**3GPP TSG RAN WG1 #102-e R1-2006985**

**e-Meeting, August 17th – 28th, 2020**

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

**Title:** Moderator summary for multi-beam enhancement: proposal categorization

**Document for:** Discussion and Decision

1. Introduction

In this summary, the term “item 1” refers to the first item in the Rel.17 NR FeMIMO WID, i.e. multi-beam enhancement:

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| 1. Enhancement on multi-beam operation, mainly targeting FR2 while also applicable to FR1:    1. Identify and specify features to facilitate more efficient (lower latency and overhead) DL/UL beam management to support higher intra- and L1/L2-centric inter-cell mobility and/or a larger number of configured TCI states:       1. Common beam for data and control transmission/reception for DL and UL, especially for intra-band CA       2. Unified TCI framework for DL and UL beam indication       3. Enhancement on signaling mechanisms for the above features to improve latency and efficiency with more usage of dynamic control signaling (as opposed to RRC)    2. Identify and specify features to facilitate UL beam selection for UEs equipped with multiple panels, considering UL coverage loss mitigation due to MPE, based on UL beam indication with the unified TCI framework for UL fast panel selection |

This summary includes the following:

* Categorization of proposals and issues in the submitted contributions
* Summary of current companies’ positions on each of the aspects within the category
* Moderator proposals

1. Categorization of issues

Based on the WID and plausible workflow throughout the WI, the proposals and/or issues raised by interested companies are organized as follows to identify pertinent aspects (including design components). This is not intended to be an exhaustive list of alternatives, but rather a skeleton to facilitate planning and progress tracking from meeting to meeting. The details on each item will be hashed out as the work progresses.

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| 1. **Unified TCI framework** – by means of extending the Rel.15/16 DL TCI framework (e.g. TCI state definition)    1. Design for UL TCI       1. Goal: utilize same unified design as DL TCI, specify UL TCI framework to facilitate common TCI state update for UL (data, PUCCH, SRS)       2. Including UL PC, timing control, PL RS, and/or default UL common beam    2. Design for DL TCI       1. Goal: identify and, if needed, specify potential refinement on Rel.15/16 DL TCI framework to facilitate common TCI state update for DL (data and DL assignment of the same UE)       2. Including default DL common beam    3. Additional QCL Type-D relations for TCI state definition       1. Goal: if supported, facilitate extended use of DL RS (e.g. SSB, CSI-RS) for UL and UL RS (e.g. SRS) for DL    4. Facilitating combined/joint and separate TCI for DL and UL:       1. Goal 1: when beam correspondence is assumed (common scenario), specify TCI framework to facilitate common TCI state update for DL and UL       2. Goal 2: when beam correspondence is not assumed (e.g. MPE event), facilitate separate TCI state updates for DL and UL    5. Note: the following factors should be considered in the above design aspects       1. CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)       2. Beam correspondence assumption       3. When applicable, performance assessment based on the agreed EVM 2. **L1/L2-centric inter-cell mobility**     1. The need for and/or the applicability and scope of L1-/L2-centric inter-cell mobility:       1. Goal: assess the need for and/or the applicability (use cases) and scope of L1/L2-centric inter-cell mobility (as an enhancement on the Rel.15/16 L3-based approach)    2. Method of enabling L1/L2-based inter-cell mobility:       1. Goal: select the type of information pertinent to non-serving cell(s) in TCI state to facilitate inter-cell mobility operation, e.g. PCI, SSB/TRS indicator    3. Note: the following factors should be considered in the above design aspects       1. CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)       2. Beam correspondence assumption       3. When applicable, performance assessment based on the agreed EVM 3. **Dynamic TCI state update signaling medium** for common TCI state update operation    1. Signaling medium: L1 control signaling (DCI-based on PDCCH) and/or MAC CE       1. Goal: select the medium and the associated detailed design used for signaling TCI state update       2. This includes DCI format when applicable, reliability (HARQ-ACK and/or repetition), UE-specific vs. UE-group, 1-part vs. 2-part signaling, timing aspect    2. Exact content:       1. Goal: define list of parameters included in the TCI state update (supporting multiple formats is possible)       2. This includes (a) separate DL and UL (DL-only and UL-only), (b) Combined joint DL and UL    3. Note: the following factors should be considered in the above design aspects       1. CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)       2. Beam correspondence assumption       3. When applicable, performance assessment based on the agreed EVM at high-speed scenarios 4. **Extension of UL TCI for UE with (capable of) multiple panels** to facilitate fast panel selection    1. The need for panel indication given the unified TCI framework design (cf. the above aspect 1 and 2)       1. Goal 1: assess if (a) any signaling from UE to NW to indicate multi-panel capability (e.g. to facilitate NW configuration) is needed, (b) resource ID or resource set ID (SRS, CSI-RS, ...) is sufficient or an explicit (new) panel ID is needed?       2. Goal 2: If panel indication is needed, specify UL TCI state update mechanism when (DL and UL TCI state update are (a) common, (b) separate    2. The need for panel-specific timing and power control enhancements in relation to panel indication and unified TCI framework design       1. Goal: assess the need for panel-specific timing and power control    3. Note: the following factors should be considered in the above design aspects       1. CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)       2. The use of UE panels for both DL reception and UL transmission, including the need for UE reporting and NW signaling       3. Beam correspondence assumption 5. **MPE mitigation**    1. The need for enhancement(s) to reduce UL coverage loss due to meeting MPE regulation, given the unified TCI framework design and multi-panel UE support (cf. the above aspect 1, 3, and 4)       1. Goal: assess the need based on a list of candidate schemes    2. Method of enabling MPE mitigation:       1. Goal: scheme selection for MPE mitigation    3. Note: the following factors should be considered in the above design aspects       1. Beam correspondence assumption       2. Performance assessment based on the agreed EVM       3. Support for fast panel selection on MP-UE 6. **Miscellaneous enhancements**, for example    1. Enhancements on SSB-based beam management via PRACH    2. Enhancements to facilitate TX beam refinement (P2), e.g. A-TRS as a QCL source    3. Enhancements on Rel.15/16 based default beam operation    4. Enhancements on beam failure recovery (BFR)    5. Enhancements specific to “dual-polarized” beam |

* 1. Unified TCI framework

Table 1 Summary of issues raised in RAN1#102-e for unified TCI framework

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 1.1 | UL TCI:   * 1.1.1: support UL TCI for PUSCH/PUCCH/SRS based on analogous design to Rel.15/16 DL TCI * 1.1.2: Content of TCI state: QCL, spatial relation, power control and SRS resource or port, PLRS | 1.1.1: Ericson, Fraunhofer IIS/ HHI, Futurewei, Huawei/HiSi, Lenovo/MotM, MediaTek, Nokia/NSB, NTT Docomo, OPPO, Qualcomm, Samsung, Spreadtrum, vivo, ZTE  1.1.2: OPPO, ZTE | Per WID (identify and specify), UL TCI for PUSCH/PUCCH/SRS will be supported. The format (e.g. analogous design to Rel.15/16 DL TCI, in what sense, issue 1.1.1) can be confirmed in RAN1#103-e or even RAN1#102-e.  The content of TCI state (issue 1.1.2) can be finalized in RAN1#103-e. |
| 1.2 | DL TCI:  -- | -- | Currently no input, but some work may be done later, e.g. default common beam for DL, after issue 1.4.x is more mature |
| 1.3 | Additional QCL Type-D relations for TCI   * 1.3.1: SRS as source RS for DL TCI and SSB/CSI-RS as source RS for UL TCI | 1.3.1:   * Support: CATT, Fraunhofer IIS/HHI, IDC, Intel, MediaTek, Samsung, vivo * Need more discussion: Huawei/HiSi | This issue can be finalized in RAN1#103-e. |
| 1.4 | * 1.4.1: Support both combined/joint (beam correspondence) and separate TCI for UL and DL * 1.4.2. Common beam (QCL update) for intra- and inter-band CA (configurable) * 1.4.3. Sharing the same TCI pool for DL and UL TCI | * 1.4.1: CMCC, Nokia/NSB, Samsung, ZTE * 1.4.2: Samsung, vivo, ZTE * 1.4.3: Ericsson, LGE, OPPO, Samsung, Sony | 1.4.1 and 1.4.2 are fundamental and should be finalized in RAN1#103-e (including the CA issue).  The rest can be finalized in later meetings. |
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* 1. L1/L2-centric inter-cell nobility

Table 1 Summary of issues in RAN1#102-e for L1/L2-centric inter-cell mobility

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 2.1 | Need/applicability/scope  2.1.1 Study latency reduction of 1st SSB transmission after MAC CE command with known TCI state  2.1.2 Deprioritize (need justification, separate from BM)  2.1.3: Need to define use cases, e.g. avoid duplication with L3-based mobility, intra- vs. inter-band | 2.1.1: ZTE  2.1.2: CMCC, Futurewei, Huawei/HiSi, Spreadtrum  2.1.4: Nokia/NSB, Samsung | This issue can be decided in RAN1#103-b. Note that 2.1.1 can be understood as a condition whether L1/L2-based inter-cell mobility should be supported |
| 2.2 | Methods, if L1/L2-based inter-cell mobility is supported  2.2.1 PCI of NSCell (non-serving cell) in TCI  2.2.2 SSB indication of NSCell in TCI  2.2.3 Multiple TAGs | 2.2.1: CATT, Ericsson, Sony, vivo  2.2.2: Apple (SSB associated with one TCI group), IDC, Qualcomm, Samsung, ZTE  2.2.3: Qualcomm | This issue can be decided in later meetings after issue 2.1 is finalized |
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* 1. Dynamic TCI signaling

Table 1 Summary of issues in RAN1#102-e for dynamic TCI signaling

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 3.1 | Signaling medium  3.1.1: DCI  3.1.2: MAC CE | 3.1.1: CATT, Fraunhofer IIS/HHI (PUSCH), Futurewei, NEC (consider HARQ), Nokia/NSB (consider HARQ), Qualcomm (consider UE-group), Samsung (consider UE-group and HARQ), ZTE  3.1.2: Apple, CATT, Fraunhofer IIS/HHI (PUCCH, SRS), Futurewei, Huawei/HiSi, MediaTek, vivo, Xiaomi | Signaling medium is also fundamental as it determines the reception of TCI update (latency, acceptable overhead, reliability). Whether DCI or MAC CE (or both, depending on use cases) is selected should be decided in RAN1#103-e.  Next level of details such as, if DCI is selected, UE group and retransmission can be finalized in later meetings |
| 3.2 | Exact content | -- | This work can start after issue 3.1 is finalized |
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* 1. Multi-panel UE (MP-UE)

Table 1 Summary of issues raised in RAN1#102-e for MP-UE

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 4.1 | The need for (explicit/new) panel ID | 4.1:   * Needed: CATT, CMCC, Huawei/HiSi, Lenovo/MotM, LGE, NTT Docomo, Sony, Spreadtrum, vivo, ZTE * Not needed: AT&T, CATT, Fraunhofer IIS/HHI (RS resource ID), IDC (UE selection), Lenovo/MotM, MediaTek (UE selection), Samsung (RS resource ID) | Since this issue heavily depends on the outcome of unified TCI and signaling (issue 1 and 3), it can be finalized in later meetings |
| 4.2 | The need for panel-specific timing and power control enhancements | 4.2:   * Needed: Huawei/HiSi, LGE, * Not needed: -- |
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* 1. MPE mitigation

Table 1 Summary of issues raised in RAN1#102-e for MPE mitigation

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 5.1 | Need for MPE mitigation | -- | Since this issue heavily depends on the outcome of unified TCI and signaling (issue 1 and 3) as well as MP-UE (issue 4), it can be finalized in later meetings |
| 5.2 | Methods, if needed  5.2.1: CRI report  5.2.2: MPE status report, e.g. BFR report, early notification  5.2.3: Panel selection report (NW configured)  5.2.4: UE-initiated UL beam or panel selection | 5.2.1: Qualcomm  5.2.2: Nokia/NSB, Qualcomm, Sony  5.2.3: APT, NTT Docomo, OPPO  5.2.4: Samsung, Sony, vivo |
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* 1. Miscellaneous enhancements

Table 1 Summary of issues raised in RAN1#102-e for miscellaneous enhancements

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 6.1 | SSB-based BM via PRACH | AT&T | These issues may not fit in the current WID but can be discussed if time permits |
| 6.2 | Faster beam acquisition/switching, e.g. enabling P2/P3 via additional QCL with A-TRS, joint P2-P3, TCI/beam group/subset, dynamic TCI for periodic RS, beam sweeping | Apple, AT&T, Nokia/NSB, Samsung |
| 6.3 | Increasing # SRS resources or MACE CE update of spatial relation for P-SRS | NTT Docomo |
| 6.4 | Beam-specific UL PC | IDC |
| 6.5 | Rel.15/16 default beam operation | vivo |
| 6.6 | BFR | AT&T |
| 6.7 | “Dual-polarized” beam | Sony |
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1. Observation and proposals

[Based on ...]

Appendix A: compilation of companies’ views from submitted contributions

Unified TCI framework

**Table 2 Views: unified TCI framework**

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| **Company** | **Input** |
| Huawei/HiSi | Proposal 1: QCL TypeD RS resource in a TCI state of a CORESET can be the source of common beam indication, for data and control transmission/reception for DL and UL, especially for intra-band CA.  Proposal 4: Further discuss and clarify benefits of using SRS resource(s) for DL beam indication in term of “unified TCI” framework.  Proposal 5: In Rel-17, when PDCCH beam is used as the common beam for both DL and UL, UE should refer to the TCI state of the latest monitored CORESET.  Proposal 6: To enable multi-TRP and multi-panel based DL data and control reception, support default Tx beams and PL-RS by common beams (i.e. plural beams), at least for intra-band CA. |
| Futurewei | Proposal 1: Consider introduce new framework for common beam management and indication  Proposal 2: Consider dynamically associate correspondence beams for uplink with downlink common beams by the reuse of SRI bit field  Proposal 4: Consider support dynamic common beam update based on measurement report |
| vivo | * Existing solution of default beam scheme in Rel-15/Rel-16 can be extended to unify the beam indication for different DL/UL channels/RSs. * The TCI state of a CORESET, e.g. CORESET with the lowest controlResourceSetId, can be used as the common beam for other DL/UL channels/RSs to reduce signaling overhead of beam indication. * Support common beam operation for multi-TRP case. * DL and UL channels can share a common TCI state pool configured by RRC. * Support configuration of SRS as QCL-TypeD source for DL channel. * For UL beam indication, it can be considered that the SRS for ‘beamManagement’ is directly applied in SRI field, the size of which can be extended with multiple bits. |
| ZTE | For unified TCI framework to achieve common beam indication for both DL and UL transmission, the following aspects can be determined according to the indicated TCI state and its association information.   * QCL assumption for DL channel(s) or RS resource(s), e.g., PDCCH/PDSCH/CSI-RS. * Spatial relation and power control parameters for UL channel or signal, e.g., PUCCH/PUSCH/SRS. * SRS resource or port parameter for PUSCH transmission.   Proposal 2: Regarding signalling structure for achieving unified TCI framework,   * The common TCI state pool for both DL and UL should be supported as a baseline * The following two candidate functionalities can be both considered in order to balance the signalling overhead and scheduling flexibility.   1. There is a common TCI state pool for both DL and UL, but data and control transmission/reception for DL and UL can be separately indicated with an independent TCI state from the pool by channel/RS-dedicated command(s).   2. There is a common TCI state pool for both DL and UL, and both data and control transmission/reception for DL and UL can be indicated with one common TCI state from the pool by a single command.   Proposal 5: Study mechanism of sharing a RRC TCI state pool for a set of CCs.   * FFS: how to determine QCL Type-A RS across CC in such case. * Note that QCL Type-D RS in a TCI state can be applied for all CCs in the set of CCs. |
| Interdigital | DL TCI state based on UL RS and UL TCI state based on DL RS should be supported. |
| Sony | * Specify the QCL assumption among SSB/CSI-RS resource sets on different BWPs/CCs (intra band). * For inter-band CCs, a common beam management procedure, including TCI states across bands, should be considered for data/control, DL/UL, multiple BWPs, multiple TRPs and multiple UE panels. * Study and specify (if necessary) a unified TCI state framework which can be applied to UL beam management in addition to DL beam management. |
| MediaTek | Proposal 1: Introduce common/default beam for CSI-RS measurement at least for CSI acquisition, and PUSCH transmission scheduled by non-fallback DCI  Proposal 2: Extend Rel-15/16 TCI framework to PUCCH, PUSCH, and SRS for UL beam indication   * Study how to indicate a TCI states for a PUCCH/PUSCH/SRS transmission * Support SRS as a spatial QCL source in a TCI state at least for UL beam indication   Proposal 3: To extend Rel-15/16 TCI framework to a PUSCH/PUCCH transmission, study how to provide a power control setting to the PUCCH/PUSCH transmission.  Proposal 4: To extend Rel-15/16 TCI framework to a non-codebook-based PUSCH transmission, study how to provide port-related information to the non-codebook-based PUSCH transmission. |
| CATT | Proposal-1:Common beam can be applied to data and control, and DL and UL.  Proposal-3: Different combinations of channels sharing the common beam should be supported.  Proposal-4: Starting and ending of CB operation could be explicitly indicated or predefined in the spec.  Proposal-5: Introduce an UL-TCI state which at least includes an RS for indication of UL spatial filter,   * The RS in UL-TCI for spatial filter indication should at least support UL RS (SRS for BM) and DL RS (CSI-RS/SSB) * FFS whether pathloss RS is directly provided in UL-TCI state, or separately |
| Fraunhofer IIS/HHI | * The UL TCI framework shall be defined as a standalone framework such as the TCI framework in the DL to replace the existing spatial relation framework. * Use DL channels as references in addition to DL reference signals for spatial relation in the UL TCI framework. |
| Lenovo/MotM | * Study how to support SDM/FDM/TDM based PDSCH scheduled by a DCI without TCI field. * Introduce UL-TCI in DCI to signal UL TX beam independently from the SRS resource to enhance flexibility for Rel-17 codebook-based PUSCH transmission. * Introduce UL-TCI based power control for Rel-17 codebook-based PUSCH transmission |
| Ericsson | Proposal 1 Focus on reducing the activation delay and speeding up the signaling.  Proposal 2 After performing a measurement on an aperiodic CSI-RS, the UE would update the TCI state used as QCL source for the PDCCH/PDSCH DMRS to the QCL source corresponding to the best CSI-RS.  Proposal 6 Implement complete support for common beam operation that considers restrictions in the UE hardware relevant for intra-band and inter-band carrier aggregation.  Proposal 7 Introduce an UL TCI which could serve as a direct source for the spatial properties of all UL signals: SRS, PUCCH and PUSCH.  Proposal 8 UL TCI is optionally configured. |
| Intel | * SRS/CRI based flexible beam mapping can be used to reduce beam indication and tracking latency. * To reduce beam acquisition latency, beam relations between different SSB beams can be indicated to the UE such that Rx beam refinement can be achieved without exhaustive search. Similar functionality can also be used for CSI-RS based narrow beam acquisition to avoid exhaustive beam search. |
| AT&T | * Uplink TCI state can replace spatial relation info for all uplink transmit signals. * From a signalling perspective, configuration of TCI states can follow that of spatial relation info for PUCCH, SRS, and PUSCH to support dynamic beam switching * Introduce more dynamic TCI configuration for periodic reference signals such as CSI-RS. |
| OPPO | Proposal 1: Support a common beam operation mode in which all the DL and UL channels and reference signals follow the same Tx beam and a single signaling can switch the Tx beam for the whole system.  Proposal 2: Support single common beam in multiple CCs.  Proposal 3: A TCI state for PUSCH shall include or be associated with the following information:   * SRS resource(s) for port indication * Spatial relation info * Pathloss reference signals and power control parameters. |
| Samsung | Proposal 1: A common beam indication (TCI state update) is used by the UE when:   * receiving DL data and UE-dedicated DL control. * transmitting UL data and UL control.   Proposal 2: When beam correspondence is assumed between DL and UL transmissions, a unified beam indication framework indicates a joint TCI state for DL and UL. When beam correspondence is not assumed between DL and UL transmissions, a unified beam indication framework indicates a DL TCI state separate from an UL TCI state.  Proposal 3: For multiple CCs, investigate how to extend the common beam indication framework to include common beam indication for a subset of CCs, cross-carrier beam indication (e.g., DCI on CC1 indicating the common beam for CC2), and cross-carrier scheduling (e.g., beams for receiving PDCCH on CC1 and PDSCH on CC2).  Proposal 7: Investigate combining TX and RX beam refinement in beam management procedure.  Proposal 8: Investigate CSI-RS design by allowing partial repetition of the CSI-RS resources across DL spatial domain transmission filters, wherein a UE may assume that a subset of CSI-RS resources have a same spatial domain transmission filter. |
| CMCC | Proposal 2: It should be clarified which pair should have the priority or should be design as a whole, considering data and control, downlink and uplink, transmission and reception, and multiple-carrier situation.  Proposal 3: Common beam mechanism can be considered to enhance the beam tuning speed of PUCCH.  Proposal 4: Support UE to report CRI/SSBRI in DL beam reporting, where the CRI/SSBRI refers to a preferred spatial relation RS for UL transmission. |
| Spreadtrum | Proposal 1: Adopt at least one of the following ways to achieve common beam   * Alt1: define unified default beams for different channels based on current beam indication mechanism * Alt2: define new beam indication signaling for different channels |
| Apple | Proposal 1: To speed up beam acquisition, RAN1 should introduce schemes to include more than one SSBs in a UE beam tracking loop.   * As a starting point, RAN1 can study schemes for gNB to provide some QCL information for SSBs within a CC and across CCs   Proposal 2: For overhead and latency reduction, support gNB to indicate whether UE can perform intra-symbol beam sweeping for 1-port CSI-RS for BM.  Proposal 3: For overhead and latency reduction, support 1 CSI-RS resource to be transmitted in multiple symbol to facilitate joint P2/P3 beam management.  Proposal 4: RAN1 should study to introduce a new QCL type indication to let UE aware that two BM-RSs are based on the same Tx beam.  Proposal 6: For uplink beam indication, when SSB/CSI-RS is indicated, it should be defined that the spatial domain Rx filter is a reference to determine spatial domain Tx filter, instead of mandating UE to use the same spatial domain filter. |
| Beijing Xiaomi | Proposal 2: Consider to modify the mechanism of PUSCH beam indication to support unified framework of DL and UL beam indication.  Proposal 3: Wide beam for high mobility UE is much more preferred.  Proposal 4: Simultaneous transmission of multiple reference signal for beam management should be considered.  Proposal 5: Larger step size for beam management report can be considered to reduce signaling overhead.  Proposal 7: Beam selection based on UE trajectory need to be considered.  Proposal 8: Conditional beam measurement report need to be supported to tradeoff the signaling overhead and latency.  Proposal 9: We prefer to reuse the TCI frame work of Multi-TRP PDSCH for UL beam indication of multi-panel and TDM based UL transmission between multi-panels is much more preferred. |
| LGE | Introduce ‘beam linkage state’ configured by RRC in which DL/UL channels/signals that share a common DL RS for QCL type-D RS and/or spatial relation RS are listed across one or multiple CCs. When a QCL type-D RS or spatial relation RS is updated for one of the channels/RSs in the list by legacy beam indication method, the same RS is applied as QCL type-D RS or spatial relation RS for other channels/RSs in the list. |
| APT | Consider the following aspects and their impact during UL TCI design: 1) multiple UE panel assumption, 2) different indication needs for UL control channel and UL signal, and UL data channel, 3) leveraging of legacy methods. |
| NTT Docomo | Proposal 2-1:   * + Enhancement to align common UL/DL beam across CCs in Rel.17 should focus on multi active beam operation (i.e. multiple beams are activated for UL/DL channels per a UE)     - 1) To align default TCI-state and default spatial relation     - 2) To align explicit indicated TCI-state and spatial relation   Proposal 2-2:   * + Update default TCI-state/QCL of PDSCH, to align with default spatial relation rule     - If CORESET is configured in the active DL BWP on the scheduled CC, TCI-state/QCL of the lowest CORESET ID; else, lowest TCI-state ID of PDSCH in the active DL BWP on the scheduled CC   Proposal 2-3:   * + TCI state field of DCI format 1\_1/1\_2 is reused to indicate UL beam of corresponding HARQ-ACK transmission on PUCCH/PUSCH, if Rel.17 higher layer parameter is configured     - No explicit beam indication is required for the PUCCH/PUSCH to align UL/DL beam   Proposal 3-1:   * + To support more efficient spatial relation update for periodic SRS, following options can be considered.     - Option1. Increase the number of SRS resources per resource set or the number of SRS resource sets.     - Option2. Support MAC CE based spatial relation update for periodic SRS.   Proposal 3-2:   * + To enable MAC CE to update TCI-state/resource of P-CSI-RS, MAC CE activates/deactivates P-CSI-RS resources     - UE is not required to receive the deactive CSI-RS resources, and hence, there is no scheduling restriction of PDSCH on the same symbol of deactive CSI-RS resources. |
| Qualcomm | Proposal 2: Support including default PDSCH beam in the common beam.  Proposal 3: Support a common beam selected for a group of UEs.  Proposal 4: Support simultaneous pathloss RS activation across multiple CCs.  Proposal 5: Support simultaneous pathloss RS activation for multiple SRS resource sets.  Proposal 6: Support to extend default UL beam to mTRP scenario.  Proposal 7: Configured UL TCI state can indicate both spatial RS and PL RS.  Proposal 8: For CB/NCB based PUSCH, scheduling DCI should indicate corresponding TPMI/TRI/SRI in or together with the UL TCI state.  Proposal 11: Default UL beam defined when spatial relation is not configured can be reused for the case when UL TCI is not indicated.  Proposal 12: gNB should enable either UL TCI state or spatial relation for UL beam indication.  Proposal 13: For L1/L2 intra-cell mobility, support multiple TAGs per serving cell.   * Each TAG can correspond to one or more TRPs with similar propagation delay to the UE. |
| Nokia/NSB | Proposal 1: Support common beam defined by a TCI state for DL control and data and UL control and data that takes into UE’s UL transmission capability, e.g. MPE. This may include the following options:   * Separate common beams for DL (control and data) and UL (control and data) * Common beam for DL and UL (control and data)   Proposal 2: Support common beam for DL and UL (control and data) per TRP in multi-TRP scenario for the UE.  Proposal 3: Support replacing spatial relation reference signal with a TCI state for PUCCH and SRS resource.  Proposal 4: TCI states that could be used for fast UL beam indication need to be restricted compared to DL beam indication e.g. due to MPE issue or UE’s transmission capability in uplink compared to reception capability in downlink in panel domain (e.g. UE may be able to receive using multiple panels at a time but transmit using a single panel at a time).  Proposal 5: Consider beam repetition/diversity transmission schemes for PUCCH and PUSCH based on TCI states where UE’s transmission capabilities e.g. in panel domain are taken into account. |

L1/L2-centric mobility

**Table 3 Views: L1/L2-centric inter-cell**

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| **Company** | **Input** |
| Huawei/HiSi | Prioritize the support of intra-cell mobility using L1/L2-centric solutions to enable/improve common beam operation for DL/UL intra-band CA and unified TCI framework used for multi-panel/M-TRP implementation scenario |
| Futurewei | Consider decouple the signaling and procedure of beam management from handover procedure for inter-cell mobility |
| vivo | * Support L1 inter-cell beam report based on L1 inter-cell beam measurement. * Support the reporting of the L1 measured inter-cell beam qualities based on legacy L3 inter-cell beam measurement behavior. * Support L1 inter-cell beam measurement outside SMTC with low increase of complexity and power consumption. * Clarify the scheduling restrictions for L1 inter-cell beam measurement. * CSI reporting/resource setting configuration could be updated to include PCI information for inter-cell beam management. * Support to report timing offset between different cells in L1/L2 report * For inter-cell mobility in Rel-17 both QCL enhancement for DL and spatial relation enhancement for UL should be considered. * TCI state/spatial relation/power control enhancement with additional information of the target cells (at least including PCI information) should be considered for inter-cell mobility. |
| ZTE | Proposal 4: Regarding L1/L2-centric intra-cell and inter-cell mobility,   * Further study the mechanism of saving latency about “first SSB transmission after MAC-CE command” for known TCI state switching. * Further study L1-RSRP reporting and dynamic indication for DL/UL beam(s) in a neighboring cell, in order to reduce the delay of applying the new TCI state including RS resource of neighbor cell, i.e., corresponding to unknown TCI state switching. |
| Interdigital | * SSB based beam measurement for inter-cell operation should be supported. * An indication of a reference signal from cells other than the serving cell should be supported in TCI state for inter-cell operation. |
| Sony | * Specify the QCL assumption among SSB/CSI-RS resource sets on different BWPs/CCs (intra band). * For inter-band CCs, a common beam management procedure, including TCI states across bands, should be considered for data/control, DL/UL, multiple BWPs, multiple TRPs and multiple UE panels. * Study and specify (if necessary) a unified TCI state framework which can be applied to UL beam management in addition to DL beam management. |
| CATT | Including PCI in the TCI states is supported. |
| Ericsson | * Include a PCI in the TCI state to facilitate the use of reference signals from non-serving cells as QCL sources. * Define the CSI-SSB-ResourceSet so that one report can contain measurements from different cells. * Introduce a PCI in the configurations related to UL transmissions: spatial relations and pathloss reference RS. |
| OPPO | Study beam measurement/reporting and/or beam indication of SS/PBCH block of target cell for inter-cell mobility. |
| Samsung | For L1/L2-centric inter-cell mobility, support   * beam measurement based on RSs associated with serving as well as neighbouring cells * beam report which includes indicator for (RS-ID, cell-ID) * TCI state definition which includes or is associated with cell-ID |
| CMCC | The motivation and benefit of DL/UL beam management enhancement to support higher L1/L2-centric inter-cell mobility needs to be clarified. |
| Spreadtrum | For Rel-17 MIMO, L1/L2-centric inter-cell mobility is de-prioritized. |
| Apple | To facilitate L1/L2 centric inter-cell mobility, the TCI states can be divided into N groups, where each group is associated with one SSB configuration   * The SSB configuration should at least include physical cell ID, SSB transmission power, and SSB periodicity |
| Qualcomm | Proposal 13: For L1/L2 intra-cell mobility, support multiple TAGs per serving cell.   * Each TAG can correspond to one or more TRPs with similar propagation delay to the UE.   Proposal 14: For L1/L2 inter-cell mobility, support TCI state with QCL source as SSB from non-serving PCI.  Proposal 15: For L1/L2 inter-cell mobility, support L1/L2 based selection of serving cell(s), including PCell.  Proposal 16: For L1/L2 inter-cell mobility, a set of candidate serving cells can be pre-configured for L1 measurement, based on which a subset of pre-configured cells can be dynamically activated by L1/L2.  Proposal 17: Support updating timing advance for non-serving cell or PCI. |
| Nokia/NSB | * L1/L2 centric inter-cell mobility utilizes the beam management framework (measurements and reporting) and should not duplicate the RRC level event based mobility procedures at the lower layer * RAN1 to discuss and clarify the scope of L1/L2 centric mobility and the relationship to inter-cell multi-TRP.   + The simplest form of L1/L2 centric mobility could be just to enable beam reporting on non-serving cells |

Dynamic TCI signaling

**Table 4 Views: dynamic TCI signaling**

|  |  |
| --- | --- |
| **Company** | **Input** |
| Huawei/HiSi | Proposal 2: Support using one MAC CE to update TCI states for multiple CORESETs within a CC as well as across multiple CCs in a given CC list.  Proposal 3: Introduce one unified enabler, e.g. by RRC or MAC CE, to configure/activate ‘common beam’ across selected CCs/channels. |
| Futurewei | Proposal 3: Consider support common beam update with both MAC-CE and L1 DCI signaling |
| vivo | * Support MAC CE-based scheme for common beam indication. * Support multiple common beams in Rel-17 for different channel/RS.   + Support MAC CE-based multiple common beams update. * Support simultaneous spatial relation update by a MAC CE for PUCCH resource/PUCCH resource group for all the BWPs in the indicated CCs. * Support MAC CE-based TCI state update for SP-/AP-CSI-RS. * Support pathloss RS update for PUCCH/PUSCH/SRS by a MAC CE for all the BWPs in the indicated CCs. |
| ZTE | Proposal 3: Support DCI based common beam indication for multiple channels in unified TCI framework, in order to further reduce indication latency and save signaling latency over Rel-15/16 default beam approach for both DL and UL.   * Further study DCI format, applicable timing and retransmission/repetition mechanism. |
| MediaTek | Proposal 6: Update associated DL CSI-RS in the SRS resource set with usage=‘nonCodebook’ by MAC-CE  Proposal 7: Support TCI-state update for NZP CSI-RS for a set of CCs in the same or different band by single MAC-CE |
| CATT | Common beam indication may be based on L1 (DCI) or L2/L3 (RRC/MAC-CE). |
| NEC | PDCCH to indicate a common beam for PDCCH and corresponding PDSCH, and application timing for the updated beam should be defined. HARQ-ACK feedback for the updating information can be considered. |
| Fraunhofer IIS/HHI | * Support MAC-CE indication of UL TCI references for PUCCH and SRS. * In the case of PUSCH, use the UL TCI for indicating spatial relation when scheduled with DCI format 0\_1. |
| Lenovo/MotM | Proposal 5: Dynamic control signaling such as MAC CE or DCI can be introduced to reduce overhead and latency for RRC configuration. |
| Samsung | Proposal 4: To support common TCI state update for DL data and the associated DL assignment (UE-dedicated control), L1-control-based beam indication is introduced in Rel-17.  Proposal 5: Investigate the use of UE-group beam indication to further reduce DL signalling overhead, baseband power consumption, as well as improve reliability. Also investigate the use of two-part beam indication to further enhance the efficiency of UE-group beam indication  Proposal 6: For L1/L2-centric inter-cell mobility, support   * beam measurement based on RSs associated with serving as well as neighbouring cells * beam report which includes indicator for (RS-ID, cell-ID) * TCI state definition which includes or is associated with cell-ID |
| Apple | Proposal 5: The beam indication signaling should be simplified and per link per CC group based beam indication should be supported.   * RAN1 should avoid DCI based beam indication in future work |
| Beijing Xiaomi | Common RRC signaling and common MAC-CE signaling for data/control of DL only, UL only or both DL and UL need to be supported. |
| LGE | Consider updating beam RS for PDCCH/PUCCH by the dynamically updated beam RS for PDSCH/PUSCH by DCI. |
| Qualcomm | Proposal 1: Support DCI based beam update for PDCCH.  Proposal 9: MAC-CE can select/activate UL TCI state for PUCCH and P/SP/AP SRS resource.  Proposal 10: For PUSCH scheduled by DCI, MAC-CE can activate a subset of configured UL TCI states, and the scheduling DCI can indicate corresponding UL TCI codepoint. |
| Nokia/NSB | Proposal 6: Support L1 based TCI state switch for PDCCH with the following functionalities:   * the target TCI state is in the active TCI state list for PDSCH * switch is confirmed with HARQ-ACK sent by the UE |

MP-UE

**Table 5 Views: MP-UE**

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| **Company** | **Input** |
| Huawei/HiSi | * For Rel-17 UL panel selection, UE implementation assumptions may be clarified firstly, including no dedicated DL/UL panels, no beam correspondence across panels and the maximum number of active panels is smaller than the number of panels equipped. * Virtual panel indication based on ‘unified TCI framework’ should be supported in Rel-17. * UE panel management should consider at least, e.g. panel status alignment between gNB and UE, panel-level timing adjustment, and panel-specific power control. |
| Futurewei | * Consider extend beam management to support simultaneous multi-panel transmission and reception for inter-cell mobility * Consider align basic UE panel and its operation assumptions for evaluation and design |
| vivo | * UE panel switching scheme enhancement in Rel-17 should at least consider the following aspects:   + UE power saving   + multi-TRP operation   + MPE mitigation. * Study the measurement, reporting, signaling and procedures for alignment of panel switching at gNB and UE. * Optimize the UE operation with only one activated panel for control/data transmission/reception for both MPUE-Assumption1 and MPUE-Assumption3 in Rel-17. * UE panel ID can be introduced to assist network and UE’s alignment of panel activation/deactivation. |
| ZTE | For fast panel selection, the following aspects should be considered.   * Spatial relation/TCI state including DL RS can be associated with activated panel IDs in the case of beam correspondence, with the assistance of UE panel-specific reporting, e.g., group based reporting. * Sounding procedure for antenna switching can be further studied for supporting UE fast panel switching. |
| Interdigital | * Beam specific power control should be supported in UL TCI state. * Discussion on specification support of panel ID indication can consider a panel ID indication in an UL TCI state as a starting point. * Consider a UE centric UL panel determination for some useful cases |
| Sony | * An ID explicitly configured in spatialRelationInfo can be used for UL panel-specific beam selection. * Confirm the working assumption on explicit panel-specific indication on PUSCH/PUCCH/SRS and include PRACH with conditions FFS. * We suggest that definition of a UE panel and the related properties are addressed prior to further advancing discussions related to UE panel enhancements. * A beam can be defined as a spatial filtering associated with one or two antenna ports carrying one or two layers separated in the polarization domain. |
| MediaTek | Proposal 8: The followings are assumed for Rel-17 enhancements on multi-panel UE:   * More than one panels can be activated at a time * UE controls panel activation and deactivation for DL reception and/or UL transmission   Proposal 9: In Rel-17, only introduce enhancement based on DL beam management for panel-specific UL beam selection  Proposal 10: Study how to provide information of panel configuration corresponding to the reported DL RSs to gNB to facilitate panel-specific UL beam selection.  Proposal 11: In Rel-17, for enhancement on multi-panel UE, introduce a unified assumption and framework to facilitate both UL transmission and DL reception. |
| CATT | Proposal-7: Following alternatives on panel selection can be considered   * Alt-1: Mapping between RS and panel is transparent to gNB. * Alt-2: Mapping between RS and panel is non-transparent to gNB, panel-ID is associated with each DL/UL signal.   Proposal-8: For panel switching, the following alternatives are to be considered   * Study network controlled and UE-initiated panel switching. * Study mechanism for UL beam management realignment between network/UE, after switching of UL panels. |
| Fraunhofer IIS/HHI | * A panel shall be defined as a set of UE antenna ports that can independently control the direction and power of a UE beam. * UE panel/port indication or selection may be kept separate from the UL TCI framework to avoid complicating the framework * The UE panel/port indication or selection may be performed by other methods such as   + association of specific indices or indicators with UL RSs or channel(s) to indicate UE panel(s), or   + autonomous selection by the UE in the case a DL RS is chosen as a reference for Tx beam selection. |
| Lenovo/MotM | Proposal 8: The definition, configuration and signaling of UE antenna panel should be studied.  Proposal 9: How to report the panel state information timely should be studied.  Proposal 10: The association relation between a beam and an activated panel should be reported to gNB as part of beam reporting.  Proposal 11: Both explicit way and implicit method of reporting of association relation between a beam and an activated panel should be studied. |
| AT&T | Panel identifier is not needed in conjunction with UL TCI framework. |
| OPPO | * UL panel selection and beam selection shall support activating only one Tx panel to save UE power. * Consider panel-specific beam measurement and reporting. |
| Samsung | For multi-panel UEs, fast panel selection is facilitated by including an index of RS resource or resource set associated with a panel into the UL TCI state definition. |
| CMCC | To support panel-specific UL transmission, DL beam reporting should be enhanced to report the panel-ID that UE has used to receive the CSI-RS/SSB along with CRI/SSBID. |
| Spreadtrum | Proposal 3: On panel specific UL beam selection, the agreements achieved in Rel-16 should be considered as a starting point.  Proposal 4: Support to introduce a new ID for indicating panel specific UL beam selection.  Proposal 5: Panel ID can be explicitly configured in spatialRelationInfo or UL TCI state together with the reference RS.  Proposal 6: Support panel selective transmission for PUSCH, PUCCH and SRS, excluding PRACH.  Proposal 7: Support UE to explicitly/implicitly report panel information in beam reporting. |
| Apple | * A panel can be defined as an antenna port(s) group, where the antenna port to antenna element mapping is up to UE implementation. * The uplink panel selection should support UE with panels with different properties, e.g. different number of RF chains, different EIRP and so on. |
| LGE | * Rel-17 MPUE enhancement should support at least 2 active panels. * Panel identification method should be supported, e.g. explicit panel ID can be configured to UL channels/RSs so that gNB can control UL triggering from a specific UE panel. * Support panel-specific power and timing control. |
| APT | Proposal 2: to enable fast panel selection operation, support the following signaling:   * NW signaling   + - * + indication to select UL transmission panel from currently active panels         + indication to request a number of panels to be activated/deactivated based on UE capability * UE reporting   + - * + Report to indicate information of currently activated panels |
| NTT Docomo | * Support gNB controlled panel selection for UE UL transmission using single panel. * Support explicit panel ID in configuration signaling or UE reporting to facilitate panel selection controlled by gNB. * Both UE controlled panel activation/deactivation with informing to NW and NW controlled panel activation/deactivation with indication to UE can be considered. |
| Nokia/NSB | Study possibility to have activated TCI state(s) for the uplink fast beam and panel selection via DCI. |

MPE mitigation

**Table 6 Views: MPE mitigation**

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| **Company** | **Input** |
| vivo | * Support MPE enhancement based on Rel-16 MPE framework in RAN4. * Support MPE enhancement per panel basis in Rel-17. * For panel switch triggered by MPE event, both multiple activated panel operation and single activated panel operation should be considered for DL reception and UL transmission. * Mechanisms for alignment of DL reception panel and UL transmission panel due to panel switch triggered by MPE should be designed to facilitate single activated panel operation. |
| ZTE | Beam/panel-specific P-MPR is introduced in UL power control framework, also study the additional parameter |
| Sony | * For UE supporting beam correspondence without UL beam sweeping, RAN1 should study and, if necessary, specify MPE-aware beam reporting. * For UE supporting beam correspondence with the aid of UL beam sweeping, RAN1 specifies UE behavior on MPE-aware UL beam sweeping. * Associate the P-MPR values with the spatial relation for UL transmission to mitigate the coverage loss due to the MPE. * Introducing a panel-specific P-MPR associated to a panel ID. * To avoid UL MPE issue, it would be beneficial for RAN1 to study and, if necessary, specify the mechanism of UE triggered UL beam/panel switch. |
| Intel | Amend RAN4 solutions for MPE to include recovery information indicating alterative UL beam with lower P-MPR or duty cycle constraints |
| OPPO | * First study the feasibility of per-beam or per-panel human detection and send LS to RAN4 to ask about the feasibility. * Based the RAN4 reply on feasibility of per-beam or per-panel human detection, consider to use the mechanism of reporting P-MPR as starting point for further enhancements. |
| Samsung | For MPE mitigation, investigate a mechanism for providing an alternate UL TX beam as well as a UE-initiated UL TX beam update. |
| Apple | RAN1 could study how to maintain the same understanding between gNB and UE on the minimal delay for a beam switching with regard to panel switching delay, as well as the MPR difference for different panels |
| NTT Docomo | * A new UL beam measurement and reporting method considering MPE can be supported. * MPE issue detection/reporting and UL beam failure recovery mechanism due to MPE issue can be considered. |
| Qualcomm | * Support UE to report preferred CRI/SSBRI for DL and UL transmissions, separately. * Support UE to report UL beam failure due to MPE issue.   + The Rel-15/16 BFR procedure can be a reference for the MPE reporting procedure. * The condition for UE to trigger MPE report should be specified. |
| Nokia/NSB | * Inform the gNB on the upcoming presence of a blocking user well before MPE actions are triggered to evaluate alternative uplink TX beams. Initiate monitoring for alternative links before the actual MPE event is triggered. In this way, the network has time to determine setup the best link maintenance for UL and/or DL during the MPE event and avoid RLF. * Support UE to report well before MPE events CRI/SSBRI, where the CRI/SSBRI refers to a preferred spatial relation RS for UL transmission and metric per CRI/SSBRI to reveal UL transmission capability under MPE events from achievable EIRP point of view (e.g. PHR or P-MPR reporting per candidate UL beam based on CRI/SSBRI). |

Miscellaneous enhancements

**Table 7 Views: miscellaneous**

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| **Company** | **Input** |
| Interdigital | Efficient beam failure recovery operation for inter-cell operation should be supported. |
| Sony | * The reporting of UE capabilities related to the ability of the UE to simultaneously steer in the same direction beams belonging to CCs in different bands should be considered. * For the optimization of TCI states across bands, the polarization property of beams should be considered. * RAN1 needs to study and specify (if necessary) whether additional signaling is necessary when a beam can support up to two independent layers separated by polarization. |
| MediaTek | Support one or more BFD/RLM RS update by single MAC-CE |
| NEC | Study the impact to beam failure detection RS if the PDCCH beam is updated dynamically |
| Lenovo/MotM | * Default TCI states for aperiodic CSI-RS reception in multi-DCI based multi-TRP scenario should be specified in Rel-17. * Default spatial relation and PL-RS for UL signal including PUCCH, SRS and PUSCH scheduled by DCI format 0\_0 in multi-TRP should be supported in Rel-17. * Default TCI state(s) for PDSCH and aperiodic CSI-RS reception should be supported for cross carrier scheduling in CA considering different multi-TRP mode configuration per carrier. |
| AT&T | * NR supports explicit SS block index indication in msg. 3. * Whether or not the SS block indices are reported in msg. 3 can be indicated to the UE. * Specify partial beam failure recovery to reduce latency and overhead * PUCCH channels corresponding to functioning CORESETs are used to carry recovery request transmission for failed CORESETs. * Beam management procedure should support the indication of partial control channel failure. |
| Sharp | Rx point specific enhancement should be introduced. |
| Nokia/NSB | * Study feasibility of having P2 CSI-RS as QCL source for TRS. * Consider supporting self-contained (no association to P-TRS) A-TRS upon P2 CSI-RS beam, i.e. P2 CSI-RS acting as a QCL source for the A-TRS. * Consider different beam reporting enhancements for Rel-17 to enable efficient multi-beam operation in single/multi-TRP environment. |

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