SELECTION OF DL-RSs FOR UE-INITIATED REPORTING

FIELD OF DISCLOSURE

The following disclosure relates to the field of communication technology, in particular communication networks, in particular wireless communication networks. The disclosure may for example relate to apparatuses that can be used to monitor or configure for monitoring a set of DL-RSs for UE-initiated reporting.

BACKGROUND

Modern communication technologies such as 5G systems provide support for beam management. The task of beam management is to establish and retain a suitable beam pair, that is, a transmitter-side beam direction and/or a corresponding receiver-side beam direction that jointly provide good connectivity between a transmission and reception point, TRP, of the network and a user equipment, UE.

To find and/or track suitable beams, the network can configure the UE to measure and report on a set of reference signals. These may correspond to different beams. The network can, based on the reporting, decide to adjust the current beam.

Currently, measurement and reporting is usually done within the framework of measuring and reporting channel state information, CSI. The framework defines that the network decides when and what the UE has to measure and when and how the UE has to report to the network. Accordingly, the UE is configured with a limited set of reference signals for monitoring and reporting.

Under various circumstances, this may be non-ideal since the UE has little flexibility to measure and/or report information. This may result in sub-optimal communication performance.

Therefore, is desirable to improve the framework for measuring and/or reporting.

SUMMARY OF SOME EXAMPLE EMBODIMENTS

Example aspects and embodiments may, at least partly, provide an improved framework for measuring and/or reporting. For example, if an apparatus (e.g., a UE) can monitor more DL-RSs associated with TCI states than the ones included in the active list of downlink reference signals, DL-RSs, configured for CSI

reporting, then the apparatus can inform the network through UE-initiated reports that a more suited TCI state/DL-RS/beam should now be monitored as part of CSI reporting, added to a list of (e.g., active) TCI states for CSI reporting and/or switched to. This may lead to better performance, may avoid potential failures and/or UE impairments can be mitigated by switching to a new TCI state.

According to a first example aspect, the following is disclosed:

A method comprising:

receiving a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

monitoring the first set of DL-RSs;

receiving a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

monitoring the second set of DL-RSs in addition to the first set of DL-RSs; and

autonomously reporting information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

The method may be performed by an apparatus, e.g., a user equipment, UE.

An apparatus comprising:

means for receiving a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

means for monitoring the first set of DL-RSs;

means for receiving a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

means for monitoring the second set of DL-RSs in addition to the first set of DL-RSs; and

means for autonomously reporting information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

The apparatus may be or comprise a UE.

According to a second example aspect, the following is disclosed:

A method comprising:

transmitting a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

transmitting a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

receiving autonomously reported information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

The method may be performed by an apparatus, e.g., a network entity.

An apparatus comprising:

means for transmitting a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

means for transmitting a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

means for receiving autonomously reported information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

The apparatus may be a network entity.

Any disclosure herein relating to any example aspect is to be understood to be equally disclosed with respect to any subject-matter according to the respective example aspect, e.g. relating to an apparatus, a method, a computer program, and a computer-readable medium. For example, any passage describing at least one processor; and at least one memory including instructions; the at least one memory and the instructions configured to, with the at least one processor, cause an apparatus at least to perform a step is to be understood as disclosing the step as a method step itself. The same holds the other way around, i.e., any passage describing a method or method step is to be understood as disclosing that at least one processor; and at least one memory including instructions; the at least one memory and the instructions configured to, with the at least one processor, cause a user equipment or network entity at least to perform the method or method step. The disclosure of a method or a method step shall also be considered as a disclosure of means for performing and/or causing to perform the respective method or method step. Likewise, the disclosure of means for performing and/or causing to perform a method or method step shall also be considered as a disclosure of the method or method step itself.

Specifically, an apparatus (e.g., a user equipment or network entity) is disclosed, configured to carry out, perform and/or control or comprising respective means for performing and/or controlling the method according to any of the above-mentioned example aspects. According to a further example aspect, an apparatus (e.g., a user equipment or network entity) is disclosed comprising at least one processor; and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to perform the method according to any aspect.

The apparatus (e.g., user equipment and/or network entity) according to any aspect may comprise means for performing the specified method or steps.

The disclosed apparatus according to any aspect may comprise only (i.e., consist of) the disclosed components, for instance means, processor, memory, circuitry, or may further comprise one or more additional components.

The means may be implemented in hardware and/or software. They may comprise for instance at least one processor for executing processor instructions for performing the required functions, at least one memory storing the instructions, or both. Alternatively, they could comprise for instance circuitry that is designed or configured to implement the required functions, for instance implemented in a chipset or a chip, like an integrated circuit. In general, the means may comprise for instance one or more processing means or processors.

As used in this application, the term “circuitry” may refer to one or more or all of the following:
(a) hardware-only circuit implementations (such as implementations in e.g. analog and/or digital circuitry) and
(b) combinations of hardware circuits and software, such as (as applicable):
(i) a combination of analog and/or digital hardware circuit(s) with software/firmware and
(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and
(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor

integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device. Any apparatus mentioned herein may comprise circuitry.

A network entity may be a network entity of a communications network, for instance a TRP, a gNB, a RAN node, a base station, or part thereof. It may be logically and/or physically distributed.

A user equipment (UE) may be an apparatus that allows a user access to network services. For example, a user equipment may be a cell phone, smartphone, tablet, laptop, TV or IoT-device. The link between the UE and the network may be a radio link.

Further, a computer program product is disclosed, the computer program product when executed by a processor of an apparatus (e.g., a user equipment or network entity) causing said apparatus to perform a method according to any example aspect.

Moreover, a computer program is disclosed, the computer program when executed by a processor causing one or more apparatuses, for instance a user equipment or network entity, to perform and/or control the actions of the method according to any example aspect.

Additionally, a computer readable storage medium (e.g. tangible and/or non-transitory) is disclosed, the computer readable storage medium comprising at least one of the disclosed computer program products or computer programs.

Furthermore, a system is disclosed. The system may comprise at least one of the following: one or more user equipment and one or more network entities.

In the following, example features and example embodiments of all aspects will be described in further detail.

An apparatus according to the second example aspect transmits, for example to an apparatus according to the first example aspect, a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting. The apparatus according to the first example aspects receives the CSI reporting configuration.

The CSI reporting configuration may configure various parameters and procedures for reporting channel state information (CSI) from a UE to a network node. The CSI reporting configuration may be an RRC-based configuration.

The CSI reporting configuration may indicate the first set of DL-RSs to monitor for CSI reporting. The DL-RSs may be, for example, non-zero power CSI-RS resources. The CSI-RS resources may be comprised

in a CSI-RS resource set. The CSI-RS resource set may be configured by the RRC layer. For instance, the information element, IE, CSI-ResourceConfig may be used to define a group of one or more NZP-CSI-RS-ResourceSet, e.g., in a 5G network.

The CSI reporting configuration may configure a periodic report, semi-persistent report or aperiodic report. For instance, the CSI reporting configuration may comprise or be associated with the IE CSI-ReportConfig. The IE CSI-ReportConfig may be used to configure a periodic or semi-persistent report sent, for example on PUCCH of the cell in which the CSI-ReportConfig is included, or to configure an aperiodic report, e.g., sent on PUSCH triggered by downlink control information (DCI) received in the cell in which the CSI-ReportConfig is included. In various embodiments, the CSI reporting may be a semi-persistent or periodic CSI reporting.

The CSI reporting configuration may configure the quantities to be reported. For instance, CSI reporting may comprise or be based on at least one of a Channel Quality Indicator (CQI), precoding matrix indicator (PMI), CSI-RS resource indicator (CRI), SS/PBCH Block Resource indicator (SSBRI), layer indicator (LI), rank indicator (RI), L1-RSRP, L1-SINR or CapabilityIndex. A UE may calculate CSI parameters (if reported) assuming one or more of the following dependencies between CSI parameters (if reported)

- LI may be calculated conditioned on the reported CQI, PMI, RI and CRI
- CQI may be calculated conditioned on the reported PMI, RI and CRI
- PMI may be calculated conditioned on the reported RI and CRI
- RI may be calculated conditioned on the reported CRI.

The Reporting configuration for CSI can be aperiodic (e.g., using PUSCH), periodic (e.g., using PUCCH) or semi-persistent (e.g., using PUCCH, and/or DCI activated PUSCH). The CSI-RS Resources can be periodic, semi-persistent, or aperiodic.

The time and frequency resources that can be used by the UE to report CSI may be controlled by the gNB, e.g., as part of the CSI reporting configuration.

The first set of DL-RSs may comprise or consist of any number of DL-RSs. One or more (or each) DL-RS may be a sequence that is generated and mapped to resource elements, e.g., according to pre-defined rules. The sequence generation may, for example, be based on a pseudo-random sequence. The DL-RSs may be transmitted by the network.

The first set of DL-RSs is configured as source RSs of a first set of transmission configuration indicator, TCI, states. However, an apparatus may additionally be configured with additional DL-RSs to monitor for CSI reporting that are not associated with any TCI states.

A TCI-State may contain parameters for configuring a quasi co-location (QCL) relationship between a source reference signal, e.g. an SSB, a tracking reference signal (TRS) or a CSI-RS, and a target reference signal, e.g. the demodulation reference signal (DM-RS) ports of PDSCH, the DM-RS port of PDCCH, or the CSI-RS port(s) of a CSI-RS resource. Two antenna ports may be 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. An antenna port may be defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed.

A TCI state may be a downlink TCI state, uplink TCI state or joint downlink/uplink TCI state. This may depend on whether the TCI state indicates a QCL relationship for receiving a target DL signal and/or transmitting a target UL signal.

An apparatus according to the second example aspect may configure an apparatus according to the first example aspect with a plurality of TCI states, e.g., a list of up to M TCI states, M being a positive integer. This configuration may be done by an RRC layer and these TCI states may be referred to as "configured TCI states" or "TCI states configured by an RRC layer". Accordingly, a pool of TCI states configured by an RRC layer may be referred to as the pool of configured TCI states.

Additionally, an apparatus according to the second example aspect may activate a number of TCI states for an apparatus according to the first example. These TCI states may be referred to as "activated TCI states", "active TCI states" or "candidate TCI states". They may be selected from or be a subset of the configured TCI states. A pool of TCI states activated by a MAC layer may be referred to as the pool of activated or candidate TCI states or "active TCI state list".

Additionally, a pool of TCI states configured by an RRC layer and not currently activated by the MAC layer may be defined. This pool may be referred to as the pool of configured non-activated TCI states.

One or more TCI states for use in downlink and/or uplink communication may be indicated through DCI. These one or more TCI states may be referred to as "indicated TCI states". The one or more indicated TCI states may be selected, e.g., by the apparatus according to the second example aspect, from the pool of activated TCI states. The apparatus according to the first aspect may be informed of the one or more indicated TCI states by the apparatus according to the second example aspect. In various embodiments, if there is only one activated TCI state, the apparatus according to the first example aspect may consider this activated TCI state to also be the indicated TCI state without further notice.

In various embodiments, the first set of TCI states corresponds to the (e.g., entire) pool of TCI states activated by a medium access control, MAC, layer. In other embodiments, the first set of TCI states corresponds to a subset of the pool of TCI states activated by a medium access control, MAC, layer. In

other embodiments, the first set of TCI states may further comprise TCI states that are configured but not activated.

The apparatus according to the first example aspect monitors the first set of DL-RSs. The apparatus may do so by determining, e.g., measuring and/or calculating, one or more of the quantities previously mentioned in the context of CSI reporting.

Additionally, the apparatus according to the first aspect receives a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs. The apparatus according to the first example aspect monitors the second set of DL-RSs in addition to the first set of DL-RSs.

The UE-initiated reporting configuration may have been transmitted by the apparatus according to the second aspect. The UE-initiated reporting configuration may comprise or consist of an RRC-based configuration and/or MAC-CE signaling and/or DCI signaling. The UE-initiated reporting configuration may comprise or correspond to one or more IEs. One or more of these IEs may have a similar structure as the IE(s) that are used for CSI reporting and/or even comprise or point to one or more IEs used also for configuring CSI reporting.

In various embodiments, each source DL-RS of the second set of DL-RSs may be associated with a TCI state of the second set of TCI states. In other embodiments, an apparatus may additionally be configured with additional DL-RSs to monitor for UE-initiated reporting that are not associated with any TCI states.

The TCI states in the second set of TCI states and/or the DL-RSs in the second set of DL-RSs may be determined by the apparatus according to the second aspect. This determining may include determining the number of TCI states in the second set of TCI states and/or the number of DL-RSs in the second set of DL-RSs.

In various embodiments, the apparatus according to the first aspect may transmit, e.g., to the apparatus according to the second aspect, capability information indicating a maximum number of DL-RSs that the apparatus is able to monitor for the UE-initiated reporting.

The apparatus according to the second aspect may receive the capability information indicating the maximum number of DL-RSs that the apparatus according to the first aspect is able to monitor for the UE-initiated reporting and determine the UE-initiated reporting configuration based on the received capability information. For example, the apparatus according to the second aspect may determine the second set of DL-RSs (and/or the second set of TCI states) so that the number of DL-RSs in the second

set of DL-RSs is less than or equal to the maximum number. The maximum number may be any positive integer, e.g., 4, 8, 16, 64, 128. It may be specified directly as a number or, for example, as a function of other parameters.

Additionally or alternatively, the apparatus according to the first aspect may select up to the maximum number of DL-RSs for the UE-initiated reporting based on received information and treat the selected DL-RSs as the second set of DL-RSs. This may, for instance, be done when the apparatus according to the first example aspect receives information indicating more than the maximum number of DL-RSs to monitor for UE-initiated reporting and is, for example, not able to monitor all of these DL-RSs for UE-initiated reporting.

The capability information may indicate further parameters concerning the capabilities of an apparatus. For example, it may indicate bandwidth and/or timing constraints that apply for monitoring DL-RSs, e.g., for UE-initiated reporting. The apparatus according to the second aspect may take one or more of these further parameters into account when determining the second set of DL-RSs and/or the second set of TCI states.

In various embodiments, capability information indicating a maximum number of DL-RSs that an apparatus is able to monitor for UE-initiated reporting may be pre-defined, e.g., in a standard.

The UE-initiated reporting configuration may be similar to the CSI reporting configuration in what is configured, for instance the reference signal resources and/or which quantities are to be measured, determined and/or reported.

In various embodiments, the UE-initiated reporting configuration indicating the second set of DL-RSs to monitor for UE-initiated reporting indicates that the monitoring comprises determining at least one of:

- one or more reference signal received powers, RSRPs, for the second set of DL-RSs;
- one or more received signal strength indicators, RSSIs, for the second set of DL-RSs;
- one or more reference signal received qualities, RSRQs, for the second set of DL-RSs;
- one or more signal to interference plus noise ratios, SINRs, for the second set of DL-RSs;
- a channel-quality indicator, CQI, for downlink communication;
- a rank indicator, RI, for downlink communication; or
- a precoder-matrix indicator, PMI, for downlink communication.

Accordingly, in various embodiments, the monitoring of the second set of DL-RSs (e.g., by the apparatus according to the first aspect) further comprises determining at least one of:

- one or more reference signal received powers, RSRPs, for the second set of monitored DL-RSs;
- one or more received signal strength indicators, RSSIs, for the second set of monitored DL-RSs;
- one or more reference signal received qualities, RSRQs, for the second set of monitored DL-RSs;

- one or more signal to interference plus noise ratios, SINRs, for the second set of monitored DL-RSs;
- a channel-quality indicator, CQI, for downlink communication;
- a rank indicator, RI, for downlink communication; or
- a precoder-matrix indicator, PMI, for downlink communication.

The UE-initiated reporting configuration may be different from the CSI reporting configuration in that it may not be able to configure, e.g., periodic reporting, since the UE may autonomously decide when to report information to the network, e.g., without being triggered by the network to report information.

Moreover, the second set of DL-RSs is configured as source RSs of a second set of TCI states, and comprises at least at least one element not belonging to the first set of DL-RSs. Thus, the first set of DL-RSs and the second set of DL-RSs are different. The at least one element not belonging to the first set of DL-RSs may be at least one DL-RS. In various embodiments, none of the elements in the second set of DL-RSs belong to the first set of DL-RSs.

The second set of TCI states may be seen to complement the first set of DL-RSs in that it allows the apparatus according to the first aspect to monitor at least one DL-RS that was not in the first set of DL-RSs to monitor for CSI reporting.

The first and second set of DL-RSs may be determined by an apparatus according to the second example aspect, e.g., a network entity.

The apparatus according to the second example aspect may determine that the second set of TCI states includes the first set of TCI states. In various embodiments, this may imply that the second set of DL-RSs includes the first set of DL-RSs.

In various embodiments, the first set of TCI states may correspond to a (e.g., entire) pool of TCI states activated by a medium access control, MAC, layer, and the second set of TCI states may be selected from a pool of TCI states configured by a radio resource control, RRC, layer. This way, additional TCI states from the pool of configured TCI states can be monitored, giving the apparatus according to the first example aspect more freedom and/or flexibility to determine which TCI state (and/or associated source DL-RS) is a preferred TCI state (and/or DL-RS).

In various example embodiments, the second set of TCI states may correspond to a pool of TCI states configured by the RRC layer and not currently activated by the MAC layer. This may allow monitoring all configured states, namely activated TCI states as part of the CSI reporting framework and configured non-activated TCI states as part of the UE-initiated reporting framework. This may give the apparatus according to the first example aspect more freedom and/or flexibility to determine which TCI state is a

preferred TCI state without having to monitor or consider for monitoring for UE-initiated reporting all configured TCI states.

Alternatively, for example, the second set of TCI states may correspond to the (e.g., entire) pool of TCI states configured by the RRC layer (e.g., also including the TCI states activated by the MAC layer). This may give the apparatus according to the first example aspect a large amount of freedom and/or flexibility to determine which TCI state is a preferred TCI state. Also considering the activated TCI states for UE-initiated reporting may be beneficial, for instance, in case CSI reporting is not frequent enough, for example with UEs having a medium or high velocity.

In various embodiments, the first set of TCI states may correspond to a subset of a pool of TCI states activated by a MAC layer, and the second set of TCI states may be selected from the pool of TCI states activated by the MAC layer and/or from a pool of TCI states configured by an RRC layer. In these embodiments, additional TCI states from the pool of activated and/or configured TCI states can be monitored, giving the apparatus according to the first example aspect more freedom and/or flexibility to determine which TCI state is a preferred TCI state.

In various embodiments, the second set of TCI states may correspond to a pool of TCI states activated by the MAC layer and not belonging to the subset.

Alternatively, in various embodiments, the second set of TCI states may correspond to the (e.g., entire) pool of TCI states activated by the MAC layer. As noted before, considering the activated TCI states for UE-initiated reporting may be beneficial, for instance, in case CSI reporting is not frequent enough, for example with UEs having a medium or high velocity.

In various embodiments, the second set of TCI states may correspond to a pool of TCI states configured by the RRC layer and not belonging to the subset. This may give the apparatus according to the first example aspect more freedom and/or flexibility to determine which TCI state is a preferred TCI state without having to monitor or consider for monitoring for UE-initiated reporting all configured TCI states, even when they are already considered in CSI reporting.

In various embodiments, the second set of TCI states may correspond to the (e.g., entire) pool of TCI states configured by the RRC layer. This may give the apparatus according to the first example aspect a large amount of freedom and/or flexibility to determine which TCI state is a preferred TCI state.

Whenever the second set of TCI states corresponds to a pool of TCI states that an apparatus is aware of or configured with or that is determinable by the apparatus, the signaling overhead to indicate the second set of TCI states may be very low. For example, the indication can be a reference or a pointer to the determinable or known pool.

Like for the first set of DL-RSs, the second set of DL-RSs may comprise or consist of any number of DL-RSs. One or more (or each) DL-RS may be a sequence that is generated and mapped to resource elements, e.g., according to pre-defined rules. The sequence generation may, for example, be based on a pseudo-random sequence. The UE-initiated reporting configuration may identify the DL-RSs of the second set. The resources may be, for example, non-zero power CSI-RS resources. The defined resources may be comprised in a resource set. The resource set may be configured by the RRC layer. For instance, the information element, IE, CSI-ResourceConfig may be used to define a group of one or more NZP-CSI-RS-ResourceSet.

In any embodiment, the first set of TCI states and/or the second set of TCI states may comprise one or more of downlink TCI states, uplink TCI states, or joint downlink/uplink TCI states.

The apparatus according to the first example aspect may determine (e.g., select) one or more preferred DL-RSs from the second set of monitored DL-RSs. The determining may be based one or more measurements and/or one or more parameters and/or one or more quantities determined for the second set, e.g., RSRPs for the second set of DL-RSs, RSSIs for the second set of DL-RSs, RSRQs for the second set of DL-RSs, SINRs, for the second set of DL-RSs, a CQI, RI, and/or PMI. The term "preferred" may be understood to mean that an apparatus expects, e.g., a good link quality or connectivity when a connection is based on the same parameters that were used for the preferred DL-RS or at least a better link quality or connectivity than with a connection that is based on parameters that correspond to those used for one or more other DL-RSs.

In various embodiments, the apparatus according to the first example aspect may determine the one or more preferred DL-RSs by determining that the one or more preferred DL-RSs are better or offset better than at least one of:

- a DL-RS that is configured as a source RS of a TCI state of a pool of TCI states activated by a MAC layer; or
- a DL-RS that is configured as a source RS of a TCI state indicated for use in downlink and/or uplink communication.

Determining that a DL-RS is better than another DL-RS may mean that one or more quantities (e.g., one or more of those mentioned above) are compared for two DL-RSs and the DL-RS with one or more quantities that indicate a higher link quality or connectivity with the network is determined as a better one. For example, a first DL-RS may be determined to be better than another DL-RS when the first DL-RS has a higher SINR than the other DL-RS.

Determining that a DL-RS is offset better than another DL-RS may be done in a similar manner. However, an offset may be considered in the determining. For example, a first DL-RS may be

determined to be offset better than another DL-RS when the first DL-RS has not only a higher SINR than the other DL-RS, but has a SINR that is higher by at least x dB than the SINR of the other DL-RS. The offset may also be negative so that a first DL-RS may be determined to be offset better than another DL-RS when the first DL-RS has a SINR that is higher than the SINR of the other DL-RS minus x dB.

Additionally or alternatively, in various embodiments, the one or more preferred DL-RSs correspond to N best monitored DL-RSs from the second set of monitored DL-RSs, wherein N is a positive integer. N may be a pre-defined number. Alternatively, it may be configured, e.g., by a network entity. Determining that one or more DL-RSs are the best may mean that they are better or offset better than (e.g., at least) the other monitored DL-RS of the second set.

The apparatus according to the first example aspect autonomously reports, e.g., to the apparatus according to the second example aspect, information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs. The apparatus according to the second example aspect receives the autonomously reported information related to the one or more preferred DL-RSs selected from the second set of DL-RSs.

The information related to the one or more preferred DL-RSs selected from the second set of monitored DL-RSs may be indicative of the one or more preferred DL-RSs. For example, information related to the one or more preferred DL-RSs may comprise one or more indices (e.g., one or more beam indices) associated with or being indicative of the one or more preferred DL-RSs. Alternatively, information related to the one or more preferred DL-RSs may comprise one or more TCI state identities corresponding to the one or more preferred DL-RSs.

In various embodiments, the information may comprise one or more quantities related to the one or more preferred DL-RSs. The one or more quantities can comprise or consist of one or more of those mentioned before, e.g., for CSI reporting.

In various embodiments, autonomously reporting the information may mean that the reporting apparatus decides itself whether it is going to report the information. This may mean, for instance, that the network does not trigger the reporting.

In various embodiments, the apparatus according to the first example aspect autonomously reports the information related to the one or more preferred DL-RSs in response to determining that one or more pre-defined events have occurred for the one or more respective preferred DL-RSs. For example, it reports the information in response to determining that one or more of the preferred DL-RSs are associated with a quantity that exceeds a threshold (thus, the event being that the threshold is exceeded). The threshold may be, for example, pre-configured or based on one or more quantities of one or more DL-RSs of the first and/or second set of DL-RSs. The pre-defined events may be pre-

defined in a standard or may be pre-defined according to one or more criteria at the reporting apparatus.

In various embodiments, autonomously reporting may additionally or alternatively mean that the reporting apparatus decides what it is going to report, e.g., the content of the reporting. For example, it may decide how many preferred DL-RSs it is going to report. Additionally or alternatively, autonomously reporting may be associated with the reporting apparatus deciding itself how it determines the one or more preferred DL-RSs, e.g., according to which criterion or which criteria.

In various embodiments, the reporting may comprise at least one of:

- sending the information related to the one or more preferred DL-RSs via a physical uplink control channel, PUCCH, as part of uplink control information, UCI;
- sending the information related to the one or more preferred DL-RSs via a physical uplink shared channel, PUSCH, as part of UCI;
- transmitting a scheduling request, and sending the information related to one or more preferred DL-RSs via a PUSCH scheduled in response to the scheduling request as part of UCI;
- sending the information related to one or more preferred DL-RSs via MAC signaling; or
- sending the information related to one or more preferred DL-RSs via RRC signaling.

Accordingly, the apparatus according to the second example aspect may perform at least one of:

- receiving the information related to the one or more preferred DL-RSs via a physical uplink control channel, PUCCH, as part of uplink control information, UCI;
- receiving the information related to the one or more preferred DL-RSs via a physical uplink shared channel, PUSCH, as part of UCI;
- receiving a scheduling request, scheduling a PUSCH in response to the scheduling request, and receiving the information related to one or more preferred DL-RSs via the scheduled PUSCH;
- receiving the information related to one or more preferred DL-RSs via MAC signaling; or
- receiving the information related to one or more preferred DL-RSs via RRC signaling.

In various scenarios the UE-initiated reporting may need to be fast and/or quick (e.g., to provide a fast and/or quick reaction to a changing quantity of a monitored DL-RS) so that reporting through PUCCH and/or PUSCH is suitable. However, in other scenarios MAC-based and/or RRC-based reporting may be possible as well.

In various embodiments, the apparatus according to the second aspect may determine a new candidate TCI state to be activated by a MAC layer based on the reported information related to the one or more preferred DL-RSs, and transmit, e.g., to the apparatus according to the first example aspect, information indicating the new TCI state activated by the MAC layer, for instance by means of MAC control element (MAC-CE) signaling. For example, the apparatus according to the second aspect may change the pool of

activated TCI states. This may be particularly beneficial when the one or more preferred DL-RSs are better or offset better than one or more DL-RSs that are configured as a source RS of a TCI state of a pool of TCI states activated by a MAC layer or one or more DL-RSs that are configured as a source RS of one or more TCI states indicated for use in downlink and/or uplink communication.

The apparatus according to the first example aspect may receive the information indicating the new TCI state activated by the MAC layer, the new TCI state being based on the reported information related to the one or more preferred DL-RSs. In various embodiments, this may imply (or it may additionally be configured) that this new activated TCI state is configured as part of the CSI monitoring framework, e.g., the apparatus may start reporting CSI associated with the source RS of the new TCI state.

In various embodiments, the apparatus according to the second example aspect may determine a new indicated TCI state for use in downlink and/or uplink communication, and transmit downlink control information, DCI, indicating the new TCI state for use in downlink and/or uplink communication. In various embodiments, the determining of the new indicated TCI state for use in downlink and/or uplink communication may be based on the reported information related to the one or more preferred DL-RSs. Additionally or alternatively, the determining of the new indicated TCI state for use in downlink and/or uplink communication may be based on CSI reporting for the TCI state. For example, if the TCI state has been activated by the MAC layer based on the reported information related to the one or more preferred DL-RSs, there may be CSI reporting for the TCI state. Based on this CSI reporting, the determining of the new indicated TCI state for use in downlink and/or uplink communication may be done.

The apparatus according to the first example aspect may receive the downlink control information, DCI, indicating the new TCI state for use in downlink and/or uplink communication. Accordingly, it may apply the new TCI state for use as indicated TCI state.

It is to be understood that the presentation in this section is merely by way of examples and non-limiting. Each step described above may happen after or in response to another, e.g., the preceding step. However, a different order of steps is also possible.

Further, it is to be understood that the terms “first” and “second”, e.g., in first and second set, are merely chosen to distinguish objects, e.g., sets. No further technical meaning is implied by “first” or “second” in this context.

Other features will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits, for which reference should be made to

the appended claims. It should be further understood that the drawings are not drawn to scale and that they are merely intended to conceptually illustrate the structures and procedures described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings are:

Fig. 1	a schematic drawing showing a system according to an example embodiment;
Fig. 2	a schematic drawing showing an example of a QCL relation;
Fig. 3	a schematic drawing showing details of a QCL relation between source and target signals for downlink and uplink;
Fig. 4	a schematic drawing showing the relation between an example TCI state and various example QCL types;
Fig. 5a	a schematic drawing showing an example QCL chain for the reception of downlink signals/channels for sTRP;
Fig. 5b	a schematic drawing showing an example QCL chain for the reception of downlink signals/channels for mTRP;
Fig. 6	a schematic drawing showing three example beam management procedures;
Fig. 7	a schematic drawing showing a TCI state configuration;
Fig. 8	a flowchart showing an example embodiment of a process, e.g., performed by a user equipment;
Fig. 9	a flowchart showing an example embodiment of a process, e.g., performed by a network entity;
Fig. 10	a schematic drawing showing a TCI state configuration including a pool of DL-RSs for UE-initiated reports;
Fig. 11	a schematic drawing showing TCI state configuration including another pool of DL-RSs for UE-initiated reports;
Fig. 12	a flowchart showing steps for a user equipment according to an example embodiment;
Fig. 13	a flowchart showing steps for a system according to an example embodiment;
Fig. 14	a schematic block diagram of an example of a UE or network entity according to any example aspect.

DETAILED DESCRIPTION OF SOME EXAMPLES

The following description serves to deepen the understanding and shall be understood to complement and be read together with the description as provided in the above summary section of this specification. Some aspects may have a different terminology than e.g. provided in the description above. The skilled person will nevertheless understand that those terms refer to the same subject-matter, e.g. by being more specific.

Fig. 1 is a schematic drawing showing a system 100 according to an example embodiment. By way of example, the system 100 comprises a user equipment, UE, 1 and a network entity 2. The UE 1 and the network entity 2 are connected by a connection 3. The connection may, for example, be a radio connection. The UE 1 and the network 3 may use connection 3 to exchange (e.g., receive/transmit) information and/or messages.

The network entity 2 may be a TRP, a base station, a network, and/or an NG-RAN node. Specifically, the network entity 2 may be a node providing NR user plane and/or control plane protocol terminations towards the UE, and/or connected via the NG interface to the 5GC. The network entity 2 may comprise or be represented by a Transmit/Receive Point, TRP. The TRP can be a single TRP, sTRP, or a multiple TRP, mTRP/multi-TRP. In multi-TRP operation, a serving cell can schedule the UE from two TRPs, possibly providing better coverage, reliability and/or data rates for PDSCH, PDCCH, PUSCH, and/or PUCCH.

The system 100 may include further entities, e.g., further apparatuses, user equipment, network entities, and/or network nodes. Network entities, e.g., NG-RAN nodes, may be interconnected with each other, e.g., by means of the Xn interface. One or more network entities may also be connected to the core network, e.g., 5GC.

The network entity 2 may transmit signals and/or information to the UE 1 using different characteristics, e.g., using different antennas, antenna precoders or spatial filters. As a result, the signals may experience different “radio channels” even if the set of antennas are located at the same site.

The UE 1 may need to be aware of which spatial filter is used at the network entity 2 and/or how the spatial filters used for different downlink transmissions or signals relate to each other. This way, the UE 1 can for example determine what (e.g., DL) reference signal(s) should be used for channel estimation for a certain downlink transmission and/or determine relevant channel-state information.

For this reason, the concept of antenna port may be used. In various embodiments, an antenna port may be defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed.

Expressed differently, each individual downlink transmission may be carried out from a specific antenna port, the identity of which is known to the device. Furthermore, the device can assume that two transmitted signals have experienced the same radio channel if (e.g., and only if) they are transmitted from the same antenna port.

An antenna port can (e.g., for the downlink) be seen as being associated with a specific reference signal, e.g., a DL-RS. A UE can then use this reference signal to estimate channel characteristics corresponding to the antenna port. The reference signal(s) can also be used (e.g., by the UE 1) to derive channel-state information associated with the antenna port.

Two (or potentially more) antenna ports can be related to each other via a quasi co-location, QCL, relation. QCL may be defined as follows: 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.

Fig. 2 is a schematic drawing showing an example of a QCL relation.

There is antenna port A 201 which is associated with reference signal, RS, #A (e.g., a DL-RS). The reference signal #A may be called a source RS. Additionally, there is antenna port B 203 which is associated with reference signal #B (e.g., another DL-RS). The RS #B may be called a target RS. Both antenna ports A and B may have a QCL relation 202. In other words, they may be said to be quasi co-located. The properties of the channel over which a symbol on antenna port B is conveyed can be inferred from the channel over which a symbol on the antenna port A is conveyed. For example, the properties of the channel over which RS #B is conveyed can be inferred from the channel over which the RS #A is conveyed.

Fig. 3 is a schematic drawing showing details of a QCL relation between source and target signals for downlink and uplink.

In a downlink scenario, the properties of the channel that can be inferred through a QCL relation may, for example, be at least one of those shown in block 304: Doppler spread, Doppler shift, average delay, delay spread, or RX beam (spatial filter).

A UE may estimate 305 one or more of these properties based on a source signal 301, e.g., a DL-RS. The UE may be configured with or informed about a QCL relation 302 of the source signal 301 with a target signal 303. Thus, the UE may apply 306 the one or more properties estimated based on the source signal 301 for reception of target signal 303. The target signal 303 may be a PDSCH, a PDCCH or a CSI-RS resource.

In principle, a QCL relationship like QCL relationship 302 may be any quasi co-location relationship between one or two downlink reference signals and the DM-RS ports of the PDSCH, the DM-RS port of PDCCH or the CSI-RS port(s) of a CSI-RS resource.

In an uplink scenario, the properties of the channel that can be inferred through a QCL relation may, for example, be at least one of those shown in block 314: TX beam or pathloss (TX power).

As in the downlink scenario, a UE may estimate 315 one or more of these properties based on a source signal 311, e.g., a DL-RS. The UE may be configured with or informed about a QCL relation 312 of the source signal 311 with a target signal 313, e.g., an uplink transmission, e.g., PUSCH. The UE may apply 316 the one or more properties estimated based on the source signal 311 for transmission of target signal 313.

The configuration of a QCL relationship may be done through a TCI state which may relate to downlink, uplink, or downlink and uplink jointly.

Fig. 4 is a schematic drawing showing the relation between an example TCI state 401 and various example QCL types 410, 420.

A TCI-State 401 may contain parameters for configuring a quasi co-location relationship between one or two downlink reference signals and the DM-RS ports of the PDSCH, the DM-RS port of PDCCH or the CSI-RS port(s) of a CSI-RS resource.

A UE can be configured with a list of up to M TCI-State configurations. The number M may depend on a UE capability.

For example, the UE can be configured with a list of up to 128 TCI-State configurations. The configuration can be done within a parameter, e.g., dl-OrJointTCI-StateList, e.g., in PDSCH-Config. It can be for providing a reference signal for the quasi co-location for DM-RS of PDSCH and DM-RS of PDCCH in a BWP/CC, for CSI-RS, and/or to provide a reference, if applicable, for determining UL TX spatial filter for dynamic-grant and/or configured-grant based PUSCH and/or PUCCH resource in a BWP/CC, and/or SRS.

The quasi co-location relationship may be configured by a parameter (e.g., a higher layer parameter qcl-Type1) for the first DL-RS 410. Additionally or alternatively, quasi co-location relationship may be configured by a parameter (e.g., the higher layer parameter qcl-Type2) for the second DL-RS 420, if the second DL RS is configured (which is optional). In various embodiments, for the case of two DL-RSs 410, 420, the QCL types shall not be the same, regardless of whether the references are the same DL-RSs 410, 420 or different DL-RSs 410, 420.

The quasi co-location types may take, for example, one of the following values:

- 'typeA': {Doppler shift, Doppler spread, average delay, delay spread}

- 'typeB': {Doppler shift, Doppler spread}
- 'typeC': {Doppler shift, average delay}
- 'typeD': {Spatial Rx parameter}

Other types could be defined that comprise one or more combinations of properties, e.g., the properties that are currently part of one or more of the types or other properties.

Types typeA 411, typeB 412, and/or typeC 413 may allow the UE to estimate large scale channel parameters. This may concern especially channels in frequency range 1, FR1, e.g., sub-6 GHz frequency bands (potentially extended to also include frequencies up to, e.g., 7125 MHz).

Some or all of types typeA 411, typeB 412, typeC 413, and/or typeD 421 may be relevant to frequency range 2, FR2 (e.g., in frequency bands at higher frequencies than FR1, e.g., from 24.25 GHz to 71.0 GHz).

The quasi co-location relationship for the first DL-RS (e.g., QCL-Type 1 RS) may be at least one of typeA 411, typeB 412, and/or typeC 413. Additionally or alternatively, in various embodiments, it may be typeD 421. The QCL type may indicate which respective parameters can be transferred to the target.

A quasi co-location relationship for a second DL-RS (e.g., QCL-Type 2 RS) may or may not be configured. It may be typeD 421. Additionally or alternatively, in various embodiments, it may be at least one of typeA 411, typeB 412, and/or typeC 413.

The quasi co-location types corresponding to each DL-RS (e.g., first and/or second) may be given by a parameter, e.g., higher layer parameter qcl-Type in QCL-Info.

Information elements, IEs, corresponding to the above-described concepts may be defined as follows.

The IE TCI-State may associate one or two DL reference signals with a corresponding quasi-colocation (QCL) type.

```
TCI-State information element
-- ASN1START
-- TAG-TCI-STATE-START
TCI-State ::= SEQUENCE {
        tci-StateId     TCI-StateId,
        qcl-Type1       QCL-Info,
        qcl-Type2       QCL-Info OPTIONAL, -- Need R
        ...,
        [[
```

```
        additionalPCI-r17                AdditionalPCIIndex-r17 OPTIONAL, -- Need R
        pathlossReferenceRS-Id-r17       PathlossReferenceRS-Id-r17 OPTIONAL, -- Cond JointTCI1
        ul-powerControl-r17              Uplink-powerControlId-r17 OPTIONAL -- Cond JointTCI
        ]]
}

QCL-Info ::= SEQUENCE {
        cell                    ServCellIndex OPTIONAL, -- Need R
        bwp-Id                  BWP-Id OPTIONAL, -- Cond CSI-RS-Indicated
        referenceSignal         CHOICE {
                csi-rs                  NZP-CSI-RS-ResourceId,
                ssb                     SSB-Index
        },
        qcl-Type                ENUMERATED {typeA, typeB, typeC, typeD},
        ...
}
-- TAG-TCI-STATE-STOP
-- ASN1STOP
```

Fig. 5a is a schematic drawing showing an example QCL chain for the reception of downlink signals/channels for sTRP.

On top, Fig. 5a shows communication between a UE 1 and a network entity 2 (e.g., a TRP). The communication may comprise PDCCH and/or PDSCH and/or CSI reporting (not shown explicitly).

Fig. 5a shows different types of reference signals relevant to PDCCH, PDSCH and CSI reporting.

In various embodiments, available reference signals in the network may include one or more of:

- Demodulation reference signals (DM-RS) for PDSCH. They may be intended for channel estimation at a UE, e.g., as part of coherent demodulation.
- Demodulation reference signals (DM-RS) for PDCCH.
- CSI reference signals (CSI-RS), which may be downlink reference signals intended to be used by one or more UEs to acquire downlink channel-state information (CSI). Specific instances of CSI reference signals can be configured for time/frequency tracking and/or mobility measurements. There may be zero-power (ZP) and/or non-zero-power (NZP) CSI-RS.
- Tracking reference signals (TRS), which may be sparse reference signals. They may be intended to assist the device (e.g., a UE) in time and/or frequency tracking. A specific CSI-RS configuration may serve the purpose of a TRS. Specifically, a parameter (e.g., trs-Info) may

indicate that a CSI-RS resource set is for tracking and, thus, a TRS. If the CSI-RS is periodic, the TRS may be called a periodic TRS, P-TRS.

NZP CSI-RS resources may be configured by a corresponding IE. For example, the IE NZP-CSI-RS-Resource may be used to configure Non-Zero-Power (NZP) CSI-RS transmitted in the cell where the IE is included, which the UE may be configured to measure on.

```
NZP-CSI-RS-Resource information element
-- ASN1START
-- TAG-NZP-CSI-RS-RESOURCE-START
NZP-CSI-RS-Resource ::= SEQUENCE {
        nzp-CSI-RS-ResourceId   NZP-CSI-RS-ResourceId,
        resourceMapping         CSI-RS-ResourceMapping,
        powerControlOffset      INTEGER (-8..15),
        powerControlOffsetSS    ENUMERATED{db-3, db0, db3, db6} OPTIONAL, -- Need R
        scramblingID            ScramblingId,
        periodicityAndOffset    CSI-ResourcePeriodicityAndOffset OPTIONAL, -- Cond
                                PeriodicOrSemiPersistent
        qcl-InfoPeriodicCSI-RS  TCI-StateId OPTIONAL, -- Cond Periodic
        ...
}
-- TAG-NZP-CSI-RS-RESOURCE-STOP
-- ASN1STOP
```

A parameter (e.g., trs-Info) may indicate that the antenna port for at least some CSI-RS resources (e.g., all NZP-CSI-RS resources) in the CSI-RS resource set is same. By way of example, a UE in RRC connected mode may be expected to receive a CSI-RS configuration (e.g, a UE specific configuration of a NZP-CSI-RSResourceSet) configured with such a parameter (e.g., trs-Info).

In addition to one or more RSs (e.g., DL-RSs), there may be a Synchronization Signal and PBCH block (SSB) 501. It may comprise or consist of primary and secondary synchronization signals (PSS, SSS). Each of the synchronization signals may occupy 1 symbol, 127 subcarriers, and/or PBCH (e.g., spanning across 3 OFDM symbols and 240 subcarriers), but possibly on one symbol leaving an unused part in the middle for SSS. Different SSBs may be transmitted (e.g., during a half-frame) in different spatial directions (e.g., using different beams which may span the coverage area of a cell).

Fig. 5a shows for the DL-RSs and SSB which QCL relationships can be, by way of example, expected between them. The arrows indicate which signal (e.g., DL-RS or SSB) is the source and which the target signal of a respective possible QCL relationship. For example, periodic tracking reference signal, P-TRS,

502 may be the source in QCL relationships of type A and, if applicable, D with DMRS of PDSCH 503, DMRS of PDCCH 504, and/or CSI-RS for CSI 505. The SSB 501 may be the source signal in the QCL relationship with target P-TRS 502.

Fig. 5b is a schematic drawing showing an example QCL chain for the reception of downlink signals/channels for mTRP.

In Multiple Transmit/Receive Point (mTRP) operation, a serving cell can schedule the UE from two TRPs, providing better coverage, reliability and/or data rates for PDSCH, PDCCH, PUSCH, and/or PUCCH.

There may be two different operation modes to schedule multi-TRP PDSCH transmissions: single-DCI and multi-DCI. For both modes, control of uplink and downlink operation can be done by physical layer and/or MAC layer, e.g., within the configuration provided by the RRC layer. In single-DCI mode, the UE may be scheduled by the same DCI for both TRPs. In multi-DCI mode, the UE may be scheduled by independent DCIs from each TRP. By way of example, Fig. 5b relates to single-DCI mode.

As can be seen, the QCL relationships for TRP1 2a concerning SSB 501a, P-TRS 502a, DMRS of PDSCH 503a, DMRS of PDCCH 504a and CSI-RS for CSI 505a are similar to those explained with respect to Fig. 5a. Thus, the corresponding explanations apply also to Fig. 5b.

In the given single-DCI mode example, the UE 1 does not receive PDCCH from TRP2 2b but only from TRP1 2a. The QCL relationships for TRP2 2b reflect this in that the DMRS for PDCCH is not considered. For the remaining QCL relationships of SSB 501b, P-TRS 502b, DMRS of PDSCH 503b and CSI-RS for CSI 505b the explanations made above apply.

Fig. 6 is a schematic drawing showing three example beam management procedures.

The beam management may be specified in 3 procedures that may be, e.g., controlled by the network: Procedure#1 (P1), Procedure#2 (P2) and Procedure#3 (P3), as described, for example, in 3GPP TS 38.214 V.17.5.0, section 5.1.5 (TCI and QCL framework) and 5.1.6 (CSI-RS reception procedures).

The three procedures are illustrated in Figure 6. They may be supported within one or multiple TRPs of the serving cell.

P1 may be used to enable UE 1 measurement on different TRP Tx beams 601 to support selection of TRP Tx beam(s) 601 and/or UE 1 Rx beam(s). In Fig. 1, the TRP is shown as network entity 2. There may be any number K of TRP Tx beams 601. By way of example, two TRP Tx beams 601 SSB2 and SSBn are shown in Fig. 6. The UE 1 Rx beam(s) are exemplarily shown as A1 to A4.

For beamforming at TRP, P1 may include an intra/inter-TRP Tx beam sweep from a set of different beams 601, e.g., SSB2 and SSBn. There may be a defined relationship between each Tx beam (e.g., SSB2, SSBn) and a corresponding RACH occasion. Accordingly, the UE 1 may transmit a PRACH on the RACH occasion corresponding to the selected Tx beam so that the network entity 2 may be able to detect which Tx beam the UE 1 has selected.

For beamforming at UE 1, P1 may include a UE 1 Rx beam sweep from a set of different beams, e.g., beams A1 to A4. UE 1 may scan its antennas/panels sequentially for each SS burst and, optionally, average over e.g. 3 samples. An example of the sweep at the UE is shown as part of the best UE array selection process 603.

P2 may be used to enable UE 1 measurement on different TRP Tx beams 611 to possibly change inter/intra-TRP Tx beam(s) 611. The selection of a TRP Tx beam 611 may possibly be from smaller set of beams 611 for beam refinement than in P1. Note that P2 can be a special case of P1. P2 may use narrower CSI beams 611 (shown by way of example as CSI1, CSI2, CSI3, CSI4 in Fig. 1) compared to SSB beams (shown by way of example as SSB2, SSBn in Fig. 6). The UE 1 may keep its beam constant during the TRP Tx beam measurements. After the measurement on the different TRP Tx beams 611, UE 1 may report 612 information related to one or more of the TRP Tx beams 611, e.g., a preferred beam.

P3 may be used to enable UE 1 measurement on a same TRP Tx beam 621 (shown by way of example as CSI3 in Fig. 1) to change UE 1 Rx beam 622, e.g., in the case UE 1 uses beamforming (e.g. mmW arrays on UEs for FR2 operation). P3 may use aperiodic CSI-RS with 'repetition' flag 'on' and/or UE L1-RSRP/SINR reporting may be disabled.

Various embodiments may be particularly useful in reporting for P2. UE measurements on different TRP TX beams, e.g., as done in P2, may be done on reference signals. For example, one or more RSs (e.g., DL-RSs of the first and/or second set of DL-RSs) may be transmitted using parameters that configure a specific beam 611. The UE 1 may monitor these DL-RSs transmitted using different beams 611.

It may be specified which reference signals are going to be transmitted. For example, in TS38.214, CSI-ResourceConfig may specify what type of reference signal (e.g., nzp-CSI-RS-SSB, csi-IM-Resource) is to be transmitted. It may also configure the types of the transmission (periodic, aperiodic, semipersistent). A parameter (e.g., reportConfigType) may indicate a scheduling method of the report. It can be periodic, aperiodic and semi-persistent as shown in the table below. The table below shows an example of triggering/activation of CSI Reporting for possible CSI-RS Configurations.

CSI-RS Configuration	Periodic CSI Reporting	Semi-Persistent CSI Reporting	Aperiodic CSI Reporting
Periodic CSI-RS	No dynamic triggering/activation	For reporting on PUCCH, the UE receives an activation command, e.g., as described in clause 6.1.3.16 of TS 38.321; for reporting on PUSCH, the UE receives triggering on DCI	Triggered by DCI; additionally, subselection indication as described in clause 6.1.3.13 of TS 38.321 possible as defined in clause 5.2.1.5.1 of TS 38.214.
Semi-Persistent CSI-RS	Not supported	For reporting on PUCCH, the UE receives an activation command, e.g., as described in clause 6.1.3.16 of TS 38.321; for reporting on PUSCH, the UE receives triggering on DCI	Triggered by DCI; additionally, subselection indication as described in clause 6.1.3.13 of TS 38.321 possible as defined in clause 5.2.1.5.1 of TS 38.214.
Aperiodic CSI-RS	Not supported	Not supported	Triggered by DCI; additionally, subselection indication as described in clause 6.1.3.13 of TS 38.321 possible as defined in clause 5.2.1.5.1 of TS 38.214.

As described before, reference signals may be quasi co-located. For the definition and/or configuration of the QCL relationships TCI states may be used.

Fig. 7 is a schematic drawing showing a TCI state configuration 700. The example shown in Fig. 7 comprises various elements and relationships, some of them as defined in Release 17/18 of 3GPP standardization.

There is a pool of TCI states 710 configured by RRC layer, e.g., using RRC messages. These TCI states 710 may be referred to as "configured TCI states". The pool of TCI states 710 may comprise or consist of up to 128 DL/UL TCI states 711 for joint configuration of DL and UL. Alternatively (or even additionally), it may comprise or consist of separate configurations for DL and UL. For example, the pool of TCI states 710 may comprise up to 64 or 128 DL TCI states 712 and/or up to 32 or 64 UL TCI states. It is to be understood that any other number of TCI states may be applicable.

The UE can be configured with a list of the up to M (e.g., 128) TCI-State configurations. For example, this may be done within the higher layer parameter dl-OrJointTCI-StateList in PDSCH-Config, e.g, for providing a reference signal for the quasi co-location for DM-RS of PDSCH and DM-RS of PDCCH in a BWP/CC, for CSI-RS, and/or to provide a reference, if applicable, for determining UL TX spatial filter for dynamic-grant and/or configured-grant based PUSCH and/or PUCCH resource in a BWP/CC, and/or SRS.

In addition to the pool of configured TCI states 710, Fig. 7 shows a pool of up to 8 activated codepoints. These may correspond to up to 8 TCI states 720 that are also in the pool of configured TCI states 710 but, additionally, have been activated, e.g., by a MAC layer (for example, by MAC-CE signaling). For example, the UE may receive an activation command. The activation process may involve a MAC activation latency. The TCI states of pool 720 may be referred to as "activated TCI states" or "active TCI states".

The pool of activated TCI states 720 may comprise or consist of up to 8 DL/UL TCI states 721 for joint configuration of DL and UL. Alternatively (or even additionally), it may comprise or consist of separate configurations for DL and UL. For example, the pool of TCI states 720 may comprise up to 8 DL TCI states 712 and/or up to 8 UL TCI states and/or up to 8 TCI states that are either UL TCI states or DL TCI states. It is to be understood that any other number of TCI states may be applicable.

Fig. 7 further shows up to two indicated TCI states 723. These up to two indicated TCI states may be joint TCI states for UL and DL or separate TCI states for UL and DL. A UE 1 may receive configuration information (e.g., DCI) indicating the one or more "indicated TCI states" 723. UE 1 may apply these one or more indicates TCI states for reception and/or transmission of information, e.g., for PDCCH reception. For example, UE 1 may apply a beamforming configuration according to the one or more indicated TCI states. This application may involve some beam application time. The indication may be done by DCI, e.g., UE 1 may receive DCI (e.g., format 1_1/1_2) providing indicated TCI-State and/or TCI-UL-State.

TCI states, e.g., from the activated TCI states 723, may be configured for CSI reporting. However, CSI reporting may have to be triggered by the network, as shown in the table above relating to the triggering/activation of CSI Reporting for possible CSI-RS Configurations.

There may be use cases where UE could benefit from initiating the beam reporting and/or initiating a beam switch. The UE-initiated TCI-state/beam reporting/switch feature may refer to the case where the UE may be configured with at least one event/condition. The UE may start TCI-state/beam reporting/switch if this at least one event/condition occurs or is satisfied.

Rel-19 MIMO work item description, as specified in RP-234007, "New WID: NR MIMO Phase 5", is as follows:

Specify enhancement to facilitate UE-initiated/event-driven beam management for reducing overhead and/or latency, assuming the unified TCI while leveraging (as much as possible) legacy CSI measurement and reporting configuration frameworks, targeting FR2 and sTRP with intra- and inter-cell beam management

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

In view of this work item description, it has to be noted that the UE-initiated reports can give the opportunity to the UE of reporting to network beams that are better suited to UE, from the UE perspective (e.g. in case of blockage, rotation, high speed) that network, for example, did not include in the pool of active TCI states (and/or which are, for example, not configured for CSI reporting).

The UE-initiated report can be associated with a CSI reporting configuration. Additionally or alternatively, a UE-initiated report can be configured to operate at least partially independent from any specific CSI reporting configuration (e.g., UE-initiated report can be generally applicable without always associating it to a CSI report configuration).

In a first approach, the CSI report associated RS resource set can be considered as the RS resource set for the UE-initiated beam reporting. However, the UE may be limited only to measure and initiate UE-side beam reports with sub-optimal freedom because the NW, in order to control the size of the CSI report, may limit the RS resource set and may hence limit the number of beams available for measurements and reporting.

In a second approach, the configuration parameters, such as RS resources that are applicable for UE-initiated beam reporting, shall be known to the UE not only to monitor those RS resources over time to initiate any reports, but also to dimension the reporting quantities (e.g., CRI bit field size). How to configure or determine the exact RS resource set applicable for the UE-initiated beam reporting is currently not known for the second approach and various embodiments address that.

In both approaches the number of RS resources are configured by the NW. However, the goal may be to increase/maximize/balance the amount of RSs known to the UE such that more flexibility is available at the UE side, for example in order to get the best RS measurements.

Fig. 8 is a flowchart showing an example embodiment of a process 800, e.g., performed by an apparatus, for example a user equipment.

Step 801 comprises receiving a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states.

Step 802 comprises monitoring the first set of DL-RSs.

Step 803 comprises receiving a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs.

Step 804 comprises monitoring the second set of DL-RSs in addition to the first set of DL-RSs.

Step 805 comprises autonomously reporting information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

It has to be understood that other steps may happen before, in between, or after steps 801 to 805, and that another order of steps is possible.

Fig. 9 is a flowchart showing an example embodiment of a process 900, e.g., performed by an apparatus, for example a network entity.

Step 901 comprises transmitting a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states.

Step 902 comprises transmitting a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs.

Step 903 comprises receiving autonomously reported information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

It can be seen that step 901 corresponds to step 801, but from different perspectives. The same is true for steps 902, 903 and 803, 805, respectively.

It has to be understood that in process 900 other steps may happen before, in between, or after steps 901 to 903, and that another order of steps is possible.

Fig. 10 is a schematic drawing showing a TCI state configuration 1000 including a pool of DL-RSs for UE-initiated reports.

By way of example, the TCI state configuration 1000 is similar to the TCI state configuration 700 in various aspects so that same numerals have been chosen for various aspects. Moreover, in the following the apparatus of the first example aspect is, by way of example, a UE, and the apparatus of the second example aspect is, by way of example, a network entity (or simply "network").

Different from the TCI state configuration in Fig. 7, the TCI state configuration 1000 comprises a UE-initiated reports configuration 10.

The network may configure UE with a pool of DL-RSs specific for UE-initiated reports (also referred to as second set of DL-RS herein). The network may decide whether this pool should be the pool of DL-RS already used for the periodic (or aperiodic or semi-persistent) CSI-reports, whether this pool should be the pool of DL-RSs corresponding to the activated TCI states 720 or whether this should be a larger pool, e.g. including also configured TCI states that are not activated, e.g., 128 for joint TCI DL/UL (as shown in 711) or 64+32 for separate TCI DL and UL (as shown in 712, 713) or including activated TCI states that are not configured for CSI reporting. Either way, the UE may receive the configuration of the pool of DL-RS to be monitored and used for UE-initiated reports.

The UE could use the same pool as the pool configured for periodic CSI-reports. However, this might be a sub-optimal DL-RS configuration for UE-initiated reports since it gives the UE only limited additional flexibility as to which DL-RSs are monitored and/or for which there is UE-initiated reporting in addition to those for which there is CSI reporting.

Fig. 11 a schematic drawing showing TCI state configuration 1100 including another pool of DL-RSs for UE-initiated reports.

Again, the TCI state configuration 1100 is similar to the TCI state configuration 700 in various aspects so that same numerals have been chosen for various aspects.

Different from Figs. 7 and 10, Fig. 11 shows, by way of example, that the pool of DL-RS for UE-initiated reports is selected from the pool of configured TCI states 710.

In one embodiment, the pool of configured TCI states (e.g., completely) is taken as pool of DL-RS for UE-initiated reports. Thus, in one embodiment, the network may indicate to the UE a pool of DL-RS for UE-initiated reporting (e.g., in UE-initiated reports configuration 10) that include all configured TCI states 710. This embodiment may outperform the baseline sub-optimal scenario of Fig. 10 where (e.g., only) activated TCI states (or TCI states configured for CSI reporting) were to be reported for the UE-initiated reporting.

In another embodiment, a UE may be capable to monitor a limited number of DL-RS for UE-initiated reporting. This may limit then the dimension in terms of TCI states that could be part of such pool. Note that the number of DL-RSs for UE-initiated reporting that a UE can monitor could be either pre-defined or a UE capability (that can, for example, be reported to the network).

In another embodiment, the network may indicate to the UE a pool of DL-RSs for UE-initiated reporting that include only a subset of the TCI states that are configured and/or only a subset of the TCI states that are configured and not activated. This solution may be beneficial for example in case UE can monitor a limited number of TCI states, and CSI reporting (e.g., for the activated TCI states) is frequent enough. In such a scenario, the network may always have up-to-date information about the activated TCI states, and therefore may use the pool of DL-RS for UE-initiated reporting (e.g., only) for TCI states for which it does not have such up-to-date information.

In another embodiment, the network may indicate to the UE a pool of DL-RS for UE-initiated reporting that include both TCI states that are configured (but not activated) and TCI states that are activated. This solution may be beneficial for example in case CSI reporting (e.g., for the activated TCI states) is not frequent enough, for instance with high mobile UEs. In such scenario, the network may:

- either add to the list of active TCI states 720 a configured (but not active) TCI that is preferred by the UE in the UE-initiated report;
- or indicate an active TCI state that is preferred by the UE in the UE-initiated report (e.g., make it an indicated TCI state for use in downlink and/or uplink communication 723, e.g., by transmitting corresponding DCI to the UE).

In another embodiment, the network may indicate to the UE a pool of DL-RS for UE-initiated reporting that is larger than the pool of configured TCI states 710 (or includes at least one element that is not included in the pool of configured TCI states 710). For example, it may include one or more RSs that are associated with configured TCI states and one or more RSs that are not associated with configured TCI states. This solution may provide the largest number of RSs and leaves to the UE the monitoring of their quality and/or inference of the TCI assumptions in case they are not available for some of the

configured RSs. Inference of the TCI assumptions may be possible at the UE with techniques such as AIML.

Various embodiments described herein are highly beneficial. If the UE can monitor more TCI states than the ones included in the active list, then UE can inform network through UE-initiated reports that a more suited beam should now be monitored, added to active TCI and/or eventually switched to. This may lead to better performance, avoid potential failures and UE impairments can potentially be mitigated by switching to a new TCI state.

Fig. 12 is a flowchart showing steps of a process 1200 for a user equipment according to an example embodiment.

Step 1201 comprises that a UE is configured for periodic CSI reports.

Step 1202 comprises that the UE is configured with a pool of active TCI states for periodic CSI reports.

Note that while the UE behavior is shown in this example for periodic CSI reports, the same is valid for aperiodic and for semi-persistent CSI reports.

Steps 1201 and 1202 are an example for transmitting, e.g., by a network entity, and receiving, by a UE, a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states.

Step 1203 comprises that the UE is configured for UE-initiated reports.

Step 1204 comprises that the UE is configured with a pool of configured TCI states (and associated DL-RS) for UE-initiated reports.

By way of example, the pool of TCI states for UE-initiated reports may be the entire pool of configured TCI states. However, as described before, the pool of TCI states for UE-initiated reports may be, for instance, a subset of the entire pool of configured TCI states. Alternatively, it may correspond to the pool of activated TCI states, a subset of the pool of activated TCI states, a pool of configured TCI states that are not activated, a subset of the pool of configured TCI states that are not activated, or a pool of TCI states selected from one or more of the aforementioned pools.

In various embodiments, the pool of TCI states for UE-initiated reports may be selected so that it complements the pool of TCI states for CSI reporting.

For example, the pool of TCI states for CSI reporting may correspond to a pool of TCI states activated by a medium access control, MAC, layer, and the pool of TCI states for UE-initiated reporting may be selected from a pool of TCI states configured by a radio resource control, RRC, layer. Specifically, the pool of TCI states for UE-initiated reporting may correspond to a pool of TCI states configured by the RRC layer and not currently activated by the MAC layer or correspond to the (e.g., entire) pool of TCI states configured by the RRC layer.

As an alternative example, the pool of TCI states for CSI reporting may correspond to a subset of a pool of TCI states activated by a MAC layer, and the pool of TCI states for UE-initiated reporting may be selected from the pool of TCI states activated by the MAC layer and/or from a pool of TCI states configured by an RRC layer. For instance, the pool of TCI states for UE-initiated reporting may correspond to a pool of TCI states activated by the MAC layer and not belonging to the subset, may correspond to the (e.g., entire) pool of TCI states activated by the MAC layer, may correspond to a pool of TCI states configured by the RRC layer and not belonging to the subset, or may correspond to the (e.g., entire) pool of TCI states configured by the RRC layer.

Steps 1203 and 1204 are an example of transmitting, e.g., by a network entity, and receiving, e.g., by a UE, a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs.

Step 1205 comprises that the UE reports periodically among pool of active TCI states. This reporting is part of the CSI reporting. As mentioned before, the periodicity is optional as the CSI reporting can instead be aperiodic and semi-persistent. The UE may have monitored the first set of DL-RSs to perform the reporting of step 1205.

Step 1206 comprises that the UE reports event-based on the pool of configured TCI states. Event-based may mean that the UE autonomously decides whether to report on the pool of configured TCI states. Further, it may mean that the UE may have determined preferred one or more DL-RSs and/or TCI states that it reports. Clearly, the UE may have monitored the second set of DL-RSs to determine any preferred DL-RSs and/or to determine whether any event-based reporting is to be done.

Step 1206 is an example of autonomously reporting, e.g., by the UE to the network, information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

Fig. 13 is a flowchart showing steps of a process 1300 for a system according to an example embodiment. The system may comprise a network, NW, (whose actions may be performed by one or more network entities) and a UE.

Step 1301 comprises that the NW receives one or more UE-initiated reports. These one or more UE-initiated reports may comprise or contain one or more DL-RSs (e.g., from among the second set of DL-RSs) preferred by the UE, e.g., represented by one or more beam indices.

The NW may determine a new candidate TCI state to be activated by a MAC layer based on the reported information related to the one or more preferred DL-RSs. For example, NW may in step 1302 add a new TCI state to the list of active TCI states. The NW may transmit information indicating the new activated TCI state and/or the new list of active TCI states to the UE. This may imply that a source RS associated with the new activated TCI state is added to the first set of DL-RSs for CSI reporting.

In step 1303 UE may report on the new TCI state with periodic CSI reports. While the network behavior in this example is shown for periodic CSI reports, the same is valid for aperiodic and for semi-persistent CSI reports.

Based on the CSI reports on the new TCI state (and/or the associated source RS), the NW may determine a new indicated TCI state for use in downlink and/or uplink communication. The network may transmit information (e.g., downlink control information, DCI) indicating the new TCI state for use in downlink and/or uplink communication to the UE. For example, in step 1304 the NW may decide to switch the indicated TCI state (associated, for example, with an indicated beam) to the new TCI state.

The result of the process 1300 may be that the UE performance is improved in step 1305, e.g., because the new indicated TCI state (and, e.g., the associated beam) used for downlink and/uplink communication improves the link quality and/or connectivity.

In the present specification, any presented connection in the described embodiments is to be understood in a way that the involved components are operationally coupled. Thus, the connections can be direct or indirect with any number or combination of intervening elements, and there may be merely a functional relationship between the components.

Fig. 14 shows a schematic block diagram of an example of an apparatus 1400, e.g., a UE or a network entity, according to any example aspect.

Apparatus or network entity 1400 comprises a processor 1401, program memory 1402, working or main memory 1403, data memory, communication interface(s) 1404, and an optional user interface 1405.

Apparatus 1400 may for instance be configured to perform and/or control or comprise respective means (at least one of 1401 to 1405) for performing and/or controlling the method according to the any example aspect. Apparatus 1400 may as well constitute a UE or network entity comprising at least

one processor (1401) and at least one memory (1402) storing instructions that, when executed by the at least one processor, cause a UE or network entity at least to perform and/or control the method according to any or all example aspects.

Processor 1401 may for instance control at least one of the memories 1402 to 1403, the communication interface(s) 1404, and/or the optional user interface 1405.

Processor 1401 may for instance execute program code stored in program memory 1402, which may for instance represent a readable storage medium comprising program code that, when executed by processor 1401, causes the processor 1401 to perform the method according to any example aspect.

Processor 1401 (and also any other processor mentioned in this specification) may be a processor of any suitable type. Processor 1401 may comprise but is not limited to one or more microprocessor(s), one or more processor(s) with accompanying one or more digital signal processor(s), one or more processor(s) without accompanying digital signal processor(s), one or more special-purpose computer chips, one or more field-programmable gate array(s) (FPGA(s)), one or more controller(s), one or more application-specific integrated circuit(s) (ASIC(s)), or one or more computer(s)/server(s). The relevant structure/hardware has been programmed in such a way to carry out the described function. Processor 1401 may for instance be an application processor that runs an operating system.

Program memory 1402 may also be included into processor 1401. This memory may for instance be fixedly connected to processor 1401, or be at least partially removable from processor 1401, for instance in the form of a memory card or stick. Program memory 1402 may for instance be non-volatile memory. It may for instance be a FLASH memory (or a part thereof), any of a ROM, PROM, EPROM and EEPROM memory (or a part thereof) or a hard disc (or a part thereof), to name but a few examples. Program memory 1402 may comprise an operating system for processor 1401. Program memory 1402 may comprise a firmware for apparatus or network entity 1400.

Communication interface(s) 1404 enable the apparatus 1400 to communicate with other entities, e.g., one or more UE or one or more network entities. The communication interface(s) 1404 may for instance comprise a wireless interface, e.g., a cellular radio communication interface and/or a WLAN interface) and/or wire-bound interface, e.g., an IP-based interface, for instance to communicate with entities via the Internet. Communication interface(s) may enable apparatus 1400 to communicate with other entities, for instance one or more entities as comprised in a mobile communication network.

User interface 1405 is optional and may comprise a display for displaying information to a user and/or an input device (e.g. a keyboard, keypad, touchpad, mouse, etc.) for receiving information from a user.

Some or all of the components of the apparatus 1400 may for instance be connected via a bus. Some or all of the components of the apparatus or network entity 1400 may for instance be combined into one or more modules.

An apparatus 1400 may further comprise at least one of the following: a receiver, e.g., for receiving information, e.g., from a network entity or a UE; a transmitter, e.g., for transmitting information, e.g., to a network entity or UE; an monitorer, e.g., for monitoring a set of DL-RSs; a reporter e.g., for reporting (for example, autonomously) information; and/or a determiner, e.g., for determining one or more preferred DL-RSs.

Moreover, any of the methods, processes and actions described or illustrated herein may be implemented using executable instructions in a general-purpose or special-purpose processor and stored on a computer-readable storage medium (e.g., disk, memory, or the like) to be executed by such a processor. References to a 'computer-readable storage medium' should be understood to encompass specialized circuits such as FPGAs, ASICs, signal processing devices, and other devices.

The expression "A and/or B" is considered to comprise any one of the following three scenarios: (i) A, (ii) B, (iii) A and B. Furthermore, the article "a" is not to be understood as "one", i.e., use of the expression "an element" does not preclude that also further elements are present. The term "comprising" is to be understood in an open sense, i.e., in a way that an object that "comprises an element A" may also comprise further elements in addition to element A. Further, the term "comprising" may be understood to also disclose "consisting of", i.e., consisting of only the specified elements.

The expression "at least one of the following: <a list of two or more elements>" and "at least one of <a list of two or more elements>" and similar wording, where the list of two or more elements are joined by "and" or "or", mean at least any one of the elements, or at least any two or more of the elements, or at least all the elements.

It will be understood that all presented embodiments are only examples, and that any feature presented for a particular example embodiment may be used with any aspect on its own or in combination with any feature presented for the same or another particular example embodiment and/or in combination with any other feature not mentioned. In particular, the example embodiments presented in this specification shall also be understood to be disclosed in all possible combinations with each other, as far as it is technically reasonable and the example embodiments are not alternatives with respect to each other. It will further be understood that any feature presented for an example embodiment in a particular category (method/apparatus/computer program/system) may also be used in a corresponding manner in an example embodiment of any other category. It should also be

understood that presence of a feature in the presented example embodiments shall not necessarily mean that this feature forms an essential feature and cannot be omitted or substituted.

The statement of a feature comprises at least one of the subsequently enumerated features is not mandatory in the way that the feature comprises all subsequently enumerated features, or at least one feature of the plurality of the subsequently enumerated features. Also, a selection of the enumerated features in any combination or a selection of only one of the enumerated features is possible. The specific combination of all subsequently enumerated features may as well be considered. Also, a plurality of only one of the enumerated features may be possible.

The sequence of all method steps presented above is not mandatory, also alternative sequences may be possible. Nevertheless, the specific sequence of method steps exemplarily shown in the drawings shall be considered as one possible sequence of method steps for the respective embodiment described by the respective drawing.

The subject-matter has been described above by means of example embodiments. It should be noted that there are alternative ways and variations which are obvious to a skilled person in the art and can be implemented without deviating from the scope of the appended claims.

List of abbreviations:

3GPP	Third Generation Partnership Project
5G	5-th Generation
AIML	Artificial Intelligence and Machine Learning
BWP	Bandwidth Part
CC	Component Carrier
CQI	Channel Quality Indicator
CRI	CSI-RS Resource Indicator
CSI	Channel State Information
DCI	Downlink Control Information
DL	Downlink
DM-RS	Demodulation Reference Signal
FR	Frequency Range
gNB	next generation NodeB
IE	Information element
L1	Layer 1
LI	Layer indicator
MAC	Medium Access Control
MAC-CE	MAC Control Element
mTRP	multi TRP

NZP-CSI-RS	non-zero power CSI-RS
NW	Network
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRACH	Physical RACH
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QCL	Quasi co-location
RAN	Radio Access Network
PMI	Precoding Matric Indicator
P-TRS	Periodic TRS
RACH	Random Access Channel
RI	Rank Indicator
RS	Reference Signal
RRC	Radio Resource Control
RSRP	Reference signal received power
RSRQ	Reference signal received quality
RSSI	Received signal strength indicator
RX	Receiver
SINR	Signal to interference plus noise ratio
SRS	Sounding reference signal
SS	Synchronization Signal
SSB	SS/PBCH block
SSBRI	SSB Resource Indicator
sTRP	single TRP
TCI	Transmission Configuration Indicator
TRP	Transmission and Reception Point
TRS	Tracking Reference Signal
TX	Transmitter
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink

Claims

1. An apparatus comprising:

means for receiving a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

means for monitoring the first set of DL-RSs;

means for receiving a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

means for monitoring the second set of DL-RSs in addition to the first set of DL-RSs; and

means for autonomously reporting information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

2. The apparatus according to claim 1, wherein the first set of TCI states corresponds to a pool of TCI states activated by a medium access control, MAC, layer, and the second set of TCI states are selected from a pool of TCI states configured by a radio resource control, RRC, layer.

3. The apparatus according to claim 2, wherein the second set of TCI states corresponds to a pool of TCI states configured by the RRC layer and not currently activated by the MAC layer.

4. The apparatus according to claim 2, wherein the second set of TCI states corresponds to the pool of TCI states configured by the RRC layer.

5. The apparatus according to claim 1, wherein the first set of TCI states corresponds to a subset of a pool of TCI states activated by a MAC layer, and the second set of TCI states are selected from the pool of TCI states activated by the MAC layer and/or from a pool of TCI states configured by an RRC layer.

6. The apparatus according to claim 5, wherein the second set of TCI states corresponds to a pool of TCI states activated by the MAC layer and not belonging to the subset.

7. The apparatus according to claim 5, wherein the second set of TCI states corresponds to the pool of TCI states activated by the MAC layer.

8. The apparatus according to claim 5, wherein the second set of TCI states corresponds to a pool of TCI states configured by the RRC layer and not belonging to the subset.

9. The apparatus according to claim 5, wherein the second set of TCI states corresponds to the pool of TCI states configured by the RRC layer.

10. The apparatus according to any one of the preceding claims, wherein the second set of TCI states includes the first set of TCI states.

11. The apparatus according to any one of the preceding claims, wherein the apparatus further comprises means for transmitting capability information indicating a maximum number of DL-RSs that the apparatus is able to monitor for the UE-initiated reporting.

12. The apparatus according to any one of the preceding claims, wherein the monitoring of the second set of DL-RSs further comprises determining at least one of:

- one or more reference signal received powers, RSRPs, for the second set of monitored DL-RSs;
- one or more received signal strength indicators, RSSIs, for the second set of monitored DL-RSs;
- one or more reference signal received qualities, RSRQs, for the second set of monitored DL-RSs;
- one or more signal to interference plus noise ratios, SINRs, for the second set of monitored DL-RSs;
- a channel-quality indicator, CQI, for downlink communication;
- a rank indicator, RI, for downlink communication; or
- a precoder-matrix indicator, PMI, for downlink communication.

13. The apparatus according to any one of the preceding claims, wherein the apparatus further comprises means for determining the one or more preferred DL-RSs by determining that the one or more preferred DL-RSs are better or offset better than at least one of:

- a DL-RS that is configured as a source RS of a TCI state of a pool of TCI states activated by a MAC layer; or
- a DL-RS that is configured as a source RS of a TCI state indicated for use in downlink and/or uplink communication.

14. The apparatus according to any one of the preceding claims, wherein the one or more preferred DL-RSs correspond to N best monitored DL-RSs from the second set of monitored DL-RSs, wherein N is a positive integer.

15. The apparatus according to any one of the preceding claims, wherein the apparatus further comprises means for receiving information indicating a new TCI state activated by a MAC layer,

the new TCI state being based on the reported information related to the one or more preferred DL-RSs.

16. The apparatus according to any one of the preceding claims, wherein the apparatus further comprises means for receiving downlink control information, DCI, indicating a new TCI state for use in downlink and/or uplink communication, the new indicated TCI state being based on the reported information related to the one or more preferred DL-RSs.

17. The apparatus according to any one of the preceding claims, wherein the apparatus further comprises at least one of:

- means for sending the information related to the one or more preferred DL-RSs via a physical uplink control channel, PUCCH, as part of uplink control information, UCI;
- means for sending the information related to the one or more preferred DL-RSs via a physical uplink shared channel, PUSCH, as part of UCI;
- means for transmitting a scheduling request, and means for sending the information related to one or more preferred DL-RSs via a PUSCH scheduled in response to the scheduling request as part of UCI;
- means for sending the information related to one or more preferred DL-RSs via MAC signaling; or
- means for sending the information related to one or more preferred DL-RSs via RRC signaling.

18. The apparatus according to any one of the preceding claims, wherein the information related to the one or more preferred DL-RSs is autonomously reported in response to determining that one or more pre-defined events have occurred for the one or more respective preferred DL-RSs.

19. The apparatus according to any one of the preceding claims, wherein the CSI reporting is a semi-persistent or periodic CSI reporting.

20. The apparatus according to any one of the preceding claims, wherein the first set of TCI states and the second set of TCI states comprise one or more of downlink TCI states, uplink TCI states, or joint downlink/uplink TCI states.

21. An apparatus comprising:

means for transmitting a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

means for transmitting a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

means for receiving autonomously reported information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

22. The apparatus according to claim 21, wherein the apparatus further comprises:

means for determining the first set of TCI states as corresponding to a pool of TCI states activated by a medium access control, MAC, layer; and

means for selecting the second set of TCI states from a pool of TCI states configured by a radio resource control, RRC, layer.

23. The apparatus according to claim 22, wherein the apparatus further comprises means for determining the second set of TCI states as corresponding to a pool of TCI states configured by the RRC layer and not currently activated by the MAC layer.

24. The apparatus according to claim 22, wherein the apparatus further comprises means for determining the second set of TCI states as corresponding to the pool of TCI states configured by the RRC layer.

25. The apparatus according to claim 21, wherein the apparatus further comprises:

means for determining the first set of TCI states as corresponding to a subset of a pool of TCI states activated by a MAC layer; and

means for selecting the second set of TCI states from the pool of TCI states activated by the MAC layer and/or from a pool of TCI states configured by an RRC layer.

26. The apparatus according to claim 25, wherein the apparatus further comprises means for determining the second set of TCI states as corresponding to a pool of TCI states activated by the MAC layer and not belonging to the subset.

27. The apparatus according to claim 25, wherein the apparatus further comprises means for determining the second set of TCI states as corresponding to the pool of TCI states activated by the MAC layer.

28. The apparatus according to claim 25, wherein the apparatus further comprises means for determining the second set of TCI states as corresponding to a pool of TCI states configured by the RRC layer and not belonging to the subset.

29. The apparatus according to claim 25, wherein the apparatus further comprises means for determining the second set of TCI states as corresponding to the pool of TCI states configured by the RRC layer.

30. The apparatus according to any one of claims 21 to 29, wherein the apparatus further comprises means for determining the second set of TCI states as including the first set of TCI states.

31. The apparatus according to any one of claims 21 to 30, wherein the apparatus further comprises:

means for receiving capability information indicating a maximum number of DL-RSs that an apparatus is able to monitor for the UE-initiated reporting; and

means for determining the UE-initiated reporting configuration based on the received capability information.

32. The apparatus according to any one of claims 21 to 31, wherein the UE-initiated reporting configuration indicating the second set of DL-RSs to monitor for UE-initiated reporting indicates that the monitoring comprises determining at least one of:

- one or more reference signal received powers, RSRPs, for the second set of DL-RSs;
- one or more received signal strength indicators, RSSIs, for the second set of DL-RSs;
- one or more reference signal received qualities, RSRQs, for the second set of DL-RSs;
- one or more signal to interference plus noise ratios, SINRs, for the second set of DL-RSs;
- a channel-quality indicator, CQI, for downlink communication;
- a rank indicator, RI, for downlink communication; or
- a precoder-matrix indicator, PMI, for downlink communication.

33. The apparatus according to any one of claims 21 to 32, wherein the one or more preferred DL-RSs are better or offset better than at least one of:

- a DL-RS that is configured as a source RS of a TCI state of a pool of TCI states activated by a MAC layer; or
- a DL-RS that is configured as a source RS of a TCI state indicated for use in downlink and/or uplink communication.

34. The apparatus according to any one of claims 21 to 33, wherein the apparatus further comprises:

means for determining a new candidate TCI state to be activated by a MAC layer based on the reported information related to the one or more preferred DL-RSs; and

means for transmitting information indicating the new TCI state activated by the MAC layer.

35. The apparatus according to any one of claims 21 to 34, wherein the apparatus further comprises:

means for determining a new indicated TCI state for use in downlink and/or uplink communication based on the reported information related to the one or more preferred DL-RSs; and

means for transmitting downlink control information, DCI, indicating the new TCI state for use in downlink and/or uplink communication.

36. The apparatus according to any one of claims 21 to 35, wherein the CSI reporting is a semi-persistent or periodic CSI reporting.

37. The apparatus according to any one of claims 21 to 36, wherein the first set of TCI states and the second set of TCI states comprise one or more of downlink TCI states, uplink TCI states, or joint downlink/uplink TCI states.

38. A method comprising:

receiving a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

monitoring the first set of DL-RSs;

receiving a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

monitoring the second set of DL-RSs in addition to the first set of DL-RSs; and

autonomously reporting information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

39. A method comprising:

transmitting a channel state information, CSI, reporting configuration indicating a first set of downlink reference signals, DL-RSs, to monitor for CSI reporting, the first set of DL-RSs being configured as source RSs of a first set of transmission configuration indicator, TCI, states;

transmitting a UE-initiated reporting configuration indicating a second set of DL-RSs to monitor for UE-initiated reporting, the second set of DL-RSs being configured as source RSs of a second set of TCI states, and having at least one element not belonging to the first set of DL-RSs;

receiving autonomously reported information related to one or more preferred DL-RSs selected from the second set of monitored DL-RSs.

40. A computer program comprising instructions, which, when executed by an apparatus, cause the apparatus to perform the method of any one of claims 38 or 39.

41. A computer-readable storage medium having stored thereon the computer program of claim 40.