**3GPP TSG RAN WG1 #104b-e R1-2103220**

**e-Meeting, April 12th – 20th, 2021**

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

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

**Document for:** Discussion and Decision

## 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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| * Enhancement on multi-beam operation, mainly targeting FR2 while also applicable to FR1:   + 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)   + 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:

* Observation and proposal
* Summary of current companies’ positions on each of the aspects within the category

## Summary of companies’ inputs

The listed issues are structured primarily to facilitate some progress on pending issues identified in the agreements especially in 103-e and 104-e (see Appendix A).

### Issue 1 (Rel.17 unified TCI framework – note: for intra-cell beam management)

Table 1 Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.1 | Additional source RS type for DL QCL Type-D reference for DL common UE-dedicated reception on PDSCH and all/subset of CORESETs  Note: CSI-RS for tracking (TRS) and CSI-RS for BM have been agreed | SSB, with TRS as QCL Type-A source RS   * **Yes:** vivo, Lenovo/MoM, Samsung, NTT Docomo, ZTE, MTK, AT&T, * **No:** Huawei/HiSi, OPPO, Spreadtrum, APT/FGI, Intel.   SRS for BM, optionally with TRS as QCL Type-A source RS   * **Yes:** IDC, vivo, Lenovo/MoM, Samsung, Nokia/NSB, ZTE, Apple, Convida, * **No:** Ericsson, Huawei/HiSi, OPPO, Spreadtrum, Intel, LGE.   CSI-RS for CSI   * **Yes:** CMCC, Huawei/HiSi, ZTE, Sony, AT&T * **No:** vivo, Spreadtrum |
| 1.2 | Additional source RS type for UL TX spatial filter  Note: SSB, SRS for BM, CSI-RS for tracking (TRS), and CSI-RS for BM have been agreed | Non-BM CSI-RS other than for tracking   * **Yes:** CMCC, ZTE, Sony * **No:** vivo   Non-BM SRS   * **Yes:** CMCC, Spreadtrum, ZTE, Sony * **No:** |
| 1.3 | Switching between joint and separate DL/UL TCI   * Alt1. A UE can be dynamically indicated with either joint DL/UL TCI or separate DL/UL TCI * Alt2A. A UE can be configured with either joint DL/UL TCI or separate DL/UL TCI via RRC signaling * Alt2B. A UE can be configured with either joint DL/UL TCI, separate DL/UL TCI, or both via RRC signaling * Alt3. A UE can be configured with either joint DL/UL TCI or separate DL/UL TCI via MAC CE signaling | **Alt1**: Lenovo/MoM, Nokia/NSB, Spreadtrum, CATT, APT/FGI, Xiaomi, Sony, AT&T.  **Alt2A**: Ericsson, NTT Docomo, LGE, NEC.  **Alt2B**: vivo  **Alt3**: CMCC, Samsung, NTT Docomo, Huawei/HiSi, CATT, [Xiaomi], Intel, Qualcomm, NEC. |
| 1.4 | Whether Rel-17 DL and, if applicable, joint TCI also applies to the following signals.   * If not applicable, how to provide DL QCL information for those signals   Note: UE-dedicated reception on PDSCH and all/subset of CORESETs have been agreed | CSI-RS resource for CSI:   * **Yes**: Lenovo/MoM, Ericsson, Nokia/NSB, OPPO, Spreadtrum, MTK, APT/FGI, Intel, Convida, AT&T, Samsung * **No**: Huawei/HiSi,   Some CSI-RS resource(s) for BM (if so, which one(s), e.g. aperiodic, repetition ‘ON’)   * **Yes**: Ericsson, Nokia/NSB, OPPO, MTK, APT/FGI, Intel, AT&T, Samsung * **No**: Huawei/HiSi,   CSI-RS for tracking:   * **Yes**: Lenovo/MoM, Ericsson, Spreadtrum, AT&T * **No**: Huawei/HiSi, MTK |
| 1.5 | Whether Rel-17 UL and, if applicable, joint TCI also applies to the following signals.   * If not applicable, how to provide UL TX spatial reference information for those signals | Some SRS resources or resource sets for BM:   * **Yes**: Lenovo/MoM, Ericsson, OPPO. MTK, Intel, * **No**: Huawei/HiSi, |
| 1.6 | Setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index): In addition to association with UL channel/RS,   * Alt1. The setting of (P0, alpha, closed loop index) is also associated with UL or (if applicable) joint TCI state * Alt2. The setting of (P0, alpha, closed loop index) is included with UL or (if applicable) joint TCI state * Alt3. The setting of (P0, alpha, closed loop index) is neither associated with nor included in UL or (if applicable) joint TCI state * Alt4. The setting of (P0, alpha, closed loop index) is determined as in Rel-16 without enhancement | **Alt1**: Lenovo, CMCC (PUCCH), Nokia/NSB, NTT Docomo, Spreadtrum, CATT, ZTE  **Alt2**: IDC, Samsung, OPPO (PUSCH, PUCCH), Intel (at least PUCCH), Apple, Qualcomm, LGE  **Alt3**: Fraunhofer IIS/HHI, CMCC (PUSCH – SRI, SRS – SRSResourceSet), Ericsson (for P0 and alpha), Sony,  **Alt4**: vivo, OPPO (SRS), MTK, |
| 1.7 | Path-loss measurement (PL RS):   * Alt1. PL-RS can be included in UL TCI state or (if applicable) joint TCI state.   + FFS: Whether it is always included or not. If not included, PL-RS is the periodic DL-RS used as a source RS for determining spatial TX filter or the PL RS used for the UL RS in UL or (if applicable) joint TCI state. * Alt2. PL-RS can be associated with (but not included in) UL TCI state or (if applicable) joint TCI state   + FFS: Exact association mechanism   + FFS: Whether it is always associated or not. If not associated, PL-RS is the periodic DL-RS used as a source RS for determining spatial TX filter or the PL RS used for the UL RS in UL or (if applicable) joint TCI state * Alt3. The periodic DL-RS used as a source RS for determining spatial TX filter can be used as PL-RS. In case the periodic DL-RS used as a source RS for determining spatial TX filter is not used as PL-RS, reuse Rel.16 procedure with the same signaling structure (MAC CE+SRI field in UL-related DCI) to indicate PL-RS for UL transmission with minimum enhancement (e.g. pertaining to the use for PUCCH, or using default PL-RS)   + PL-RS is not additionally configured in or associated to UL TCI state or (if applicable) joint TCI state * Alt4. UE calculates path-loss based on periodic DL RS configured as the source RS or a periodic QCL-Type-D/spatialRelationInfo source of the source RS in UL TCI state or (if applicable) joint TCI state   + FFS: Whether UE can calculate path-loss based on DL periodic RS for path-loss calculation for UL RS in the UL TCI | **Alt1**: IDC, Fraunhofer IIS/HHI, Ericsson (if UL RS in TCI state), NTT Docomo, OPPO, Intel (at least PUCCH), Qualcomm, AT&T, LGE  **Alt2**: Lenovo/MoM, CMCC, NTT Docomo, Huawei/HiSi, Spreadtrum, CATT, ZTE, MTK, Futurewei, Sony  **Alt3**: vivo  **Alt4**: Ericsson (if DL RS in TCI state), Samsung, Apple, |
| 1.8 | [Based on offline discussion, cf. Yuki, *reformulated for better clarity*] Carrier aggregation  For common TCI state(s) across a set of CCs (that is associated with the same gNB beam):   * Alt1: CC-specific QCL-TypeD RS can be determined from the common TCI state(s). The determined QCL-TypeD RSs for the set of CCs are further associated with a same QCL-TypeD RS. * Alt2: A single QCL-TypeD RS is determined from the common TCI state(s), and support enhanced QCL chain: support “i) only”, “ii) only”, or “both i) and ii)” from the following:   + i) the QCL type A TRS and, if any, QCL type D TRS, in the same/different CSI-RS resources   + ii) the QCL type A TRS and, if any, QCL type D SSB | **Alt1**: Nokia/NSB, NTT Docomo, Intel, Apple  **Alt2**: vivo, Samsung, NTT Docomo, ZTE, MTK |
| 1.9 | For separate TCI, UL TCI state pool  Alt1: Shared pool with joint/DL TCI state  Alt2: Separate pool | **Alt1**: vivo, Samsung, Spreadtrum, ZTE, MTK, Xiaomi, Intel, Qualcomm, Sony, Convida,  **Alt2**: Fraunhofer IIS/HHI, CMCC, Ericsson, OPPO, Futurewei, |
| 1.10 | TCI state pool for CA  Alt1: Separate, per CC  Alt2: Shared among all CCs  Note: This can be better formulated after #1.8 is finalized | **Alt1:** Nokia/NSB, CATT, Sony (separate per BWP).  **Alt2:** vivo, Samsung, Spreadtrum, ZTE, MTK, Xiaomi, Intel, Apple, Qualcomm. |
| 1.11 | Maximum value of M (DL) and N (UL) along with the use case(s) | Max M:   * **1**: Samsung (depending on issue 3 outcome), NTT Docomo (1st priority), Spreadtrum, ZTE (high priority), MTK, Convida * **2**: Nokia/NSB, * **>2 (specify)**: Vivo, APT/FGI, Futurewei, Qualcomm, LGE   Max N:   * **1**: Samsung (depending on issue 3 outcome), NTT Docomo (1st priority), Spreadtrum, ZTE (high priority), MTK, Convida * **2**: Nokia/NSB, * **>2 (specify)**: Vivo, APT/FGI, Futurewei, Qualcomm, LGE |
| 1.12 | TCI for non-UE-dedicated reception on PDSCH and all/subset of CORESETs  Alt1: Extend (use) Rel-17 unified TCI  Alt2: Reuse Rel-15/16 TCI | **Alt1**: vivo, Samsung  **Alt2**: |

**Proposal 1.1**: On Rel.17 unified TCI framework, ...

Table 2 Additional inputs: issue 1

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### Issue 2 (L1/L2-centric inter-cell mobility)

Table 4 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.1 | Support CSI-RS associated with/configured for non-serving cell(s) as a measurement RS  Note: Supporting this implies the support of Rel-15 CSI-RSRP as beam metric/reporting | CSI-RS for mobility/RRM associated with NSC:   * **Yes**: Huawei/HiSi, ZTE, CATT, Sony, LGE * **No**: Samsung, Nokia/NSB, OPPO, MTK, Xiaomi,   CSI-RS for BM configured for NSC:   * **Yes**: Ericsson, Nokia/NSB * **No**: Samsung, OPPO, MTK, Xiaomi,   CSI-RS for tracking (TRS) configured for NSC:   * **Yes**: Nokia/NSB, IDC (add PCI in TRS) * **No**: OPPO, MTK, Xiaomi, |
| 2.2 | Whether the measurement for SS-RSRP is limited within SMTC | **Yes**: vivo (follow L3-RSRP)  **No**: CATT, MTK, |
| 2.3 | Maximum value of K (beams associated at least with non-serving cell(s) reported in a single CSI reporting instance) | **1**:  **>1 (specify)**: Ericsson (up to 8, UE capability), Nokia/NSB (4), MTK (4), Intel (UE capability), Samsung (UE capability) |
| 2.4 | If max K>1, how to set the value of K  Alt1: RRC configured (based on UE capability)  Alt2: Dynamically selected by NW via MAC CE  Alt3: Dynamically selected by NW via DCI  Alt4: Dynamically selected by UE (indicated in CSI reporting) | **Alt1**:  **Alt2**: MTK  **Alt3**:  **Alt4**: Samsung |
| 2.5 | Can beam reporting associated with non-serving cell(s) be mixed with that with serving-cell in one reporting instance? | **Yes**: vivo, Ericsson, Samsung, Nokia/NSB, Spreadtrum, CATT, Intel, LGE  **No**: ASUSTeK, MTK |
| 2.6 | The maximum value of N1 (number of non-serving cell(s) RRC configured for measurement/reporting) | **1**: Apple  **>1 (specify)**: Samsung (UE capability) |
| 2.7 | The maximum value of N2 (number of non-serving cell(s) in a single CSI reporting instance comprising K beams) | **1**: OPPO, Spreadtrum  **≤ N1**: NTT Docomo (3), CATT (UE capability), Xiaomi (3), Samsung |
| 2.8 | Supported DL QCL Type-D and/or UL TX spatial reference source RS type(s) for L1/L2-centric inter-cell mobility by extending Rel-17 unified TCI framework to inter-cell indication | DL QCL Type-D:   * CSI-RS for BM configured for NSC: MTK, Sony * CSI-RS for tracking configured for NSC: NTT Docomo, MTK, Sony * CSI-RS for mobility associated with NSC: Sony * SSB associated with NSC as direct QCL source: Samsung, NTT Docomo, MTK, * SSB associated with NSC as indirect QCL source: Sony * SRS for BM configured for NSC: * Other:   UL TX spatial reference:   * CSI-RS for BM configured for NSC: * CSI-RS for tracking configured for NSC: * CSI-RS for mobility associated with NSC: * SSB associated with NSC as direct QCL source: Samsung, NTT Docomo, MTK * SSB associated with NSC as indirect QCL source: * SRS for BM configured for NSC: MTK * Other: |
| 2.9 | Support for event-triggered (UE-initiated) inter-cell SS-RSRP reporting | **Yes**: Huawei/HiSi, Qualcomm, Sony, Apple, Samsung, Xiaomi, ASUSTeK, IDC (inter-cell BFR)  **No**: |
| 2.10 | Timing assumption (e.g. time of arrival and time of the measurement) for measurement of non-serving cell measurement RS | TA/TAG of SC and configured NSC(s) shall be the **same**:  TA/TAG of SC and configured NSC(s) can be **different**: vivo (UE can report), Intel, Apple (with PDCCH ordered NSC PRACH), Qualcomm, CATT (TA difference is configured) |

**Proposal 2.1**: On Rel.17 multi beam measurement/reporting enhancements for L1/L2-centric inter-cell mobility and inter-cell mTRP ...

Table 5 Additional inputs: issue 2

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### Issue 3 (beam indication signaling medium)

Table 6 Summary: issue 3

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| **#** | **Issue** | **Companies’ views** |
| 3.1 | Support for DCI formats for Rel.17 unified TCI framework beam indication (TCI state update) beyond the agreed DCI formats 1\_1/1\_2 with DL assignment   * Alt0: No additional DCI format is supported * Alt1: DCI formats 1\_1 and 1\_2 without DL assignment, applicable for joint TCI as well as separate DL/UL TCI   + Support DCI acknowledgment mechanism, e.g. based on SPS PDSCH release, based on triggered SRS, based on DCI indicating SCell dormancy   + FFS: How to identify DCI formats 1\_1/1\_2 used for beam indication only (not for scheduling a PDSCH reception, not indicating a SPS PDSCH release, or not indicating SCell dormancy), considering impacts on PDCCH coverage and scheduling mechanism   + FFS: Whether the UE can/shall assume the gNB configured application time is after ACK transmission * Alt2: Dedicated DCI format other than 1\_1/1\_2 without DL assignment, applicable for joint TCI as well as separate DL/UL TCI * Alt3: UL-related DCI formats 0\_1/0\_2 with UL grant, applicable only for UL-only TCI of separate DL/UL TCI | **Alt0**: Fujitsu, Ericsson, Huawei/HiSi,  **Alt1**: CMCC, Nokia/NSB, Samsung (2nd preference), NTT Docomo, OPPO, Spreadtrum, CATT, ZTE, MTK, APT/FGI, Futurewei, Intel, Apple, Qualcomm, Sony, Convida,  **Alt2**: Samsung (1st preference), OPPO (DCI Format 1\_0), Intel  **Alt3**: IDC, Lenovo/MoM, MTK, Xiaomi, Intel, Sony, LGE, NEC. |
| 3.2 | If Alt1/Alt2 is supported, DCI acknowledgment mechanism (including supported codebooks and timing relationship) | **Mechanism analogous to Rel-15/16 SPS PDSCH release** (both Rel-15/16 type-1 and type-2 codebooks): ZTE, MTK, APT/FGI, Apple, Samsung, Qualcomm, OPPO, NTT Docomo, CATT, Sony  **HARQ timing analogous on Rel-15/16 definition** (ACK reported in PUCCH *k* slots after PDCCH reception where *k* is indicated by the PDSCH-to-HARQ\_feedback timing indicator DCI field, else RRC configured): Samsung, ZTE, MTK, APT/FGI, Apple, Qualcomm, OPPO, NTT Docomo, CATT, Sony |
| 3.3 | If Alt1/Alt2 is supported, mechanism for identifying/differentiating the DCI format used for beam indication only | Combination of DCI fields with set values (differentiating from SPS PDSCH release):   * FDRA: Spreadtrum, MTK, Apple, ZTE, Qualcomm, Samsung * MCS: Spreadtrum(1’s), MTK (1’s), Apple, ZTE, Qualcomm, Samsung * RV: MTK (1’s), Apple, ZTE, Qualcomm, Samsung * NDI: Spreadtrum (0’s), MTK (0’s), Apple, ZTE, Qualcomm, Samsung   RNTI:   * **CS-RNTI** (following SPS PDSCH release): Spreadtrum, MTK, ZTE, APT/FGI, Apple, Qualcomm, Samsung, NTT Docomo * **Other RNTI**: CATT, Futurewei |
| 3.4 | If Alt1/Alt2 is supported, which DCI fields are needed/used (in addition to TCI field(s))?  Note: As it is customary to do so, the remaining unused DCI fields and codepoints can be utilized for future use | DCI fields:   * Identifier for DCI formats: Samsung, ZTE, MTK * Carrier indicator: ZTE, MTK, Samsung * Bandwidth part indicator: ZTE, MTK * TDRA: ZTE * DAI (if configured): ZTE * TPC command for scheduled PUCCH: ZTE * PUCCH resource indicator: Samsung, ZTE * PDSCH-to-HARQ\_feedback timing indicator (if present): Samsung, ZTE |
| 3.5 | The use of TCI fields for beam indication  Note: This can be dependent on the DCI format | **Joint TCI**: ZTE, MTK, Apple, Qualcomm, OPPO, Samsung, Nokia/NSB,  **Either DL TCI or UL TCI for separate DL/UL TCI**: ZTE, MTK, Apple, Qualcomm, OPPO, Samsung, Nokia/NSB,  **Both DL TCI and UL TCI for separate DL/UL TCI**: Nokia/NSB, Samsung (only if DCI without DLA is supported) |
| 3.6 | Beam application time (BAT):   * Alt1: the first slot that is at least X ms or Y symbols after the [first/last] symbol of the DCI with the joint or separate DL/UL beam indication * Alt2A: the first slot that is at least X ms or Y symbols after the [first/last] symbol of the acknowledgment of the joint or separate DL/UL beam indication * Alt 2B: the first slot that is at least X ms or Y symbols after the [first/last] symbol of the acknowledgment of the joint or separate DL/UL beam indication, except that the (new) TCI state update can be applied to the PDSCH, if it exists, (scheduled by the beam indication DCI) and corresponding ACK transmission (provided that the time offset between the DCI and the scheduled PDSCH exceed the threshold, analogous to Rel.15/16) * Alt2C: Support both Alt1 and Alt2A, and introduce a UE capability that indicates the support of Alt1 or Alt2A * Alt3: the first slot that is at least X1 ms or Y1 symbols after the [first/last] symbol of the DCI with beam indication and X2 ms or Y2 symbols after the [first/last] symbol of the acknowledgment of the beam indication | **Alt1**: vivo, Ericsson, Samsung (DCI with DLA), Convida  **Alt2A**: IDC, Fujitsu, Lenovo/MoM, NTT Docomo, Huawei/HiSi, OPPO, Spreadtrum, CATT, ZTE, APT/FGI, Intel, Apple, Qualcomm, Sony, Samsung (DCI without DLA)  **Alt2B**: Nokia/NSB, NTT Docomo, Xiaomi, LGE, NEC, Samsung (DCI with DLA)  **Alt2C**: MTK  **Alt3**: OPPO |
| 3.7 | Support for group-based DCI in Rel.17 unified TCI framework | **Yes:** Intel  **No:** IDC |

**Proposal 3.1**: For beam indication with Rel-17 unified TCI, ...

Table 7 Additional inputs: issue 3

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### Issue 4 (MP-UE)

Table 8 Summary: issue 4

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| **#** | **Issue** | **Companies’ views** |
| 4.1 | Additional specification support for enabling UE-initiated   * Panel activation (activating L out of P available UE panels at least for DL/UL measurement), and/or * Panel selection (activating 1 out of L activated UE panels for UL transmission)   Note: If a feature is supported, we will need to discuss whether this applies to activation, selection, or both | * **Not needed**: Ericsson, OPPO * **Indicator/association for panel entity**: IDC, vivo, Lenovo/MoM, ZTE, Qualcomm, Sony, MTK, Fraunhofer IIS/HHI * **Event of panel switch reporting**: CATT * **Transmission process**: Apple |
| 4.2 | Additional specification support for NW-initiated panel selection (via Rel-17 TCI state update)  Note: the use of Rel-17 unified TCI and Rel-17 beam indication for panel selection has been agreed. “Additional” implies on top of this. | * **Not needed**: vivo (implicit), Fraunhofer IIS/HHI (implicit), Ericsson, Xiaomi, OPPO, CATT, Sony * **Indicator/association for panel entity**: IDC, ZTE * **Handshake mechanism/panel alignment**: Huawei/HiSi, Qualcomm |
| 4.3 | For CSI/beam reporting, what indicates a panel entity (comprising one or more RS resources)? | * **CRI/SSBRI**: LGE (per panel) * **Association with CSI-RS resource set index (transparent)**: Lenovo/MoM, Samsung, Huawei/HiSi, Spreadtrum, Sony, CATT * **New panel ID**: IDC, vivo, Lenovo/MoM, Xiaomi, NTT Docomo, Spreadtrum, NTK (PEI) * **Transmission process index:** Apple |
| 4.4 | For beam indication, what indicates a panel entity (comprising one or more RS resources)? | * **CRI/SSBRI/SRI**: vivo * **CSI-RS resource set index/SRS resource set index**: Fraunhofer IIS/HHI, Samsung, Huawei/HiSi, Sony, CATT * **New panel ID**: IDC, Xiaomi, LGE |

**Proposal 4.1**: On Rel.17 enhancements to facilitate UL beam selection for MP-UE,

Table 9 Additional inputs: issue 4

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### Issue 5 (MPE mitigation)

Table 10 Summary: issue 5

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| **#** | **Issue** | **Companies’ views** |
| 5.1 | Whether to support at least one the following:   * {Rel.16 P-MPR based (beam/panel-level)} + {A}, where A is either Opt1A, Opt1B, Opt1C, or Opt1D:   + Option 1A: Virtual PHR or a modified version associated with each activated UL TCI or, if applicable, joint TCI   + Option 1B: {SSBRI(s)/CRI(s) and/or panel indication}   + Option 1C: {SSBRI(s)/CRI(s) and/or panel indication} + virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)   + Option 1D: No additional reporting quantity * {SSBRI(s)/CRI(s) and/or panel indication} + {A}, where A is either Opt2A, Opt2B, Opt2A+ Opt2B, or Option 2C   + Option 2A: L1-RSRP [L1-SINR] or a modified version that accounts for MPE effect associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)   + Option 2B: Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)   + Option 2C: No additional reporting quantity | Rel-16 P-MPR based:   * **Option 1A**: Nokia/NSB, NTT Docomo, OPPO * **Option 1B**: Sony, Intel * **Option 1C**: ZTE, Apple, Qualcomm * **Option 1D**: vivo, Spreadtrum, MTK   SSBRI/CRI-based:   * **Option 2A**: CMCC, Ericsson (*UL-RSRP = L1-RSRP – PDL + PUL*), Samsung (modified RSRP), NTT Docomo, CATT (scaled RSRP), MTK, Sony, LGE * **Option 2B**: CATT, ZTE, Convida * **Option 2A+2B** (in one report): Nokia/NSB, Apple * **Option 2C**: Spreadtrum * **Other option**(s): IDC (TCI state group indication + gNB confirmation) |
| 5.2 | If Opt1A/B/C/D in 5.1 is supported:   * Alt1. Beam-level reporting * Alt2. Panel-level reporting | **Alt1**: Nokia/NSB, MTK, Qualcomm  **Alt2**: vivo, Lenovo/MoM, Xiaomi, Spreadtrum |
| 5.3 | If Opt2A/B/C in 5.1 is supported:   * Alt1 (beam-level): Reporting of at least SSBRI(s)/CRI(s) to indicate gNB beam(s) that is feasible for UL transmission * Alt2 (panel-level): Reporting of at least an indicator associated with a UE ‘panel’ that is feasible for UL transmission | **Alt1**: IDC, Nokia/NSB  **Alt2**: Lenovo/MoM, Xiaomi, Samsung, LGE |
| 5.4 | Reporting mechanism | **UE-initiated (event-triggered) without NW triggering via CSI request:** Sony, Qualcomm, Samsung, Nokia/NSNB (BFR like),  **NW triggering via CSI request (just as the regular A-CSI):** |

**Proposal 5.1**: On Rel.17 enhancements to facilitate MPE mitigation, support the following schemes ...

Table 11 Additional inputs: issue 5

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### Issue 6 (advanced beam refinement/tracking)

Table 12 Summary: issue 6

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| **#** | **Issue** | **Companies’ views on specific candidate schemes** |
| 6.1 | Group 1: Beam management with reduced DL signaling to reduce latency | **TCI-state-update/activation-triggered measurement**: Samsung (plus reporting), Nokia/NSB (P3), OPPO. MTK (activation triggered)  **TCI state update based on measurement/reporting without beam indication**: Ericsson, Nokia/NSB, MTK, Qualcomm, Futurewei  **Semi-static beam selection (without beam indication and measurement/reporting)**: NTT Docomo (for HST)  **UE-initiated beam switch**: OPPO |
| 6.2 | Group 2: Reducing activation delay of TCI states and PL-RSs (including other WGs, e.g. RAN4)  Note: A number of companies argued that most of the schemes in this category can be handled exclusively in RAN4 | **AP TRS triggering**: vivo, Apple (MAC CE/DCI),  **MAC CE based update/activation**:   * PL-RS: vivo, Qualcomm (reducing application time) * QCL info for CSI-RS/SSB: Intel, ZTE, vivo, Lenovo/MoM * SSB pool (ZTE)   **Direct SCell TCI state activation**: Qualcomm  **One-shot timing update**: Ericsson  **Pre-stored QCL configuration**: Ericsson, NTT Docomo |

**Proposal 6.1**: On Rel.17 enhancements to facilitate advanced beam refinement/tracking, perform study and, if needed, specify the following candidate schemes ...

Table 13 Additional inputs: issue 6

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## Appendix A: Collection of Agreements up to RAN1#104-e

**Issue 1**

* [Issue 1] For Rel.17 NR FeMIMO, on the unified TCI framework
  1. Support joint TCI for DL and UL based on and analogous to Rel.15/16 DL TCI framework
     + The term “TCI” at least comprises a TCI state that includes at least one source RS to provide a reference (UE assumption) for determining QCL and/or spatial filter
     + The source reference signal(s) in M TCIs provide common QCL information at least for UE-dedicated reception on PDSCH and all or subset of CORESETs in a CC
       - FFS: Optionally this common QCL information can also apply to CSI-RS resource for CSI, CSI-RS resource for BM, and CSI-RS for tracking
       - FFS: Applicability on PDSCH includes PDSCH default beam
       - Working Assumption: Select between M=1 and M>=1
     + The source reference signal(s) in N TCIs provide a reference for determining common UL TX spatial filter(s) at least for dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC,
       - Optionally, this UL TX spatial filter can also apply to all SRS resources in resource set(s) configured for antenna switching/codebook-based/non-codebook-based UL transmissions
       - FFS: applicability of this UL TX spatial filter to SRS configured for beam management (BM)
       - FFS: PUSCH port determination based on the TCI, e.g., to be mapped with SRS ports analogous to Rel.15/16
       - Working Assumption: Select between N=1 and N>=1
     + FFS: extension to common QCL information applied to only some of the CORESETs or PUCCH resources in a CC, e.g. for mTRP
     + FFS: When used for the purpose of joint beam indication for UL and DL, whether a joint TCI pool for DL and UL dedicated for the purpose is used, or the same TCI pool as that used for the purpose of separate DL/UL beam indication is used
     + Note: The resulting beam indication directly refers to the associated source RS(s)
     + FFS (RAN1#103-e): Details on extension to intra- and inter-band CA
     + FFS (RAN1#103-e): The supported number of active TCI states considering factors such as multi-TRP and issue 6
     + FFS (RAN1#103-e): Applicable QCL types, and co-existence with DL TCI and spatial relation indication in Rel.15/16
  2. In RAN1#103-e, investigate, for the purpose of down selection, the following alternatives for accommodating the case of separate beam indication for UL and DL
     + Alt1. Utilize the joint TCI to include references for both DL and UL beams
     + Alt2. Utilize two separate TCI states, one for DL and one for UL. The TCI state for the DL is the same as agreed in 1a. The TCI state for the UL can be newly introduced.
       - Alt 2-1: The UL TCI state is taken from the same pool of TCI states as the DL TCI state
       - Alt 2-2: The UL TCI state is taken from another pool of TCI states than the DL TCI state
     + Note: The resulting beam indication directly refers to the associated source RS(s)
     + FFS (RAN1#103-e): Details on extension to intra- and inter-band CA
     + Note: This may be related to issue 5 as well as other reasons for different TCIs such as network flexibility/scheduling
  3. Support the use of SSB/CSI-RS for BM and/or SRS for BM as source RS to determine a UL TX spatial filter in the unified TCI framework
     + Whether the UL TX spatial filter corresponds to UL TCI (separate from DL TCI) depends on the outcome of 1b) above
     + FFS: Support the use of non-BM CSI-RS and/or non-BM SRS in addition
  4. In RAN1#103-e, decide if SRS for BM can be configured as a source RS to represent a DL RX spatial filter in the unified TCI framework
  5. In RAN1#103-e, decide/finalize all other parameters included in or concurrent with (but not included in) the TCI, e.g. UL-PC-related parameters (involving P0/alpha, PL RS, and/or closed loop index), UL-timing-related parameters
  6. In RAN1#103-e, identify issues pertaining to alignment between DL and UL default beam assumptions using the unified TCI framework

On Rel-17 unified TCI framework, to accommodate the case of separate beam indication for UL and DL:

* Utilize two separate TCI states, one for DL and one for UL.
  + FFS: Contents of separate UL TCI state
  + Note: For FR1, UE does not expect UL TCI to provide a reference for determining common UL TX spatial filter(s), if UL TCI is supported for FR1
* For the separate DL TCI:
  + The source reference signal(s) in M TCIs provide QCL information at least for UE-dedicated reception on PDSCH and for UE-dedicated reception on all or subset of CORESETs in a CC
* For the separate UL TCI:
  + The source reference signal(s) in N TCIs provide a reference for determining common UL TX spatial filter(s) at least for dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC
  + Optionally, this UL TX spatial filter can also apply to all SRS resources in resource set(s) configured for antenna switching/codebook-based/non-codebook-based UL transmissions
* FFS: Whether the UL TCI state is taken from a common/same or separate TCI state pool from DL TCI state
  + Note that TCI state pool for joint DL and UL beam indication is still FFS
* FFS: Whether Rel.17 supports TCI configured for single channel (e.g. PDSCH only, single CORESET)
* Note: This does not preclude the type of UE supporting only 1 beam tracking loop, i.e. UE reports value of 1 in UE FG 2-62.

**Conclusion**

There is no consensus in RAN1 to include the following as part of RAN1 agreement for AI 8.1.1 in RAN1 #103e:

* FFS beam indication for the TCI state assumption/update for the following cases:
  + The beam indication UE-specific DCI (i.e. the CORESETs with the DCI received by UE), the scheduled PDSCH by the DCI and the associated PUCCH for the acknowledgment of the beam indication DCI

Non-UE-specific CORESETs and PUSCH/PDSCH scheduled/activated and PUCCH transmission triggered by non-UE-specific CORESETs

On Rel-17 unified TCI framework, support common TCI state ID update and activation to provide common QCL information and/or common UL TX spatial filter(s) across a set of configured CCs:

* The above applies to intra-band CA
* The above applies to joint DL/UL and separate DL/UL beam indications
* Just as Rel.16, the RS in the TCI state that provides QCL-TypeA [or QCL-TypeB] shall be in the same CC as the target channel or RS
* The common TCI state ID implies that the same/single RS determined according to the TCI state(s) indicated by a common TCI state ID is used to provide QCL Type-D indication and to determine UL TX spatial filter across the set of configured CCs
* FFS: The above also applies to inter-band CA
* FFS: TCI state pool for CA
  + Opt-1: sharing a single RRC TCI state pool for the set of configured CCs, e.g., cell-group TCI state pool, or reuse TCI state pool for PDSCH in a reference cell; A CC ID for QCL-Type A RS is absent in a TCI state, and the CC ID for QCL-Type A RS is determined according to a target CC of the TCI state.
    - FFS: Whether it is possible that a single TCI state in the pool includes all source RSs from different CCs
  + Opt-2: configuring RRC TCI state pool per individual CC
* FFS: Whether the Rel-17 common beam update across multiple CCs applies to beam indication for single channel (e.g. PDSCH only, single CORESET), a subset of channels, or all channels

On Rel-17 unified TCI framework:

* A pool of joint DL/UL TCI state is used for joint DL/UL TCI state update (beam indication).
* FFS: The pool for separate DL and UL TCI state update (beam indication)
* Note: Here, TCI state pool refers to a pool configured via higher-layer (RRC) signaling
* FFS: Whether joint TCI may include UL specific parameter(s) such as UL PC/timing parameters, PL RS, panel-related indication,etc. and if it is included, it is used only for UL transmission of the DL and UL transmissions to which the joint TCI is applied

**Conclusion**

On Rel.17 unified TCI framework, based on the agreements in RAN1#102-e and 103-e, the following terms are defined as follows (at least for the purpose of discussion and reaching agreements).

For M=1:

* DL TCI: The source reference signal(s) (analogous to Rel.15, two, if qcl\_Type2 is configured in addition to qcl\_Type1) in the DL TCI provides QCL information at least for UE-dedicated reception on PDSCH and all of CORESETs in a CC

For N=1:

* UL TCI: The source reference signal in the UL TCI provides a reference for determining UL TX spatial filter at least for dynamic-grant/configured-grant based PUSCH and all of dedicated PUCCH resources in a CC

For M=N=1:

* Joint DL/UL TCI: A TCI refers to at least a common source reference RS used for determining both the DL QCL information and the UL TX spatial filter.
* Separate DL/UL TCI: The DL TCI and UL TCI are distinct (therefore, separate).

For M>1:

* DL TCI: Each of the M source reference signals (or 2M, if qcl\_Type2 is configured in addition to qcl\_Type1) in the M DL TCIs provides QCL information at least for one of the M beam pair links for UE-dedicated receptions on PDSCH and/or subset of CORESETs in a CC

For N>1:

* UL TCI: Each of the N source reference signals in the N UL TCIs provide a reference for determining UL TX spatial filter at least for one of the N beam pair links associated with dynamic-grant(s)/configured-grant(s) based PUSCH, and/or subset of dedicated PUCCH resources in a CC

For M>1 and/or N>1:

* Joint DL/UL TCI: A TCI refers to at least a common source reference RS used for determining both the DL QCL information and the UL TX spatial filter. In this case, M=N.
* Separate DL/UL TCI: The M DL TCIs and N UL TCIs are distinct (therefore, separate).

Note: Other TCI types/terms such as “common TCI” are not used.

On Rel.17 unified TCI framework, the supported source/target QCL relations in the current TS38.214 V16.4.0 is supported for QCL Type D.

* Note: This implies that the following source RS types for DL QCL (Type D, for DL RX spatial filter reference) information for DL UE-dedicated reception on PDSCH and all/subset of CORESETs are supported:
  + CSI-RS for beam management
  + CSI-RS for tracking
* FFS (to be decided by RAN1#104bis-e): If SSB, CSI-RS for CSI, and/or SRS for BM are also supported as source RS types

On Rel.17 unified TCI framework, the following source RS types for UL TX spatial filter are supported:

* CSI-RS for tracking
* Note: SRS for BM, SSB, and CSI-RS for BM have been agreed in RAN1#102-e
* FFS (to be decided by RAN1#104bis-e): non-BM CSI-RS other than for tracking, non-BM SRS

On Rel.17 unified TCI framework:

* For joint and separate DL/UL TCI, DL large scale QCL properties are inferred from one (qcl-Type1) or two RSs (qcl-Type1 and qcl-Type2) analogous to Rel.15/16
* For joint DL/UL TCI, UL spatial filter is derived from the RS of DL QCL Type D

On Rel.17 unified TCI framework, by RAN1#104bis-e, down select or modify at least one from the following alternatives:

* Alt1. A UE can be dynamically indicated with either joint DL/UL TCI or separate DL/UL TCI
  + Details on dynamic indication are FFS
  + FFS: UE capability for the support of joint DL/UL TCI and/or separate DL/UL TCI
* Alt2A. A UE can be configured with either joint DL/UL TCI or separate DL/UL TCI via RRC signaling
* Alt2B. A UE can be configured with either joint DL/UL TCI, separate DL/UL TCI, or both via RRC signaling
* Alt3. A UE can be configured with either joint DL/UL TCI or separate DL/UL TCI via MAC CE signaling
  + Details on how this is signaled in relation to TCI activation are FFS

On Rel.17 unified TCI framework, decide by RAN1#104bis-e:

* Whether DL or, if applicable, joint TCI also applies to the following signals. If not, FFS any other enhancement over Rel.15/16:
  + CSI-RS resources for CSI
  + Some CSI-RS resources for BM, if so, which ones (e.g. aperiodic, repetition ‘ON’)
  + CSI-RS for tracking
* Whether UL or, if applicable, joint TCI also applies to the following signals
  + Some SRS resources or resource sets for BM

On the setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index) for Rel.17 unified TCI framework:

* The setting of (P0, alpha, closed loop index) is at least associated with UL channel or UL RS
* Select or modify from one of the following alternatives by RAN1#104bis-e for PUCCH, PUSCH, and SRS separately:
  + Alt1. The setting of (P0, alpha, closed loop index) is also associated with UL or (if applicable) joint TCI state
  + Alt2. The setting of (P0, alpha, closed loop index) is included with UL or (if applicable) joint TCI state
  + Alt3. The setting of (P0, alpha, closed loop index) is neither associated with nor included in UL or (if applicable) joint TCI state
  + Alt4. The setting of (P0, alpha, closed loop index) is determined as in Rel-16 without enhancement

On Rel.17 unified TCI framework:

* Select at least one of the following alternatives by RAN1#104bis-e for path-loss measurement (PL-RS):
  + Alt1. PL-RS can be included in UL TCI state or (if applicable) joint TCI state.
    - FFS: Whether it is always included or not. If not included, PL-RS is the periodic DL-RS used as a source RS for determining spatial TX filter or the PL RS used for the UL RS in UL or (if applicable) joint TCI state.
  + Alt2. PL-RS can be associated with (but not included in) UL TCI state or (if applicable) joint TCI state
    - FFS: Exact association mechanism
    - FFS: Whether it is always associated or not. If not associated, PL-RS is the periodic DL-RS used as a source RS for determining spatial TX filter or the PL RS used for the UL RS in UL or (if applicable) joint TCI state
  + Alt3. The periodic DL-RS used as a source RS for determining spatial TX filter can be used as PL-RS. In case the periodic DL-RS used as a source RS for determining spatial TX filter is not used as PL-RS, reuse Rel.16 procedure with the same signaling structure (MAC CE+SRI field in UL-related DCI) to indicate PL-RS for UL transmission with minimum enhancement (e.g. pertaining to the use for PUCCH, or using default PL-RS)
    - PL-RS is not additionally configured in or associated to UL TCI state or (if applicable) joint TCI state
  + Alt4. UE calculates path-loss based on periodic DL RS configured as the source RS or a periodic QCL-Type-D/spatialRelationInfo source of the source RS in UL TCI state or (if applicable) joint TCI state
    - FFS: Whether UE can calculate path-loss based on DL periodic RS for path-loss calculation for UL RS in the UL TCI
* FFS: Application time of PL-RS
* NOTE: As in Rel-16, a UE does not expect to simultaneously maintain more than four path-loss estimates per serving cell for all PUSCH/PUCCH/SRS transmissions
  + FFS: investigate the condition(s) agreed in Rel-17 and, if needed, study whether a UE can simultaneously maintain more than four path-loss estimates

**Issue 2**

* [Issue 2] For Rel.17 NR FeMIMO, on L1/L2-centric inter-cell mobility:
  1. In RAN1#103-e, finalize scope and use cases for L1/L2-centric inter-cell mobility, including:
     + Applicability in various non-CA and CA setups such as intra-band and inter-band CA
     + Use cases in comparison to Rel.15 L3-based handover (HO) taking into account potential extension of DAPS-based Rel.16 mobility enhancement to FR2-FR2 HO
     + The extent of RAN2 impact (MAC CE, RRC, user plane protocols)
     + Network architecture, e.g. NSA vs. SA, inter-RAT scenarios
  2. In RAN1#103-e, depending on the outcome of 2a), further identify additional components –along with the associated alternatives –required for supporting inter-cell mobility based on the same unified TCI framework as that for intra-cell mobility (including dynamic TCI state update signaling), including
     + Method(s) for incorporating non-serving cell information associated with TCI
     + Method(s) for DL measurements and UE reporting (e.g. L1-RSRP) associated with non-serving cell(s)
     + UE behavior for reception of signals and non-UE-specific control and data channels associated with non-serving cell(s)
     + UL-related enhancements, e.g. related to RA procedure including TA
     + Beam-level event-driven mechanism for L1/L2-centric inter-cell mobility

On Rel-17 enhancements to enable L1/L2-centric inter-cell mobility:

* The following use cases are assumed:
  + Network architecture:
    - NSA, i.e. LTE PCell and NR-PSCell
    - SA
  + Intra-band CA
    - FFS: If inter-band CA is also included
  + Intra- RAT (excluding inter-RAT)
  + Intra-frequency scenario:
    - The SSBs of non-serving cells have the same center frequency and SCS as the SSBs of the serving cell
    - An SSB of a non-serving cell is associated with a PCI different from the PCI of the serving cell
    - FFS: Support for inter-frequency scenario
  + FFS: Whether to support intra-DU only operation, or whether inter-DU is also allowed
* The following enhancement scope is assumed:
  + Facilitating measurement and reporting of non-serving RSs via incorporating non-serving cell info with some TCI(s), along with the necessary measurement and reporting scheme(s)
    - FFS: Detailed/exact method(s)
    - FFS: Whether this also implies the support of beam indication (TCI state update along with the necessary TCI state activation) for TCI(s) associated with non-serving cell RS(s)
    - FFS: Metric for the measurement and reporting, e.g. L1-RSRP or L3-RSRP or time- or spatial-domain-filtered L1-RSRP
    - FFS: Beam-level event-driven mechanism, using serving cell RS and/or non-serving cell RS
  + Facilitate serving cell to provide configurations for non-serving cell SSBs via RRC
    - FFS: details for the configurations, e.g. time/frequency location, transmission power, etc.
    - FFS: other information needed for inter-cell mobility
  + Note: In RAN1's understanding, non-serving cell SSB and non-serving cell RS can be part of the serving cell configuration
* FFS: The following enhancement scope is assumed by RAN1:
  + Whether RRC reconfiguration signaling is needed or not when a TCI associated with non-serving cell RS is indicated
    - A non-serving cell RS is an RS that is or has an SSB of a non-serving cell as direct or indirect QCL source
    - This implies no C-RNTI update when UE receives DL channel RS associated to non-serving cell RS as QCL source.
    - FFS whether TCI associated with non-serving cell can be indicated to or are applicable for all channels.
  + Whether some RRC parameters need to be updated without additional RRC signaling, e.g. some RRC parameters are pre-configured, which are associated with TCI states with neighbor cell RS as QCL source
  + Whether UE needs/can change serving cell during L1/L2-centric inter-cell mobility.
  + The above assumption to be verified by RAN2

On Rel.17 multi beam measurement/reporting enhancements for L1/L2-centric inter-cell mobility and inter-cell mTRP:

* A quality of up to K beams associated at least with non-serving cell(s) can be reported in a single CSI reporting instance
  + For each beam, the UE can report at least: (1) a Measured RS Indicator, and (2) a Beam Metric associated with the Measured RS Indicator
  + FFS: Maximum value of K
  + FFS: If K is fixed, configured, reported by UE capability, or dynamically selected
  + FFS: The type of beam metric (e.g. L1-RSRP, L3-RSRP, or hybrid L1/L3-RSRP) and related measurement behavior
  + FFS: Whether or not beam reporting associated with non-serving cell(s) can be mixed with that with serving-cell in one reporting instance

At the end of RAN1#104-e, send an LS to RAN2 with all the RAN1-related inter-cell mobility agreements done so far during Rel17.

On Rel.17 multi beam measurement/reporting enhancements for L1/L2-centric inter-cell mobility and inter-cell mTRP:

* Rel.15 L1-RSRP is used as reporting quantity for measurement and reporting of non-serving-cell(s)
  + Support SSB as a measurement RS for L1/L2-centric inter-cell mobility and inter-cell mTRP, and Rel.15 SS-RSRP calculated from SSB of non-serving cell(s)
    - FFS: Whether the measurement for SS-RSRP is limited within SMTC
    - FFS: Detailed reporting method, e.g. via including existing L1-RSRP report, UE-initiated report etc.
  + FFS: Whether or not to support CSI-RS (for e.g. mobility and/or tracking) of non-serving cell(s) as a measurement RS for L1/L2-centric inter-cell mobility and inter-cell mTRP. If the support of CSI-RS (for e.g. mobility and/or tracking) of non-serving cell(s) as a measurement RS for L1/L2-centric inter-cell mobility and inter-cell mTRP is confirmed, Rel.15 CSI-RSRP is also supported
    - Whether the support applies to CSI-RS with or without QCL source, or both
  + FFS: The number of non-serving cell(s) for measurement/reporting
  + FFS: time behavior of the reporting, i.e. periodic, semi-persistent, aperiodic, or UE-initiated
* FFS: If other reporting quantities are supported, e.g. L3-RSRP, hybrid L1/L3-RSRP
* FFS: Dynamic activation/deactivation/selection of the beam measurement on the RS(s) associated with non-serving cell(s) via MAC CE
* FFS: Timing assumption (e.g. time of arrival and time of the measurement) for measurement of non-serving cell RS measurement

On Rel.17 enhancements for L1/L2-centric inter-cell mobility,

* Discuss whether to support at least the source RS types already agreed for intra-cell mobility for the purpose of referencing to non-serving cell(s). Note: This implies the following source RS(s):
  + CSI-RS for BM configured for non-serving cell(s) for DL QCL and UL TX spatial references
  + CSI-RS for tracking (TRS) configured for non-serving cell(s) for DL QCL and UL TX spatial references
  + SSB configured for non-serving cell(s) for UL TX spatial references
  + SRS for BM configured for non-serving cell(s) for UL TX spatial references
  + FFS: whether to support CSI-RS for mobility
  + FFS: whether to support other source RS(s) potentially agreed later for intra-cell mobility
  + FFS: whether to support CSI-RS for BM and tracking configured for non-serving cell(s) and without non-serving cell SSB as QCL-TypeD source

**Issue 3**

* [Issue 3] For Rel.17 NR FeMIMO, on dynamic TCI state update signaling medium:
  1. In RAN1#103-e, investigate, for the purpose of down selection, the following alternatives:
     + Alt1. DCI
     + Alt2. MAC CE
     + Note: Combination between DCI and MAC CE for, e.g. different use cases or control information partitioning can also be considered
     + Note: The study should consider factors such as feasibility for pertinent use cases, performance (based on at least the agreed EVM), overhead (including PDCCH capacity), latency, flexibility, reliability including the support of retransmission
     + Note: This may be related to outcome of issue 1a), 1b), and 6a)
  2. In RAN1#103-e, depending on the outcome of 3a), identify candidates for more detailed design issues for the dynamic TCI state update such as
     + Exact content
     + Signaling format
     + Reliability aspects including the support of retransmission
     + Extensions, including the support of UE-group (in contrast to UE-dedicated) signaling

On beam indication signaling medium to support joint or separate DL/UL beam indication in Rel.17 unified TCI framework:

* Support L1-based beam indication using at least UE-specific (unicast) DCI to indicate joint or separate DL/UL beam indication from the active TCI states
  + The existing DCI formats 1\_1 and 1\_2 are reused for beam indication
  + Support a mechanism for UE to acknowledge successful decoding of beam indication
    - The ACK/NAK of the PDSCH scheduled by the DCI carrying the beam indication can be used as an ACK also for the DCI
    - FFS: Whether any additional specification support is needed
* Support activation of one or more TCI states via MAC CE analogous to Rel.15/16:
  + At least for the single activated TCI state, the activated TCI state is applied
  + The content for the MAC CE is determined based on the outcome of issue 1
  + FFS: If supported, default TCI state when more than one TCI states are activated by MAC CE
  + Note: There is no implications on the support of single TRP or multi-TRP
* FFS: Additional enhancement such as L1-based beam indication with group-common DCI
* FFS: Whether the Rel.17 beam indication can also apply to beam indication for single channel (e.g. PDSCH only, single CORESET) or a subset of channels
* FFS: Additional details on extending the support of L1-based beam indication when separate UL (from DL) common beam indication is configured

In RAN1#104-e, on the Rel-17 L1-based TCI state update (beam indication) for the unified TCI framework, interested companies are to provide the following:

* How to use DCI formats 1\_1 and 1\_2 for UL-only (in case of separate DL/UL) TCI state update (beam indication)
  + Note: The agreement implies that DCI formats 1\_1 and 1\_2 can be used for UL-only TCI state update beam indication).
  + FFS: Using DCI format 1\_1 and 1\_2 without DL assignment, and with a new acknowledgment mechanism directly in response to decoding DCI format 1\_1 and 1\_2, e.g., analogous to SPS PDSCH release
* Whether/how to support at least one additional DCI format dedicated for UL-only beam indication (in case of separate DL/UL), including:
  + Whether the format can also be used for DL-only beam indication (in case of separate DL/UL) and joint DL/UL beam indication
  + Whether it is a “brand new” format or based on some extension of the existing DCI formats other than 1\_1 and 1\_2 (e.g. 1\_0, 0\_0, 0\_1, or 0\_2)
    - If UL-related DCI is used, whether it is accompanied with UL grant or not
  + Acknowledgment mechanism

On Rel.17 DCI-based beam indication:

* Regarding application time of the beam indication: if beam indication is received, down-select from the following:
  + Alt1: the first slot that is at least X ms or Y symbols after the DCI with the joint or separate DL/UL beam indication
  + Alt2: the first slot that is at least X ms or Y symbols after the acknowledgment of the joint or separate DL/UL beam indication
  + FFS: whether any existing timing defined for DCI based TCI/spatial relation update can be used for X/Y
* FFS: When to apply the minimum indication delay (e.g., when the newly indicated beam is different with the previously indicated beam)

On Rel.17 DCI-based beam indication, the beam application time is to be down-selected or modified from the following:

* Alt1: The beam application time can be configured by the gNB based on UE capability
  + Support a UE capability for the minimum value of beam application time
  + FFS: the exact minimum values of beam application time supported by UE
  + FFS: whether existing UE capability can be reused as this UE capability.
  + FFS: whether different beam application time values are supported for uplink and downlink
  + FFS: whether UE capability needs to be introduced for the maximum value of beam application time
* Alt2: The beam application time is fixed and defined in specification
* Alt3: The beam application time can be configured by the gNB where the minimum value of beam application time is fixed and defined in specification

Consider multi-panel UE, layer 1/2 inter-cell cases, carrier aggregation aspects

On the beam application time for Rel.17 DCI-based beam indication, the beam application time can be configured by the gNB based on UE capability

* Support a UE capability for the minimum value of beam application time
* FFS: the exact minimum values of beam application time supported by UE
* FFS: whether existing UE capability can be reused as this UE capability.
* FFS: whether different beam application time values are supported for uplink and downlink
* FFS: whether UE capability needs to be introduced for the maximum value of beam application time
* FFS: the reference for defining the UE capability (e.g. from DCI reception or ACK transmission)
* FFS: whether a UE is allowed to report more than 1 values in case of MPUE
* FFS: the application time when DCI and applied channel(s) are on different CCs with same/different SCS(s)s

On the Rel.17 DCI-based beam indication, in RAN1#104bis-e, down-select at least one of the following alternatives regarding the support of DCI format(s) for beam indication in addition to the agreed DCI formats 1\_1/1\_2 with DL assignment (in RAN1#103-e):

* Alt0: No additional DCI format is supported
* Alt1: DCI formats 1\_1 and 1\_2 without DL assignment, applicable for joint TCI as well as separate DL/UL TCI
  + Support DCI acknowledgment mechanism, e.g. based on SPS PDSCH release, based on triggered SRS, based on DCI indicating SCell dormancy
  + FFS: How to identify DCI formats 1\_1/1\_2 used for beam indication only (not for scheduling a PDSCH reception, not indicating a SPS PDSCH release, or not indicating SCell dormancy), considering impacts on PDCCH coverage and scheduling mechanism
  + FFS: Whether the UE can/shall assume the gNB configured application time is after ACK transmission
* Alt2: Dedicated DCI format other than 1\_1/1\_2 without DL assignment, applicable for joint TCI as well as separate DL/UL TCI
  + Support DCI acknowledgment mechanism, e.g. based on SPS PDSCH release, based on triggered SRS, based on DCI indicating SCell dormancy
  + FFS: If the format is based on an existing DCI format, how to identify the DCI format used for beam indication only
  + FFS: Whether the UE can/shall assume the gNB configured application time is after ACK transmission
* Alt3: UL-related DCI formats 0\_1/0\_2 with UL grant, applicable only for UL-only TCI of separate DL/UL TCI

On Rel.17 DCI-based beam indication, regarding application time of the beam indication: if beam indication is successfully received and the newly indicated beam in the beam indication is different from the previously indicated beam, down-select (no later than RAN1#105-e) one from the following. No other alternatives will be considered:

* Alt1: the first slot that is at least X ms or Y symbols after the [first/last] symbol of the DCI with the joint or separate DL/UL beam indication
* Alt2A: the first slot that is at least X ms or Y symbols after the [first/last] symbol of the acknowledgment of the joint or separate DL/UL beam indication
* Alt 2B: the first slot that is at least X ms or Y symbols after the [first/last] symbol of the acknowledgment of the joint or separate DL/UL beam indication, except that the (new) TCI state update can be applied to the PDSCH, if it exists, (scheduled by the beam indication DCI) and corresponding ACK transmission (provided that the time offset between the DCI and the scheduled PDSCH exceed the threshold, analogous to Rel.15/16)
* Alt2C: Support both Alt1 and Alt2A, and introduce a UE capability that indicates the support of Alt1 or Alt2A
* Alt3: the first slot that is at least X1 ms or Y1 symbols after the [first/last] symbol of the DCI with beam indication and X2 ms or Y2 symbols after the [first/last] symbol of the acknowledgment of the beam indication
* FFS: whether any existing timing defined for DCI based TCI/spatial relation update can be used for X/Y

**Issue 4**

* [Issue 4] For Rel.17 NR FeMIMO, on MP-UE assumption to facilitate fast UL panel selection:
  1. The following assumptions are used:
     + In terms of RF functionality, a UE panel comprises a collection of TXRUs that is able to generate one analog beam (one beam may correspond to two antenna ports if dual-polarized array is used)
     + UE panels can constitute the same as well as different number of antenna ports, number of beams, and EIRP
     + No beam correspondence across different UE panels
     + FFS: For each UE panel, it can comprise an independent unit of PC, FFT timing window, and/or TA.
     + FFS: Same or different sets of UE panels can be used for DL reception and UL transmission, respectively
  2. In RAN1#103-e, identify candidate use cases including MPE, and consider remaining aspects if use cases are identified
  3. In RAN1#103-e, identify candidate signaling schemes for the following:
     + NW to MP-UE (taking into account potential extension of the unified TCI framework in issue 1)
     + MP-UE to NW

In Rel-17 enhancement for facilitating fast uplink panel selection, the following use cases are assumed:

* MPE mitigation
* UE power saving
* UL interference management
* Support different configurations across panels
* UL mTRP

In Rel-17 enhancement on MP-UE to facilitate fast UL panel selection and MPE mitigation, UL Tx panel(s) are assumed to be a same set or subset of DL Rx panel(s)

In Rel.17 enhancement for facilitating fast uplink panel selection, UE-initiated UL panel selection/activation are supported:

* FFS: Whether NW-initiated panel selection/activation is also supported
* FFS: Whether specification support for this feature is necessary and if so the details of such spec support.

**Conclusion**: On Rel.17 enhancements to facilitate UL beam selection for MP-UE, the following terms are used at least for the purpose of discussion:

* ‘Panel activation’ (at least for DL/UL measurement): activating L out of P available UE panel(s) at least for the purpose of DL and UL beam measurements (e.g. reception of DL measurement RS, transmission of SRS)
* ‘Panel selection’ (for UL transmission): selecting 1 out of L activated UE panel(s) for the purpose of UL transmission
* Note: UE-initiated panel activation and selection have been agreed in RAN1#103-e

On Rel.17 enhancement for facilitating fast uplink panel selection,

* Rel.17 TCI state update (based on MAC CE + DCI along with the necessary TCI state activation, or MAC CE only) can be used for UE UL panel selection
* FFS: Whether specification support for this feature is necessary and if so the details of such spec support, e.g.
  + Additional spec support in TCI state definition to accommodate UL panel
  + UE reporting to facilitate UL panel selection
  + UE reporting, e.g. panel-specific report, including UE-panel state, e.g. inactive, active for DL/UL measurement, active for DL reception only, active for UL transmission, or other combination(s) of UE-panel states
  + Support for linking or association of UE panels with CSI-RS/SSB resources or resource sets, SRS resource sets, and/or PUCCH resource groups, etc.

On Rel.17 enhancement for facilitating fast uplink panel selection, for discussion purpose, a panel entity corresponds to one or more RS resources:

* For CSI/beam reporting, the RS resource is an RS associated with measurement and/or reporting
* For beam indication, the RS resource is a source RS for UL TX spatial filter information
* Note: For one RS resource, the corresponding panel entity may vary and is controlled by the UE, and whether/how to maintain a common understanding between gNB and UE can be further discussed/decided
* Note: The above does not preclude possibility that an RS resource can be mapped to multiple panels
* Note: The one or more RS resources may correspond to one or more RS resource set(s) depending on further discussion/decision
* Note: Specification should not be designed in such a way that the UE is required to disclose its antenna implementation

**Issue 5**

* [Issue 5] For Rel.17 NR FeMIMO, on MPE mitigation (that is, minimizing the UL coverage loss due to the UE having to meet the MPE regulation), in RAN1#103-e:
  1. If needed, identify candidate solutions to be down-selected in future meeting(s). The following sub-categories can be used:
     + CAT0. The need for specification support for MPE event detection and, if needed, candidate solutions
     + CAT1. The need for UE reporting associated with an MPE and/or a potential/anticipated MPE event if the UE selects a certain UL spatial resource, e.g., corresponding to DL or UL RS
     + CAT2. The need for NW signaling in response to the reported MPE event (taking into account issue 1) and UE behavior after receiving the NW signaling
     + Note: RAN4 has agreed to specify P-MPR reporting (cf. CRs for TS 38.101/102/133) which can be used as a baseline scheme for further enhancement
     + Note: This may be related to outcome of issue 4b)
  2. Companies are encouraged to submit evaluation results based on the agreed EVM to justify the benefits of the candidate solutions

On UE reporting for MPE mitigation for Rel-17, investigate and, if needed, specify the following:

* Reporting of P-MPR report based on Rel.16 framework.
  + FFS: Whether panel/beam level based P-MPR report is supported
  + FFS: Maximum reported number of panels, e.g. single or multiple
* Reporting SSBRI(s)/CRI(s) and/or indication of panel selection for the purpose of indicating:
  + Alt1: alternative UE panel(s) or TX beam(s) for UL transmission
  + Alt2: feasible UE panel(s) or TX beam(s) for UL transmission taking the MPE effect into account
  + FFS: indication of panel selection details (e.g. explicit/implicit)
* Any additional reporting content: down-select from the following in RAN1#104-e
  + Alt0: no additional reporting content
  + Alt1: Additional reporting content is included (for example P-MPR + L1-RSRP, virtual PHR + L1-RSRP, L1-RSRP/SINR with and without MPE effect, virtual PHR, P-MPR or virtual PHR + CRI/SSBRI, estimated max UL RSRP)
    - Note: Other options are not precluded
    - FFS: Whether the above reporting is triggered by UE or configured by NW

On Rel.17 enhancements to facilitate MPE mitigation,

* On further enhancing the P-MPR report in Rel.16 (already agreed RAN4 framework, including triggering), down select between beam-level and panel-select reporting
* On SSBRI(s)/CRI(s) and/or indication of panel selection, focus study on the following:
  + Reporting of at least SSBRI(s)/CRI(s) to indicate gNB beam(s) that is feasible for UL transmission: additional reporting quantities are FFS
  + Reporting of at least an indicator associated with a UE ‘panel’ that is feasible for UL transmission: additional reporting quantities are FFS
* Note: Just as agreed in RAN1#103-e, the purpose is to assess whether specification is needed or not

On Rel.17 enhancements to facilitate MPE mitigation, decide in RAN1#104bis-e whether to support at least one the following (not necessarily, but can be, in one reporting instance):

* {Rel.16 P-MPR based (beam/panel-level)} + {A}, where A is either Opt1A, Opt1B, Opt1C, or Opt1D:
  + Option 1A: Virtual PHR or a modified version associated with each activated UL TCI or, if applicable, joint TCI
  + Option 1B: {SSBRI(s)/CRI(s) and/or panel indication}
  + Option 1C: {SSBRI(s)/CRI(s) and/or panel indication} + virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)
  + Option 1D: No additional reporting quantity
* {SSBRI(s)/CRI(s) and/or panel indication} + {A}, where A is either Opt2A, Opt2B, Opt2A+ Opt2B, or Option 2C
  + Option 2A: L1-RSRP [L1-SINR] or a modified version that accounts for MPE effect associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)
    - FFS: How panel-level L1-RSRP [L1-SINR] is reported if L1-RSRP [L1-SINR] is associated with panel
    - FFS: Whether/how to account for MPE effect in L1-RSRP [L1-SINR] report, e.g. by using scaled L1-RSRP [L1-SINR]
    - FFS: Whether/how to enhance existing beam reporting format to support Option 2A
  + Option 2B: Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)
  + Option 2C: No additional reporting quantity

**Issue 6**

On Rel.17 enhancements based on the unified TCI framework, perform study and, if needed, specify the following:

* Group1: Beam management with reduced DL signaling to reduce latency
* Group2: Reducing activation delay of TCI states and PL-RSs (including other WGs, e.g. RAN4)
  + On RAN4-related matters, assessment/study phase can be done in RAN1. If RAN4-based enhancements are found necessary, a LS to RAN4 will be sent (to prepare RAN4 work)

Note: Given its dependence on the maturity compared to other issues (1 to 5), when to start the work and how much work is done on issue 6 should depend on the progress on the other issues.

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | [R1-2102333](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102333.zip) | Enhancements on multi-beam operation | Huawei, HiSilicon |
| 2 | R1-2102378 | Enhancements on Multi-beam Operation | OPPO |
| 3 | [R1-2102432](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102432.zip) | Remaining Issues on Multi-beam Operation | InterDigital, Inc. |
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| 5 | [R1-2102506](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2102506.zip) | Further discussion on multi beam enhancement | vivo |
| 6 | R1-2102598 | Discussions on enhancements on multi-beam operation | CATT |
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| 17 | R1-2103014 | Enhancements to Multi-Beam Operations | Intel Corporation |
| 18 | [R1-2103088](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103088.zip) | Views on Rel-17 Beam Management enhancement | Apple |
| 19 | R1-2103150 | Enhancements on Multi-beam Operation | Qualcomm Incorporated |
| 20 | [R1-2103221](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104b-e/Docs/R1-2103221.zip) | Multi-Beam Enhancements | Samsung |
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