2 may be applied for deriving a BFD RS set for a (TRP-specific) BFR procedure. In some implementations, the Method#2 may be applied iteratively for deriving another BFD RS set for another (TRP-specific) BFR procedure. If more TCI states than needed remain after applying the Method#A rule, the TCI states with lower (or higher) TCI state index may be selected. If more TCI states than needed remain after applying the Method#A rules, the TCI states corresponding to intra-band serving cell of the concerned serving cell may be selected first. The concerned serving cell may be the serving cell where beam failure detection is targeted for, based on the selected BFD RS. If still too many, the TCI states with lower (or higher) TCI state index may be selected.

[00144] Method#3: Prioritizing CORESETs with multiple TCI states

[00145] The TCI states associated with CORESET(s) with multiple TCI states may be selected with (higher) priority. If the resultant number of TCI states is larger than the required number, further rules, e.g., Method#1 to Method #4 provided in the present disclosure, may be applied for down selection. If the resultant number of TCI states is smaller than the required number, the TCI states associated with 1-TCI-State CORESET(s) may be selected gradually also based on the rules, e.g., Method#1 to Method#4 provided in the present disclosure. It may be noted that the Method#3 may be applied for deriving a BFD RS set for a (TRP-specific) BFR procedure. In some implementations, the Method#3 may be applied iteratively for deriving another BFD RS set for another (TRP-specific) BFR procedure.

The TCI states associated with CORESET(s) with multiple TCI states may be selected. If the resultant number of TCI states is larger than the required number, a subset of the resultant TCI states above may be excluded so that the remaining number of TCI states meets the requirement. The exclusion principle may be based on the UE implementation. The exclusion principle may be based on the Method#2. If the resultant number of TCI states is smaller than the required number, additional TCI state(s) associated with CORESET(s) with 1 TCI state may be selected until a total number of selected TCI states meets the requirement. The selection may be based on the UE implementation. The selection may be based on Method#A selection rule. The selection may be limited to selecting 1-TCI-state CORESET(s) for BFD RSs. The selection may be limited to selecting 2-TCI-state CORESET(s) for BFD RSs.

[00146] Method#4: Prioritizing CORESET(s) with 1 TCI state

[00147] The TCI states associated with CORESET(s) with 1 TCI states may be selected with (higher) priority. If the resultant number of TCI states is larger than the required number, further rules, e.g., Method#1 to Method #4 provided in the present disclosure, may be applied for down selection. If the resultant number of TCI states is smaller than the required number, the TCI states associated with multiple-TCI-State CORESET(s) may be selected gradually based on the rules, e.g., Method#1 to Method #4 provided in the present disclosure, until the total number of TCI states meets a required number. It is noted that the Method#4 may be applied for deriving a BFD RS set for a (TRP-specific) BFR procedure. In some implementations, the Method#4 may be applied iteratively for deriving another BFD RS set for another (TRP-specific) BFR procedure. The TCI states associated with CORESET(s) with one TCI state may be selected. If the resultant number of TCI states is larger than the required number, a subset of the resultant TCI states may be excluded so that the remaining number of TCI states meets a required number. The exclusion principle may be based on the UE implementation. The exclusion principle may be based on the Method#A selection rule. If the resultant number of TCI states is smaller than the required number, additional TCI state(s) associated with CORESET(s) with multiple TCI states may be selected until a total number of selected TCI states meets the requirement. The selection may be based on the UE implementation. The selection may be based on the Method#2.

[00148] For TRP-specific BFR procedure, how to associate a detected beam failure with a set of BFR procedures may need to be determined, especially in implicit BFD RS configuration case. In some implementations, which TRP-specific BFR procedure(s) to trigger may need to be determined after deciding that beam failure associated with the channel quality of 2-TCI-state CORESET(s) (optionally, and other related CORESET(s) of the beam failure detection) is detected. In this situation, PDCCH channel quality associated with a CORESET may be jointly determined based on all of its

activated TCI states, irrespective of the fact that a CORESET may be activated with multiple TCI states and thus, may be associated with multiple TRPs.

[00149] For an active BWP, a UE may be configured with one or more CORESET(s). The CORESET(s) may include only 2-TCI-state CORESET, or may include both 1-TCI-state CORESET and 2-TCI-state CORESET.

[00150] For detection of beam failure, the activated TCI states of CORESET(s) associated with an active BWP may be used. The RS(s) from the activated TCI states may be used for beam failure detection. The QCL-typeD RS(s) from the activated TCI states may be used for beam failure detection. In a case that there is a threshold number of (BFD) RSs to be used for beam failure detection, the down-selection from the RS(s) from the activated TCI states of CORESET(s) may be needed. The resolution for selecting the RS(s) from the activated TCI states may be CORESET. That is, all QCL-typeD RS(s) of a CORESET may be selected as the BFD RS(s) when the CORESET is selected as performance metric for the beam failure detection. The CORESET may be considered as failed if both hypothetical block error rate (BLER) derived based on all QCL-typeD RS(s) is higher than a threshold value. The CORESET may be considered as failed if both hypothetical BLER derived based on all QCL-typeD RS(s) is higher than one or more threshold values, where each of QCL-typeD RS may be compared with different threshold values. Methods provided in the present disclosure, e.g., Method#1 to Method#4, may be applied, at least for determining (QCL-typeD) RS(s) as BFD RS(s) for beam failure detection. If all (QCL-typeD) RS(s) associated with the selected CORESET(s) indicates that their individual PDCCH channel quality is lower than a threshold (e.g., the BLER value is higher than a threshold value), the beam failure detection may be considered true for the active BWP.

[00151] More than one BFR procedure may be configured for the determined BFD RS(s). For example, two BFR procedures may be associated with the determined BFD RS(s). The determined BFD RS(s) may constitute a BFD RS set. After detection of beam failure, only one of the BFR procedures may be declared beam failure and its subsequent steps may be triggered for the beam failure recovery. The declared BFR procedure may be (pre-)specified/(pre-)configured. The declared BFR procedure may be determined based on the first/last activated TCI state of a 2-TCI-state CORESET. The TCI state may provide identity information related to a cell or a TRP. A BFR associated with the cell/TRP index of the first/last activated TCI state may be selected. The 2-TCI-state CORESET may be selected based on CORESET priority described in the present disclosure. The 2-TCI-state CORESET may be any one of 2-TCI-state CORESET(s) and thus, up to the UE implementation. In some implementations, using any of 2-TCI-state CORESET(s) for the BFR procedure selection may provide the same result. The selection of the BFR procedures may be based on UE's Doppler/mobility information. A BFR procedure associated with a cell/TRP with its Doppler/mobility information

showing the UE is e.g., approaching the cell/TRP, may be selected.

[00152] Only one BFR procedure may be configured for the determined BFR RS(s). Subsequent BFRQ information may be transmitted to the gNB by either the MAC-CE or by the configured UL resources of the BFR procedure. A new beam q_new information carried in the BFRQ information may be determined from a set of candidate RSs/beams provided in the BFR procedure configuration. The candidate RSs/beams may be associated with different cells/TRPs. The TCI state may provide identity information related to a cell or a TRP. The new beam q_new may be selected from the subset of candidate RSs/beams that is associated with the cell/TRP of the first/last activated TCI state of a 2-TCI-state CORESET. The 2-TCI-state CORESET may be selected based on CORESET priority described in the present disclosure. The 2-TCI-state CORESET may be any one of 2-TCI-state CORESET(s) and thus, up to the UE implementation. In some implementations, using any of 2-TCI-state CORESET(s) for the BFR procedure selection may provide the same result. A cell/TRP may be selected based on the UE's Doppler/mobility information. The new beam q_new may be selected from the subset of candidate RSs/beams that is associated with the selected cell/TRP.

[00153] In some implementations, the methods provided in the present disclosure may be applied to a CORESET or at least a DL channel, which is indicated/activated to receive more than one TCI states (or QCL assumptions). It may imply that a CORESET with 3 TCI states to receive may be applicable.

[00154] FIG. 3 is a flowchart illustrating a method 300 performed by a UE for beam operation according to an example implementation of the present disclosure. Although actions 302, 304, 306, 308, 310, 312 and 314 are illustrated as separate actions represented as independent blocks in FIG. 3, these separately illustrated actions should not be construed as necessarily order dependent. The order in which the actions are performed in FIG. 3 is not intended to be construed as a limitation, and any number of the disclosed blocks may be combined in any order to implement the method, or an alternate method. Moreover, each of actions 302, 304, 306, 308, 310, 312 and 314 may be performed independent of other actions and can be omitted in some implementations of the present disclosure.

[00155] In action 302, the UE may receive, a radio resource control (RRC) configuration for configuring at least one of a first set of first Transmission Configuration Indication (TCI) states, a second set of second TCI states and a third set of third TCI states. The first TCI states may be referred to as joint TCI states. The second TCI states may be referred to as uplink (UL)-only TCI states. The third TCI states may be referred to as downlink (DL)-only TCI states.

[00156] In action 304, the UE may receive, a medium access control (MAC)-control element (CE) for activating a first TCI state combination or a second TCI state combination. The first TCI state combination may include at least one of the first TCI states, and the second TCI state combination may

include at least one of the second TCI states and the third TCI states. That is, the first TCI state combination may include at least one first TCI state. The second TCI state combination may include only at least one second TCI state. The second TCI state combination may include only at least one third TCI state. The second TCI state combination may include at least one second TCI state and at least one third TCI state.

[00157] In action 306, the UE may map, based on the first TCI state combination or the second TCI state combination activated by the MAC CE, the first TCI state combination or the second TCI state combination to codepoints of a TCI field in downlink control information (DCI).

[00158] In action 308, the UE may receive, the DCI for indicating the at least one of the first TCI states, the second TCI states and the third TCI states included in the first TCI state combination or the second TCI state combination activated by the MAC-CE. That is, if the first TCI state combination is activated by the MAC-CE, the DCI may indicate the at least one first TCI state included in the first TCI state combination which is activated by the MAC-CE. If the second TCI state combination is activated by the MAC-CE and the second TCI state combination includes only the at least one second TCI state, the DCI may indicate the at least one second TCI state included in the second TCI state combination which is activated by the MAC-CE. If the second TCI state combination is activated by the MAC-CE and the second TCI state combination includes only the at least one third TCI state, the DCI may indicate the at least one third TCI state included in the second TCI state combination which is activated by the MAC-CE. If the second TCI state combination is activated by the MAC-CE and the second TCI state combination includes the at least one second TCI state and the at least one third TCI state, the DCI may indicate the at least one second TCI state and the at least one third TCI state included in the second TCI state combination which is activated by the MAC-CE. The DCI may include a scheduling field for indicating scheduling information for a physical downlink shared channel (PDSCH). In some implementations, each bit in at least one field in the DCI is set to "0" or "1", and the at least one field may be different from the TCI field and the scheduling field. That is, the at least one field other than the TCI field and the scheduling field in the DCI may be set to a specific value, and the specific value may be one of all 0's or all 1's.

[00159] In action 310, the UE may transmit, in response to the reception of the DCI, a first Hybrid Automatic Repeat Request-Acknowledgement (HARQ-ACK) bit.

[00160] In action 312, the UE may transmit, after determining that bit value in the scheduling field is valid for scheduling the PDSCH, a second HARQ-ACK bit. In some implementations, the bit value in the scheduling field may be invalid for scheduling the PDSCH.

[00161] In action 314, the UE may apply, after transmitting the first HARQ-ACK bit, the at least one of the first TCI states, the second TCI states and the third TCI states indicated by the DCI for

transmission or reception. In some implementations, the UE may apply, after determining that the DCI format indicates the first TCI states, receiver (RX) parameters for receiving one or more configured downlink (DL) transmissions and transmitter (TX) parameters for transmitting one or more configured uplink (UL) transmissions, and the first TCI states may include the RX parameters and the TX parameters. In some implementations, the UE may apply, after determining that the DCI format indicates the second TCI states, transmitter (TX) parameters for transmitting one or more configured uplink (UL) transmissions, and the second TCI states may include the TX parameters. In some implementations, the UE may apply, after determining the DCI format indicates the third TCI states, receiver (RX) parameters for receiving one or more configured downlink (DL) transmissions, and the third TCI states may include the RX parameters.

[00162] In the present disclosure, several methods for enabling common beam indication and its acknowledgement are provided. Details on beam indication format, as well as acknowledgement mechanism/format are provided. The methods provided in the present disclosure include modifying DCI formats with various purposes for common beam indication purpose. The methods provided in the present disclosure consider adding extra HARQ-ACK bits and new MAC-CE for confirming successful reception of common beam indication. The methods provided in the present disclosure consider both joint DL/UL common beam indication and separate DL/UL common beam indication, as well as impact from the number of TRPs.

[00163] FIG. 4 is a block diagram illustrating a node 400 for wireless communication according to an example implementation of the present disclosure. As illustrated in FIG. 4, a node 400 may include a transceiver 420, a processor 428, a memory 434, one or more presentation components 438, and at least one antenna 436. The node 400 may also include a radio frequency (RF) spectrum band module, a BS communications module, a network communications module, and a system communications management module, Input / Output (I/O) ports, I/O components, and a power supply (not illustrated in FIG. 4).

[00164] Each of the components may directly or indirectly communicate with each other over one or more buses 440. The node 400 may be a UE or a BS that performs various functions disclosed with reference to FIG. 3.

[00165] The transceiver 420 has a transmitter 422 (e.g., transmitting/transmission circuitry) and a receiver 424 (e.g., receiving/reception circuitry) and may be configured to transmit and/or receive time and/or frequency resource partitioning information. The transceiver 420 may be configured to transmit in different types of subframes and slots including but not limited to usable, non-usable and flexibly usable subframes and slot formats. The transceiver 420 may be configured to receive data and control channels.

[00166] The node 400 may include a variety of computer-readable media. Computer-readable media may be any available media that may be accessed by the node 400 and include volatile (and/or non-volatile) media and removable (and/or non-removable) media.

[00167] The computer-readable media may include computer-storage media and communication media. Computer-storage media may include both volatile (and/or non-volatile media), and removable (and/or non-removable) media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or data.

[00168] Computer-storage media may include RAM, ROM, EPROM, EEPROM, flash memory (or other memory technology), CD-ROM, Digital Versatile Disks (DVD) (or other optical disk storage), magnetic cassettes, magnetic tape, magnetic disk storage (or other magnetic storage devices), etc. Computer-storage media may not include a propagated data signal. Communication media may typically embody computer-readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanisms and include any information delivery media.

[00169] The term “modulated data signal” may mean a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. Communication media may include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of any of the previously listed components may also be included within the scope of computer-readable media.

[00170] The memory 434 may include computer-storage media in the form of volatile and/or non-volatile memory. The memory 434 may be removable, non-removable, or a combination thereof. Example memory may include solid-state memory, hard drives, optical-disc drives, etc. As illustrated in FIG. 4, the memory 434 may store a computer-readable and/or computer-executable program 432 (e.g., software codes) that are configured to, when executed, cause the processor 428 to perform various functions disclosed herein, for example, with reference to FIG. 3. Alternatively, the program 432 may not be directly executable by the processor 428 but may be configured to cause the node 400 (e.g., when compiled and executed) to perform various functions disclosed herein.

[00171] The processor 428 (e.g., having processing circuitry) may include an intelligent hardware device, e.g., a Central Processing Unit (CPU), a microcontroller, an ASIC, etc. The processor 428 may include memory. The processor 428 may process the data 430 and the program 432 received from the memory 434, and information transmitted and received via the transceiver 420, the base band communications module, and/or the network communications module. The processor 428 may also process information to send to the transceiver 420 for transmission via the antenna 436 to the network communications module for transmission to a CN.

[00172] One or more presentation components 438 may present data indications to a person or another device. Examples of presentation components 438 may include a display device, a speaker, a printing component, a vibrating component, etc.

[00173] In view of the present disclosure, it is obvious that various techniques may be used for implementing the disclosed concepts without departing from the scope of those concepts. Moreover, while the concepts have been disclosed with specific reference to certain implementations, a person of ordinary skill in the art may recognize that changes may be made in form and detail without departing from the scope of those concepts. As such, the disclosed implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present disclosure is not limited to the particular implementations disclosed and many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

CLAIMS**WHAT IS CLAIMED IS:**

1. A method performed by a user equipment (UE) for beam operation, the method comprising:
 receiving, a radio resource control (RRC) configuration for configuring at least one of a first set of first Transmission Configuration Indication (TCI) states, a second set of second TCI states and a third set of third TCI states;

receiving, a medium access control (MAC)-control element (CE) for activating a first TCI state combination or a second TCI state combination, wherein the first TCI state combination includes at least one of the first TCI states, and the second TCI state combination includes at least one of the second TCI states and the third TCI states;

mapping, based on the first TCI state combination or the second TCI state combination activated by the MAC CE, the first TCI state combination or the second TCI state combination to codepoints of a TCI field in downlink control information (DCI);

receiving, the DCI for indicating the at least one of the first TCI states, the second TCI states and the third TCI states included in the first TCI state combination or the second TCI state combination activated by the MAC-CE, the DCI including a scheduling field for indicating scheduling information for a physical downlink shared channel (PDSCH);

transmitting, in response to the reception of the DCI, a first Hybrid Automatic Repeat Request-Acknowledgement (HARQ-ACK) bit;

transmitting, after determining that bit value in the scheduling field is valid for scheduling the PDSCH, a second HARQ-ACK bit; and

applying, after transmitting the first HARQ-ACK bit, the at least one of the first TCI states, the second TCI states and the third TCI states indicated by the DCI for transmission or reception.

2. The method of claim 1, wherein the bit value in the scheduling field is invalid for scheduling the PDSCH.

3. The method of claim 1, wherein each bit in at least one field in the DCI is set to “0” or “1”, and the at least one field is different from the TCI field and the scheduling field.

4. The method of claim 1, further comprising:

applying, after determining that the DCI format indicates the first TCI states, receiver (RX) parameters for receiving one or more configured downlink (DL) transmissions and transmitter (TX)

parameters for transmitting one or more configured uplink (UL) transmissions, wherein the first TCI states include the RX parameters and the TX parameters.

5. The method of claim 1, further comprising:

applying, after determining that the DCI format indicates the second TCI states, transmitter (TX) parameters for transmitting one or more configured uplink (UL) transmissions, wherein the second TCI states include the TX parameters.

6. The method of claim 1, further comprising:

applying, after determining the DCI format indicates the third TCI states, receiver (RX) parameters for receiving one or more configured downlink (DL) transmissions, wherein the third TCI states include the RX parameters.

7. The method of claim 1, wherein the first TCI states are referred to as joint TCI states.

8. The method of claim 1, wherein the second TCI states are referred to as uplink (UL)-only TCI states.

9. The method of claim 1, wherein the third TCI states are referred to as downlink (DL)-only TCI states.

10. A user equipment (UE) for beam operation, the UE comprising:

a processor; and

a memory coupled to the processor, wherein the memory stores a computer-executable program that when executed by the processor, causes the processor to perform the method of any of claims 1 to 9.

100

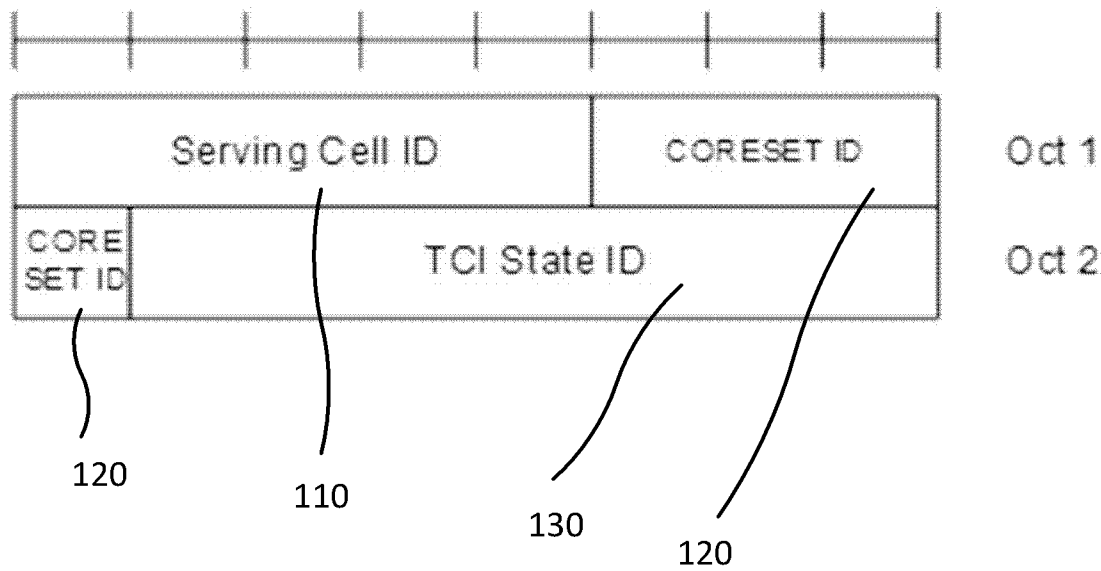


FIG. 1

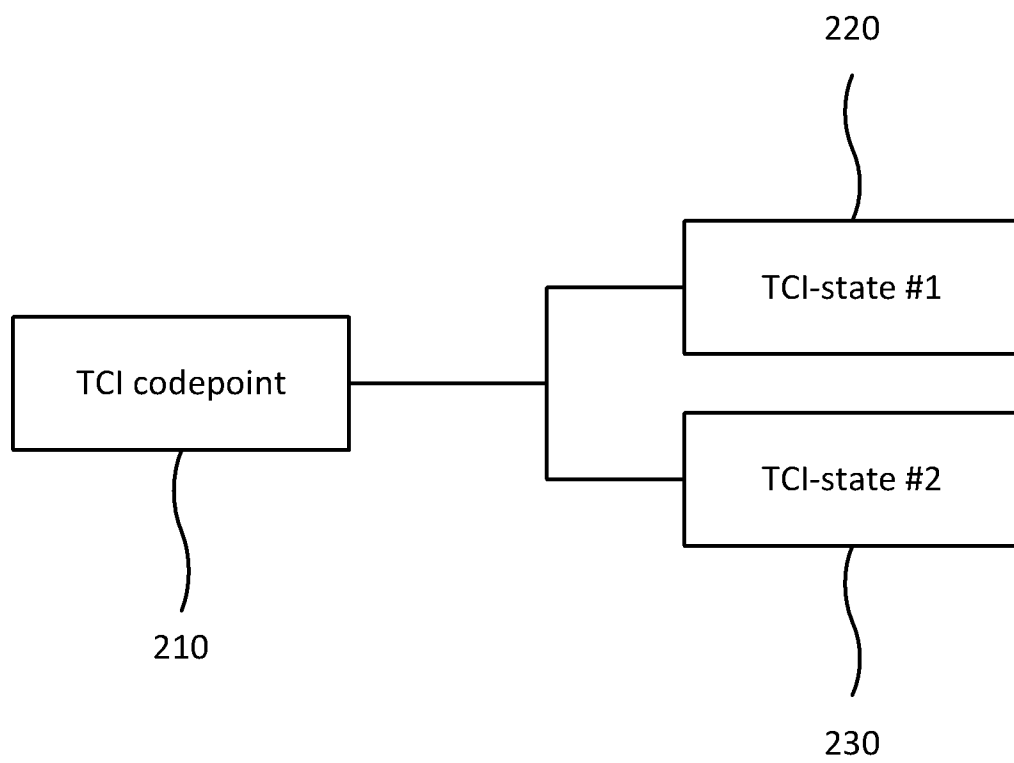
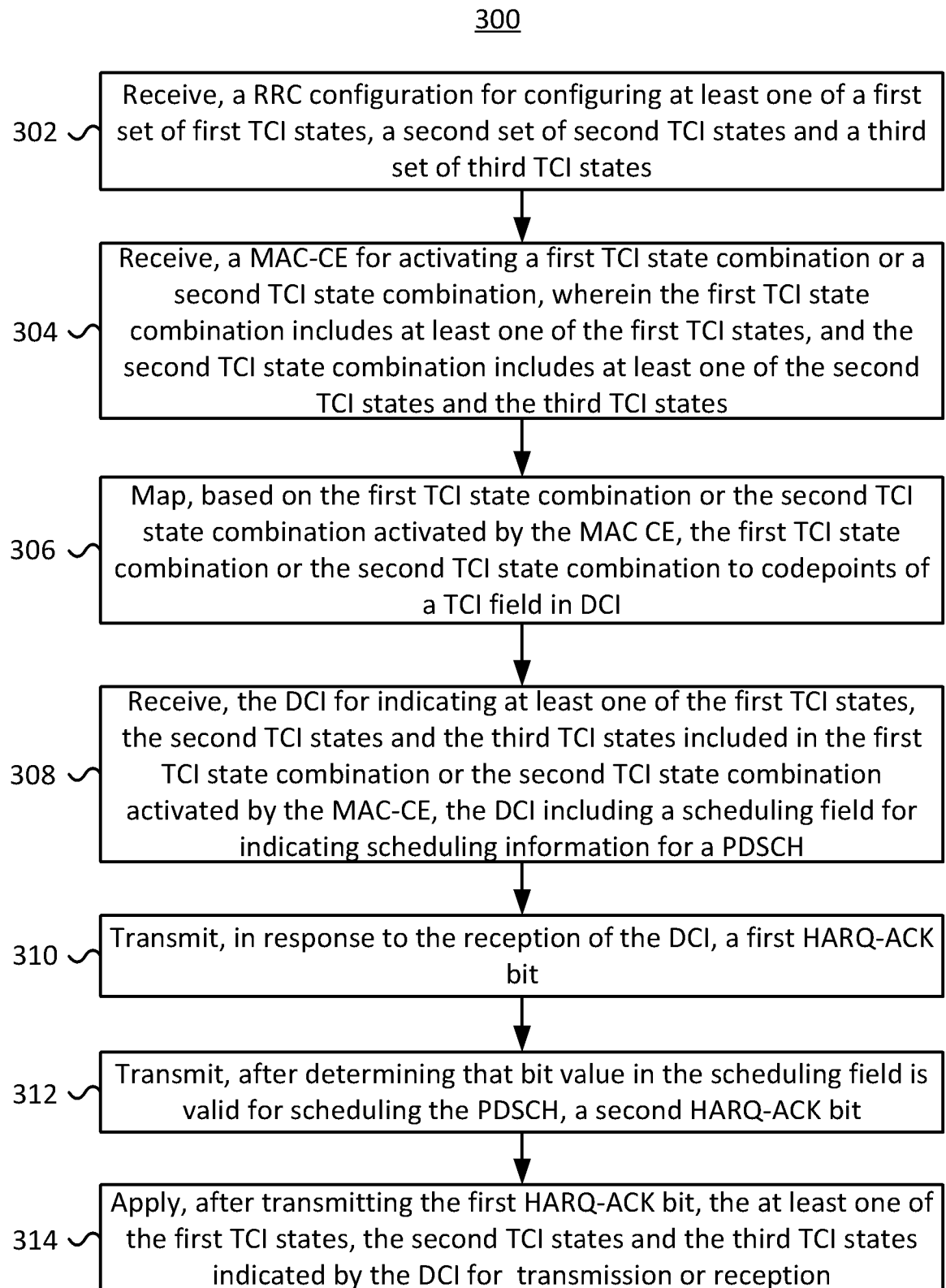
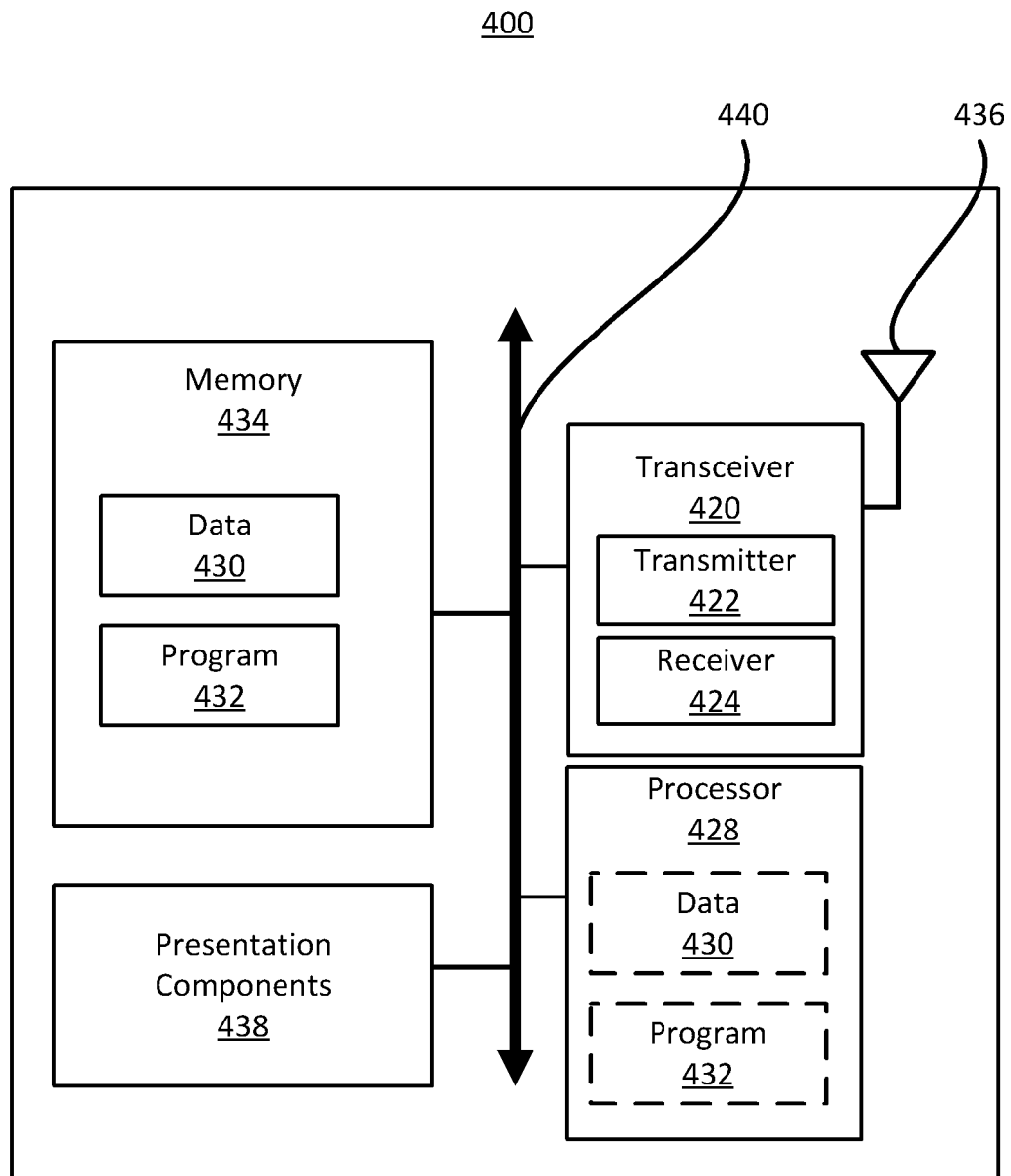


FIG. 2

**FIG. 3**

**FIG. 4**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2022/071666

A. CLASSIFICATION OF SUBJECT MATTER

H04L 5/00(2006.01)i; H04W 72/04(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L,H04W,H04B,H04Q

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ZTE. "Enhancements on Multi-beam Operation" 3GPP TSG RAN WG1 Meeting #103-e R1-2007763, 13 November 2020 (2020-11-13), section 2	1-10
Y	FUTUREWEL. "Enhancement on multi-beam operation" 3GPP TSG RAN WG1 Meeting #103-e R1-2007546, 13 November 2020 (2020-11-13), section 3	1-10
A	US 2020107353 A1 (LENOVOSINGAPORE PTE. LTD.) 02 April 2020 (2020-04-02) the whole document	1-10
A	WO 2020225081 A1 (FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V.) 12 November 2020 (2020-11-12) the whole document	1-10
A	US 2019349964 A1 (ASUSTEK COMPUTER INC.) 14 November 2019 (2019-11-14) the whole document	1-10
A	WO 2020209282 A1 (NTT DOCOMO, INC.) 15 October 2020 (2020-10-15) the whole document	1-10
A	CN 111316739 A (SAMSUNG ELECTRONICS CO., LTD.) 19 June 2020 (2020-06-19) the whole document	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

"O" document referring to an oral disclosure, use, exhibition or other means

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

16 March 2022

Date of mailing of the international search report

29 March 2022

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2022/071666

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