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Title: Maintenance for beam management
Agenda Item: 7.1.2.3
Document for: Discussion and Decision

1. Introduction

In this contribution, we discuss several remaining issues on beam measurement, beam reporting and beam failure recovery.

2. Discussion

2.1. Beam Management

2.1.1. CORESET #0 related issues

Regarding CORESET #0 reception, we have the following proposals.

Proposal 1:

- TCI state configurations should be allowed for CORESET #0.

Proposal 2:

- If TCI state configuration is not allowed for CORESET #0, UE is not expected to receive Type 3 CSS and UE-specific search space set in CORESET #0.
 - CORESET #0 should not be used as default QCL assumption for buffering data.
 - CORESET #0 should not be monitored for BFR.

2.1.2. DCI format 0_0 scheduled PUSCH beam

For PUSCH scheduled by DCI format 0_0, the spatial relation of PUSCH is determined according to the dedicated PUCCH resources but not common PUCCH resources. And the UE shall not expect PUSCH scheduled by DCI format 0_0 in a component carrier without configured PUCCH resource with PUCCH-SpatialRelationInfo in FR2 after initial access. So the spec needs to be modified in TS38.214 section 6.1. Moreover, current scheme is to use the lowest ID PUCCH beam within the active BWP for DCI format 0_0 scheduled PUSCH transmission. If there is no PUCCH configuration in the BWP, the DCI format 0_0 scheduled transmission should not be possible.

Proposal 3: Text proposal for 38.214 section 6.1.

< Unchanged parts are omitted >

For PUSCH scheduled by DCI format 0_0 on a cell, the UE shall transmit PUSCH according to the spatial relation, if applicable, corresponding to the **dedicated** PUCCH resource with the lowest ID within the active UL BWP of the cell, as described in sub-clause 9.2.1 of [6, TS 38.213].

< Unchanged parts are omitted >

Two transmission schemes are supported for PUSCH: codebook based transmission and non-codebook based transmission. The UE is configured with codebook based transmission when the higher layer parameter *txConfig* in *PUSCH-Config* is set to 'codebook', the UE is configured non-codebook based transmission when the higher layer parameter *txConfig* is set to 'nonCodebook'. If the higher layer parameter *txConfig* is not configured, the UE is not expected to be scheduled by DCI format 0_1. If PUSCH is scheduled by DCI format 0_0, the PUSCH transmission is based on a single antenna port. **After initial access, the UE shall not expect PUSCH scheduled by DCI format 0_0 in a ~~component carrier~~ BWP without configured PUCCH resource with PUCCH-SpatialRelationInfo in frequency range 2.**

< Unchanged parts are omitted >

2.1.3. Beam indication for AP-CSI-RS

There are following agreements regarding beam indication for AP-CSI-RS.

Agreement

NW may schedule an ap-CSI-RS with a shorter delay than a threshold, and the UE applies a default QCL assumption

- At least applies for CSI-RS for CSI acquisition
- All CSI-RS symbols in one resource set should be below the threshold or all CSI-RS symbols in one resource set should be above the threshold
- FFS: Default QCL assumption
- FFS: Exact threshold with reference to UE capability

Based on UE capability, AP-CSI-RS beam switching timing refers to the minimum time between the DCI triggering of AP-CSI-RS and aperiodic CSI-RS transmission, i.e. at least K_{Bi} symbols. For AP-CSI-RS for CSI acquisition, default QCL assumption can be the same as that for PDSCH, e.g. same scheduling offset threshold and same rule for QCL parameters (follow lowest CORESET-ID). But for AP-CSI-RS for beam management, it is not allowed to be triggered within the reported AP-CSI-RS beam switching timing.

Proposal 4:

- *Threshold and default QCL assumption for AP-CSI-RS for CSI acquisition are the same as that for PDSCH.*
- *For AP-CSI-RS for beam management, it is not allowed to be triggered within the reported AP-CSI-RS beam switching timing.*

2.1.4. Default Beam for PDCCH/ PUCCH/PUSCH

In the agreements each state of M candidate TCI states are RRC configured with a DL RS set used as a QCL reference. For PDSCH QCL indication, MAC-CE is used to select up to 8 TCI states out of M. The same set of M TCI states is reused for CORESET. When K>1 TCI states are configured per CORESET, MAC-CE can indicate which one TCI state to use for PDCCH QCL state. There is ambiguity that which TCI state is used for PDCCH QCL between RRC re-configuration and MAC-CE activation. So a default TCI state, e.g. the lowest entry of *TCI-StatesPDCCH*, can be introduced to provide the PDCCH QCL until MAC-CE activation.

Proposal 5:

- *The UE can assume the lowest entry of TCI-StatesPDCCH as default TCI state to provide the PDCCH QCL between RRC re-configuration and MAC-CE activation.*

In the agreement of RAN1 #93 meeting, if a UE does not have dedicated PUCCH resource configuration, the UE transmits the PUCCH using the same spatial domain transmission filter as for the Msg3 PUSCH transmission. For the PUCCH spatial relation after RRC re-configuration of a list of spatial relations in *PUCCH-SpatialRelationInfo* and before MAC-CE selection of one of the spatial relations in the list, the UE can assume a default spatial relation for PUCCH, e.g. the lowest entry of the list of spatial relation *PUCCH-SpatialRelationInfo*.

Proposal 6:

- *The UE can assume the lowest entry of PUCCH-SpatialRelationInfo as default spatial relation to provide the PUCCH QCL between RRC re-configuration and MAC-CE activation.*

There are several cases that default UL transmission beams should be specified. Before configuration of SRS/beam RRC configuration, the beam derived in initial access procedure could be used. The UE can assume PUSCH are spatially QCL-ed with msg3. PUSCH scheduling restriction by DCI format 0_0 due to lack of PUCCH spatial relation should be limited to 'after initial access' procedure.

Proposal 7:

- *Before RRC configuration, the UL transmission beam is derived from initial access procedure, i.e. the UE assumes PUSCH are spatially QCL-ed with Msg3.*

2.1.5. Cross-carrier beam indication

For the cross carrier scheduling, when TCI state is not configured or is configured 'disabled' for CORESET scheduling the PDSCH, the UE expects a default beam for PDSCH reception. For example, if both carriers are at high band, the PDSCH follows the PDCCH QCL indication; if PDCCH carrier is at low band and PDSCH

carrier is at high band, the pre-configured QCL indication or QCL indication of lowest CORESET ID can be used for the PDSCH reception.

When CORESET is not configured or TCI state is not configured for CORESET on PDSCH carrier, the UE expects a default beam for PDSCH reception. For example, if the time offset between the reception of the DL DCI and the corresponding PDSCH is less than a threshold, the default QCL can be used for PDSCH when there is an activated high band cell for PDCCH monitoring, or the pre-configured QCL can be used for PDSCH when there is no CORESET with 'enabled' TCI state configured on high band cell.

Proposal 8:

- For low band carrier scheduling high band carrier, when PDCCH in low band carrier configured without *tcj-PresentInDCI* 'enabled', UE uses the default data buffering beam to receive the PDSCH.
- For Scell in high band where there is no configured CORESET, the beam of CORESET with lowest ID in the Scell with lowest cell ID in the same band could be used for data buffering.

2.1.6. Text proposal for TS 38.214

There are some other parts not captured correctly in TS 38.214 section 5.1.5.

< Unchanged parts are omitted >

The UE receives an activation command [10, TS 38.321] used to map up to 8 TCI states to the codepoints of the DCI field '*Transmission Configuration Indication*'. When the HARQ-ACK corresponding to the PDSCH carrying the activation command is transmitted in slot n , the indicated mapping between TCI states and codepoints of the DCI field '*Transmission Configuration Indication*' should be applied starting from slot $n + 3N_{\text{slot}}^{\text{subframe},\mu} + 1$. After a UE receives initial higher layer configuration of TCI states and before reception of the activation command, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the SS/PBCH block determined in the initial access procedure with respect to 'QCL-TypeA', and when applicable, also with respect to 'QCL-TypeD'.

< Unchanged parts are omitted >

If the *tcj-PresentInDCI* is set as 'enabled', the TCI field in DCI in the scheduling component carrier points to the activated TCI states in the scheduled component carrier or DL BWP and when the PDSCH is scheduled by DCI format 1_1, the UE shall use the *TCI-State* according to the value of the '*Transmission Configuration Indication*' field in the detected PDCCH with DCI for determining PDSCH antenna port quasi co-location. The UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL type parameter(s) given by the indicated TCI state if the time offset between the reception of the DL DCI and the corresponding PDSCH is equal to or greater than a threshold ~~*timeDurationForQCL Threshold Sched-Offset*~~, where the threshold is based on reported UE capability [12, TS 38.331]. When the UE is configured with a single slot PDSCH, the indicated TCI state should be based on the activated TCI states in the slot with the scheduled PDSCH

For ~~both~~ the cases when *tcj-PresentInDCI* is set to 'enabled', ~~and~~ *tcj-PresentInDCI* is not configured in RRC connected mode ~~or the PDSCH is scheduled by a DCI format 1_0~~, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold ~~*timeDurationForQCL Threshold Sched-Offset*~~, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest ~~*CORESET-ID*~~ with TCI state configuration in the latest slot in which ~~search spaces on~~ one or more CORESETs within the active BWP of the serving cell are configured for the UE. If none of configured TCI states contains 'QCL-TypeD', the UE shall obtain the other QCL assumptions from the indicated TCI states for its scheduled PDSCH irrespective of the time offset between the reception of the DL DCI and the corresponding PDSCH.

< Unchanged parts are omitted >

There are also some other parts not captured correctly in TS38.214 section 5.2.1.4.

< Unchanged parts are omitted >

If the UE is configured with a *CSI-ReportConfig* with the higher layer parameter *reportQuantity* set to 'cri-RSRP' or 'ssb-Index-RSRP'

- if the UE is configured with the higher layer parameter *groupBasedBeamReporting* set to 'disabled', the UE is not required to update measurements for more than 64 CSI-RS ~~and/or~~ SSB resources, and the UE

shall report in a single report *nrofReportedRS* (higher layer configured) different CRI or SSBRI for each report setting.

- if the UE is configured with the higher layer parameter *groupBasedBeamReporting* set to 'enabled', the UE is not required to update measurements for more than 64 CSI-RS ~~and/or~~ SSB resources, and the UE shall report in a single reporting instance two different CRI or SSBRI for each report setting, where CSI-RS ~~and/or~~ SSB resources can be received simultaneously by the UE either with a single spatial domain receive filter, or with multiple simultaneous spatial domain receive filters.

< Unchanged parts are omitted >

2.1.7. Text proposal for TS 38.215

In TS38.215 section 5, the UE measurement capabilities for NR are specified. However not all physical layer measurement should be reported to higher layers, e.g. L1-RSRP for beam management. So there is a text proposal for TS38.215 section 5.

< Unchanged parts are omitted >

In this chapter the physical layer measurements ~~reported to higher layers~~ are defined.

< Unchanged parts are omitted >

2.2. Beam failure recovery

2.2.1. Beam failure detection

If the UE is not provided with higher layer parameter *failureDetectionResources*, and if RS index with QCL type D in the RS sets indicated by the TCI states for respective CORESETs is not on current active BWP, then there is an ambiguity about UE monitoring CORESETs for BFD. So the set \bar{q}_0 should be configured on current active BWP, or the RS index with QCL type D in the RS sets indicated by the TCI states for respective CORESETs is configured on current active BWP.

Proposal 9:

- *UE is not expected to be configured with RS for BFD in inactive BWP.*

2.2.2. Beam failure recovery request

When no RACH resources (including both CFRA and CBRA) are configured on the active BWP, the UE can switch to the initial BWP for PRACH transmission. If there are CORESET-BFR and CFRA on initial BWP, then UE can transmit CFRA and monitor CORESET-BFR on initial BWP. In this case UE does not expect to be configured with candidate beam RSs for monitoring.

Proposal 10:

- *If no RACH resource (including both CFRA and CBRA) are configured on active BWP and UE switches to initial BWP and starts BFR procedure in the initial BWP, UE is not expected to be configured with candidate beam RSs in the active BWP.*

2.2.3. Default PUCCH beam after successful BFR

There are following agreements regarding default PUCCH spatial relation after successful BFR.

Agreement

Downselect among the following two alternatives in RAN1#94bis

- Alt 1: K symbols after successfully receiving BFR gNB response, the PUCCH transmissions shall use the same spatial filter as the PRACH transmission until the UE receives an activation or reconfiguration of *PUCCH-Spatialrelationinfo* of at least one of configured PUCCH resources
 - o Note: The latency of RRC or MAC CE configuration is included as part of time duration for applying the same spatial filter as the PRACH transmission
 - o FFS: value of K

- Alt 4: K symbols after successfully receiving BFR gNB response, the transmissions of PUCCH resources for HARQ ACK/NACK feedback of a corresponding DL PDSCH scheduled from SearchSpace-BFR shall use the same spatial filter as the PRACH transmission until the UE receives a MAC-CE activation or reconfiguration of *PUCCH-Spatialrelationinfo* of at least one of configured PUCCH resources
 - o FFS: value of K
 - o Note: The latency of RRC or MAC CE configuration is included as part of time duration for applying the same spatial filter as the PRACH transmission

Based on these agreements, the spatial filter for PUCCH transmission after successful BFR should be clarified. These two alternatives introduce the PUCCH transmission restriction for the spatial relation, and the enhancement of performance robustness is not clear. By implementation, the network could configure UE with robust beams to avoid such problems.

Proposal 11:

- For PUCCH transmission after successful BFR, there is no need to change spec.

2.2.4. Text proposal for TS38.213

There are some other parts not captured correctly in TS38.213 section 6.

< Unchanged parts are omitted >

A UE can be provided, for a serving cell, with a set \bar{q}_0 of periodic CSI-RS resource configuration indexes by higher layer parameter *failureDetectionResources* and with a set \bar{q}_1 of periodic CSI-RS resource configuration indexes and/or SS/PBCH block indexes by higher layer parameter *candidateBeamRSList* for radio link quality measurements on the serving cell. If the UE is not provided with higher layer parameter *failureDetectionResources*, the UE determines the set \bar{q}_0 to include periodic CSI-RS resource configuration indexes with same values as the RS indexes associated with QCL type D in the RS sets indicated by higher layer parameter *TCI-states* for respective control resource sets on active BWP of the current cell that the UE uses for monitoring PDCCH. The UE expects the set \bar{q}_0 to include up to two RS indexes and, if there are two RS indexes in a TCI state, the set \bar{q}_0 includes RS indexes with QCL-TypeD configuration for the corresponding TCI states. The UE expects single port RS in the set \bar{q}_0 .

< Unchanged parts are omitted >

The physical layer in the UE provides an indication to higher layers when the radio link quality for all corresponding resource configurations in the set \bar{q}_0 that the UE uses to assess the radio link quality is worse than the threshold $Q_{out,LR}$. The physical layer informs the higher layers when the radio link quality is worse than the threshold $Q_{out,LR}$ with a periodicity determined by the maximum between the shortest periodicity among the periodic CSI-RS configurations and/or SS/PBCH blocks in the set \bar{q}_0 that the UE uses to assess the radio link quality and 2 msec.

< Unchanged parts are omitted >

The UE may receive by higher layer parameter *PRACH-ResourceDedicatedBFR*, a configuration for PRACH transmission as described in Subclause 8.1. For PRACH transmission in slot n and according to antenna port *spatial* quasi co-location parameters associated with periodic CSI-RS resource configuration or with SS/PBCH block associated with index q_{new} provided by higher layers [11, TS 38.321], the UE monitors PDCCH in a search space set provided by higher layer parameter *recoverySearchSpaceId* for detection of a DCI format with CRC scrambled by C-RNTI or ~~MCS-C-RNTI~~ starting from slot $n + 4$ within a window configured by higher layer parameter *BeamFailureRecoveryConfig*. For the PDCCH monitoring and for the corresponding PDSCH reception, the UE assumes the same antenna port quasi-collocation parameters as the ones associated with index q_{new} until the UE receives by higher layers an activation for a TCI state or any of the parameters *TCI-StatesPDCCH-ToAddlist* and/or *TCI-StatesPDCCH-ToReleaseList*. After the UE detects a DCI format with CRC scrambled by C-RNTI or ~~MCS-C-RNTI~~ in the search space set provided by *recoverySearchSpaceId*, the UE continues to monitor PDCCH candidates in the search space set provided by *recoverySearchSpaceId* until the UE receives a MAC CE activation command for a TCI state or higher layer parameters *TCI-StatesPDCCH-ToAddlist* and/or *TCI-StatesPDCCH-ToReleaseList*.

< Unchanged parts are omitted >

3. Conclusion

In this contribution the issues on beam measurement, beam reporting and beam failure recovery are discussed, and the following proposals are given:

Proposal 1:

- *TCI state configurations should be allowed for CORESET #0.*

Proposal 2:

- *If TCI state configuration is not allowed for CORESET #0, UE is not expected to receive Type 3 CSS and UE-specific search space set in CORESET #0.*
 - *CORESET #0 should not be used as default QCL assumption for buffering data.*
 - *CORESET #0 should not be monitored for BFR.*

Proposal 3: *Text proposal for 38.214 section 6.1.*

Proposal 4:

- *Threshold and default QCL assumption for AP-CSI-RS for CSI acquisition are the same as that for PDSCH.*
- *For AP-CSI-RS for beam management, it is not allowed to be triggered within the reported AP-CSI-RS beam switching timing.*

Proposal 5:

- *The UE can assume the lowest entry of TCI-StatesPDCCH as default TCI state to provide the PDCCH QCL between RRC re-configuration and MAC-CE activation.*

Proposal 6:

- *The UE can assume the lowest entry of PUCCH-SpatialRelationInfo as default spatial relation to provide the PUCCH QCL between RRC re-configuration and MAC-CE activation.*

Proposal 7:

- *Before RRC configuration, the UL transmission beam is derived from initial access procedure, i.e. the UE assumes PUSCH are spatially QCL-ed with Msg3.*

Proposal 8:

- *For low band carrier scheduling high band carrier, when PDCCH in low band carrier configured without tci-PresentInDCI 'enabled', UE uses the default data buffering beam to receive the PDSCH.*
- *For Scell in high band where there is no configured CORESET, the beam of CORESET with lowest ID in the Scell with lowest cell ID in the same band could be used for data buffering.*

Proposal 9:

- *UE is not expected to be configured with RS for BFD in inactive BWP.*

Proposal 10:

- *If no RACH resource (including both CFRA and CBRA) are configured on active BWP and UE switches to initial BWP and starts BFR procedure in the initial BWP, UE is not expected to be configured with candidate beam RSs in the active BWP.*

Proposal 11:

- *For PUCCH transmission after successful BFR, there is no need to change spec.*