**3GPP TSG RAN WG1 #104-e R1-2101185**

**e-Meeting, January 25th – February 5th, 2021**

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

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

**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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| * 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:

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

1. Issue Categorization (from RAN1#102-e)

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.

Table 1 Category of issues

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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 common 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 common 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   *Note: the following factors should be considered in the above design aspects*   * + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*     - *Beam correspondence assumption*     - *When applicable, performance assessment based on the agreed EVM*  1. **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 TAGs, L1-RSRP report for RS in a neighboring cell   *Note: the following factors should be considered in the above design aspects*   * + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*     - *Beam correspondence assumption*     - *When applicable, performance assessment based on the agreed EVM*  1. **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   *Note: the following factors should be considered in the above design aspects*   * + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*     - *Beam correspondence assumption*     - *When applicable, performance assessment based on the agreed EVM at high-speed scenarios*  1. **Extension of UL TCI for UE with (capable of) multiple panels** to facilitate UL fast panel selection, given the unified TCI framework design (cf. the above aspect 1 and 3)    1. Mechanism to identify a UE panel:       1. Goal: Assess whether resource ID or resource set ID (SRS, CSI-RS, ...) is sufficient or an explicit (new) panel ID is needed    2. Signaling mechanism to enable UL fast panel selection,       1. Goal 1: assess needed signaling from UE to NW, e.g. to indicate multi-panel capability, UE reporting       2. Goal 2: extending UL TCI state update mechanism for various scenarios for UL fast panel selection, e.g. if supported, DL and UL TCI state update are (a) common, (b) separate;    3. 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 and, if needed, the associated specification features   *Note: the following factors should be considered in the above design aspects*   * + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*     - *The use of UE panels for both DL reception and UL transmission, including the need for UE reporting and NW signaling*     - *Beam correspondence assumption*  1. **MPE mitigation -** given the unified TCI framework design and multi-panel UE support (cf. the above aspect 1, 3, and 4)    1. The need for enhancement(s) to reduce UL coverage loss due to meeting MPE regulation       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   *Note: the following factors should be considered in the above design aspects*   * + - *Beam correspondence assumption*     - *Performance assessment based on the agreed EVM*     - *Support for fast panel selection on MP-UE*  1. **Advanced beam refinement and tracking** targeting high-mobility and large number of configured TCI states **-** given the unified TCI framework design for intra- and L1/L2-centric inter-cell mobility, and multi-panel UE support (cf. the above aspect 1, 2, 3, and 4)    1. Overhead and latency reduction of beam refinement       1. Goal: evaluate and select schemes (including NW signaling and configuration as well as UE signaling) to enable faster gNB/UE beam refinement       2. Refinement is understood as selecting narrower (more spatially precise) beam from a set of candidate beams (gNB and/or UE beams, jointly or separately) which also includes beam sweeping    2. Overhead and latency reduction of beam tracking       1. Goal: evaluate and select schemes (including NW signaling and configuration as well as UE signaling) to enable faster gNB and/or UE beam tracking       2. Tracking is understood as prompt/predictive response to the change in propagation link   *Note: the following factors should be considered in the above design aspects*   * + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*     - *Beam correspondence assumption*     - *Performance assessment based on the agreed EVM* |

1. Summary of companies’ inputs based on the issue category in Table 1

The summary is based on the issue categorization in Table 1. The listed issues are structured primarily to facilitate some progress on pending issues identified in the agreements made in RAN1#103-e and 104-e (see Appendix A).

* 1. Issue 1 (Rel.17 unified TCI framework)

Table 2 Summary: issue 1

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| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 1.1 | Source RS type for DL QCL (Type D, for DL RX spatial filter reference) information for DL common UE-dedicated reception on PDSCH and all/subset of CORESETs | CSI-RS for BM (\*)   * **Yes:** Ericsson, Huawei/HiSi, Samsung * **No:**   CSI-RS for tracking (\*)   * **Yes:** Ericsson, Samsung * **No:**   SSB   * **Yes:** Ericsson, Samsung * **No:** Huawei/HiSi   CSI-RS for CSI   * **Yes:** * **No:**   SRS for BM   * **Yes:** IDC, Futurewei, Spreadtrum, Nokia/NSB, Apple (with periodic DL RS), ZTE (also need support for SRS beam sweeping), Convida, Samsung * **No:** Huawei/HiSi, Ericsson, Intel | (\*) Note that the following is supported as QCL Type-D source RS for PDSCH and PDCCH in Rel.15/16:   * CSI-RS for BM * CSI-RS for tracking   (\*\*) Note that the following is supported as QCL Type-D source RS for PDSCH in Rel.15/16:   * CSI-RS for CSI |
| 1.2 | Additional source RS type for UL TX spatial filter  Note: SSB and CSI-RS for BM have been agreed | CSI-RS for tracking   * **Yes:** Ericsson * **No:**   Non-BM CSI-RS   * **Yes:** Sony * **No:**   Non-BM SRS-RS   * **Yes:** Sony * **No:** |  |
| 1.3 | Supported QCL types | DL large scale properties inferred from one (qcl-Type1) or two RSs (qcl-Type1 and qcl-Type2) analogous to Rel.15/16:   * **Yes**: Ericsson, MTK, Samsung, OPPO * **No**:   DL TCI state for separate DL/UL TCI is always configured with 2 source RSs:   * **Yes**: CMCC * **No**:   UL spatial filter derived from one RS of QCL Type D:   * **Yes**: Ericsson, Convida, MTK, Samsung * **No**: |  |
| 1.4 | Additional applicability of the common DL QCL information  Note: UE-dedicated reception on PDSCH and all/subset of CORESETs have been agreed | CSI-RS resource for CSI:   * **Yes**: OPPO, Spreadtrum, Ericsson, vivo, MTK, AT&T, Convida, Samsung * **No**: Apple, Huawei/HiSi   Some CSI-RS resource(s) for BM:   * **Yes**: OPPO (some), Ericsson (all), AT&T(some), Samsung (some) * **No**: Huawei/HiSi, vivo, Apple, APT   CSI-RS for tracking:   * **Yes**: Spreadtrum, AT&T * **No**: Huawei/HiSi, Apple |  |
| 1.5 | Additional applicability of the common UL TX spatial filter reference to SRS | Some SRS (resource set(s)) for BM:   * **Yes**: OPPO, Samsung * **No**: Huawei/HiSi, APT | Note: SRS for CB/NCB/antenna switching is already agreed as optional |
| 1.6 | PL-RS in relation to UL TCI state and channels | Alternatives:   * **PL-RS included in UL TCI state:** IDC, CMCC, Ericsson (optional for DL RS), Apple, vivo (in case of DL RS in TCI state), MTK (for no PL-RS configured, and DL CSI-RS or SSB), Intel, AT&T, OPPO (separate RS), Fraunhofer IIS/HHI (separate RS) * **PL-RS associated with UL TCI state:** Futurewei, OPPO, Spreadtrum, Nokia/NSB, Huawei/HiSi, MTK, Sony, Qualcomm, CATT * **PL-RS not associated with UL TCI state:** Fraunhofer IIS/HHI, Ericsson (in case of UL RS in TCI state) * **Use Rel-16 PL-RS framework:** vivo (for UL RS in TCI state)   MAC CE configures association between activated TCI states and PL-RS/PC: CATT, MTK, Qualcomm |  |
| 1.7 | UL parameters in relation to UL TCI state and channels | Alternatives:   * **UL parameters included in UL TCI state:** ID, Apple, LGE, Intel * **UL parameters associated with UL TCI state:** Nokia/NSB, ZTE, Sony, Samsung, CATT, MTK, Qualcomm * **UL parameters associated with channel and UL TCI state:** Nokia/NSB, ZTE, Sony, Samsung * **UL parameters not associated with UL TCI state:** Ericsson, Huawei/HiSi, vivo * **Use Rel-16 framework:** CMCC, MTK   MAC CE configures association between activated TCI states and PL-RS/PC: CATT, MTK, Qualcomm |  |
| 1.8 | Maximum value of M (DL) and N (UL) | **Max=1 for sTRP**: OPPO, Spreadtrum, ZTE, MTK, Convida, Samsung  **Max M=2 for mTRP**: Nokia/NSB, Samsung, APT, AT&T  **Max M>1 and N>1**: Futurewei |  |
| 1.9 | TCI state applicability to a subset of DL channels or CORESETs (in addition to all CORESETs) | **Yes**: LGE, Nokia/NSB, Qualcomm  **No, at least for M=N=1 (applies to all UE specific channels)**: OPPO, Samsung |  |
| 1.10 | TCI state applicability to a subset of UL channels or PUCCHs (in addition to all PUCCHs) | **Yes**: LGE, Nokia/NSB, Qualcomm  **No, at least for M=N=1** (applies to all UE specific channels): OPPO, Samsung |  |
| 1.11 | TCI State pool for CA  Alt1: Shared among CCs  Alt2: Individually configured per CC | **Alt1**: Spreadtrum, Xiaomi, ZTE, vivo, MTK, LGE (through RRC configured beam linkage state), Intel, Sony, NTT Docomo, Samsung  **Alt2**: OPPO, Nokia/NSB, CMCC, Huawei/HiSi, CATT, APT, TCL  **QCL Type-A implicitly determined based on CC:** Intel, Samsung |  |
| 1.12 | For separate TCI, UL TCI state pool  Alt1: Shared pool with joint/DL TCI state  Alt2: Separate pool | **Alt1**: Fraunhofer IIS/HHI, Spreadtrum, Xiaomi, ZTE, CATT, vivo, MTK, Intel, Convida, Qualcomm, Samsung  **Alt2**: Futurewei, OPPO, Lenovo/MoM, Nokia/NSB, CMCC, Ericsson, Huawei/HiSi, CATT, AT&T, Sony |  |
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Re issue 1.1 and 1.3, the following DL QCL configurations are supported in Rel.15/16 (cf. R1-1808001 section 7.1.2.3.7):

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| For the next two tables, if QCL type-D is applicable, DL RS2 and QCL type-2 shall be configured for the UE except for the default case (fourth row in the two tables below). If TRS for downlink is used for QCL type-D, the TRS must have an SSB or CSI-RS for BM as source RS for QCL type-D.  For the DM-RS of PDCCH, the UE should only expect the following three configurations of the higher layer parameter *TCI-State* while the fourth configuration is valid as default, before TRS is configured:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Valid TCI state Configuration** | **DL RS 1** | ***qcl-Type1*** | **DL RS 2 (if configured)** | ***qcl-Type2* (if configured)** | | 1 | TRS | QCL-TypeA | TRS | QCL-TypeD | | 2 | TRS | QCL-TypeA | CSI-RS (BM) | QCL-TypeD | | 3\*\* | CSI-RS (CSI) | QCL-TypeA |  |  | | 4\* | SS/PBCH Block\* | QCL-TypeA | SS/PBCH Block\* | QCL-TypeD |   \* Before TRS configured. Note: this is not a TCI state, rather a valid QCL assumption  \*\*Note: Only when QCL type-D is not applicable  For the DM-RS of PDSCH, the UE should only expect the three following configurations of the higher layer parameter *TCI-State* while the fourth is valid by default, before TRS is configured:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Valid TCI state Configuration** | **DL RS 1** | ***qcl-Type1*** | **DL RS 2 (if configured)** | ***qcl-Type2* (if configured)** | | 1 | TRS | QCL-TypeA | TRS | QCL-TypeD | | 2 | TRS | QCL-TypeA | CSI-RS (BM) | QCL-TypeD | | 3\*\* | CSI-RS (CSI) | QCL-TypeA | CSI-RS (CSI) | QCL-TypeD | | 4\* | SS/PBCH Block\* | QCL-TypeA | SS/PBCH Block\* | QCL-TypeD |   \* Before TRS configured. Note: this is not a TCI state, rather a valid QCL assumption  \*\* Note: QCL parameters may not be derived directly from CSI-RS (CSI) |

**Proposal 1.1**: On Rel.17 unified TCI framework, based on the agreements in RAN1#103-e and 103-e, the following terms are defined as follows (at least for discussion and agreement purposes) for M=N=1:

* DL TCI: The source reference signal(s) (one for QCL-TypeD) in the DL TCI provides common QCL information at least for UE-dedicated reception on PDSCH and all or subset of CORESETs in a CC
* UL TCI: The source reference signal in the UL TCI provides a reference for determining common UL TX spatial filter at least for dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC
* Joint DL/UL TCI: When configured, a common (therefore, joint) TCI is shared by the above DL TCI and UL TCI.
* Separate DL/UL TCI: When configured, the above DL TCI and UL TCI are distinct (therefore, separate).

The definition for M>1 or N>1 is FFS (note: pending further study on multiple options and alternatives).

**Proposal 1.2**: On Rel.17 unified TCI framework, a UE can be configured with either joint DL/UL TCI or separate DL/UL TCI via higher-layer (RRC) signaling.

**Proposal 1.3**: (on issue I.1)

Table 3 Additional inputs: issue 1

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| **Company** | **Input** |
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* 1. Issue 2 (L1/L2-centric inter-cell mobility)

Table 4 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 2.1 | Assumptions on scenarios with potential higher-layer (RAN2, RAN3) impacts | RRC reconfiguration needed:   * **Yes**: * **No**: Ericsson, Apple   Change in serving cell:   * **Yes**: OPPO, ASUS * **No**: Futurewei   Change in C-RNTI:   * **Yes**: * **No**: Huawei/HiSi   Inter-DU (requiring RAN3) vs. intra-DU:   * **Inter-DU**: * **Intra-DU**: OPPO, Huawei/HiSi, Samsung |  |
| 2.2 | Type of beam metric for measurement and reporting:  L1-RSRP or L3-RSRP | Alternatives**:**   * **L1-RSRP:** vivo, MTK, Samsung * **L3-RSRP:** OPPO, Lenovo/MoM * **Hybrid L1+L3-RSRP:** Apple, CATT (with SD filter L3-RSRP) |  |
| 2.3 | Beam measurement/reporting mechanism | Content of reporting:   * Only one (Beam metric,SourceRS) pair: Spreadtrum * More than one (Beam metric,SourceRS) pairs: Ericsson, Samsung, vivo, Qualcomm, Futurewei, Lenovo/MoM   Event-based beam reporting for non-serving cell(s) – event FFS:   * **Yes**: Xiaomi, Apple, Huawei/HiSi, Sony, Samsung * **No** (pre-configured): |  |
| 2.4 | QCL enhancement (including TCI state definition) | Where to include PCI of non-serving cells:   * In CSI-SSB-ResourceSet: Nokia/NSB * Per TCI state: vivo, LGE, Intel, Sony, Qualcomm * Signaled via MAC CE: CATT * Implicit (re-indexing with SSB/source RS index): Xiaomi, Samsung   Where to include SSBs/source RSs of non-serving cells   * Per TCI state: Nokia/NSB, Ericsson, Samsung * Per TCI state group: Apple (per SSB configuration) |  |
| 2.5 | Additional source RS type(s) | CSI-RS for mobility:   * **Yes**: Lenovo/MoM, Huawei/HiSi, LGE, Sony * **No**: Samsung   CSI-RS for tracking:   * **Yes**: Samsung, NTT Docomo * **No**: | Note: SSB has been agreed  Note: This also depends on the type of beam metric |
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**Proposal 2.1**: On Rel.17 enhancements to enable L1/L2-centric inter-cell mobility:

Table 5 Additional inputs: issue 2

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* 1. Issue 3 (beam indication signaling medium)

Table 6 Summary: issue 3

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| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 3.1 | Beam application time definition:  Alt1: Measured from DCI reception  Alt2: Measured from ACK transmission | **Alt1 (DCI):** Spreadtrum, Xiaomi, Ericsson, CATT, MTK, NEC, Samsung  **Alt2 (ACK):** IDC, Lenovo/MoM, Fujitsu, Nokia/NSB, CMCC, Apple, Huawei/HiSi, ZTE, vivo, Intel, Sony, Qualcomm, NTT Docomo  **Alt1 and Alt 2:** OPPO | Other aspects mentioned for next-level details: when TCI state is unknown, panel activation/deactivation, PUCCH repetition |
| 3.2 | Configurability of beam application time  Alt1: UE capability  Alt2: Fixed in spec | **Alt1 (UE capability):** IDC, Fujitsu, Nokia/NSB, Xiaomi, Ericsson, Apple, ZTE, CATT, vivo, MTK, Intel, Qualcomm, NTT Docomo, Samsung  **Alt2 (fixed):** Lenovo/MoM  **Alt1+Alt2:** OPPO |
| 3.3 | Additional design details on agreed DCI formats 1\_1/1\_2 for Rel.17 unified TCI framework beam indication (TCI state update) | How to support separate DL/UL TCI:   * **New field to indicate UL TCI:** Xiaomi, ZTE, CATT, Intel, Samsung * **MAC CE to pair DL TCI and UL TCI:** OPPO, Xiaomi, Ericsson, Huawei/HiSi, MTK, Intel * **Different RNTIs for DL vs UL TCI:** Futurewei, Intel * **Add a DCI field to indicate DL vs UL TCI:** MTK, Intel, Convida   Support for an additional dedicated ACK mechanism for the DCI based on SPS PDSCH release:   * **Yes**: ZTE, NEC, Samsung * **No**: Ericsson | Note: The agreement encompasses only DCI formats 1\_1/1\_2 with DL assignment |
| 3.4 | Support for additional DCI formats for Rel.17 unified TCI framework beam indication (TCI state update) | DCI formats 1\_1/1\_2 without DL assignment:   * **Yes**: OPPO, Fujitsu, Spreadtrum, Nokia/NSB, CATT, vivo (at least for UL-only TCI), MTK, Qualcomm, Samsung * **No**:   DCI formats 0\_1/0\_2 with UL grant:   * **Yes**: IDC, Nokia/NSB, Xiaomi (at least for UL-only TCI), ZTE (at least for UL-only TCI), MTK, LGE, Intel, Sony (Study), Qualcomm * **No**: OPPO, CMCC, Ericsson, Huawei/HiSi, Convida   Dedicated DCI format for beam indication, with dedicated ACK based on SPS PDSCH release:   * **Yes**: Futurewei, ZTE, CATT, Intel, Sony, NTT Docomo, OPPO (based on format 1\_0 without DL assignment), Samsung, Nokia/NSB (based on format 0\_1/0\_2 without UL grant), Qualcomm (based on format 0\_1/0\_2 without UL grant) * **No**: Ericsson, MTK, COnvida,   **Support extending existing DCI formats for UL-only TCI**: APT |  |
| 3.4 | HARQ-ACK codebook issues | **Only positive ACK for alignment:** OPPO  **Dedicated A/N bit in codebook**: Lenovo/MoM, Apple |  |
| 3.6 | Support for group-based DCI in Rel.17 unified TCI framework | * **Yes:** ZTE (study), Intel, Sony (study), Qualcomm, Samsung * **No:** IDC |  |

**Proposal 3.1**:

Table 7 Additional inputs: issue 3

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* 1. Issue 4 (MP-UE)

Table 8 Summary: issue 4

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| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
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**Proposal 4.1**: To facilitate fast UL panel selection for MP-UEs, *...*

Table 9 Additional inputs: issue 4

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* 1. Issue 5 (MPE mitigation)

Table 10 Summary: issue 5

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| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
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**Proposal 5.1**:

Table 11 Additional inputs: issue 5

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* 1. Issue 6 (beam refinement/tracking)

Table 12 Summary: issue 6

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| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
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**Proposal 6.1**:

Table 13 Additional inputs: issue 6

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Appendix A: Agreements in RAN1#102-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

**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

**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

**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.

**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

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|  |  |  |  |
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