**3GPP TSG RAN WG1 #105-e R1-2105290**

**e-Meeting, May 10th – 27th, 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 (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 | For QCL-Type D configuration in TCI state(s) shared across a set of CCs (that is associated with the same gNB beam):   * **Alt1**: Separate QCL-Type D RS for each of the CCs can be determined from the TCI state(s). The determined QCL-Type D RSs for the set of CCs are further associated with a same QCL-Type D RS. * **Alt2**: A single QCL-Type D RS for the set of the CCs is determined from the TCI state(s), and support enhanced QCL chain:   + **Alt.2-1**: Support Opt. A only.   + **Alt.2-2**: Support Opt. B only.   + **Alt.2-3**: Support both Opt. A and Opt. B.   Options of the enhanced QCL chain:   * Opt. A: The QCL-Type A TRS and, if any, QCL-Type D CSI-RS, with different CSI-RS resources. * Opt. B: The QCL-Type A TRS and, if any, QCL-Type D SSB. | **Alt 1**: Nokia/NSB, CATT, Apple, Sony, NTT Docomo, Intel, LG  **Alt 2-1**: OPPO, MTK (2nd)  **Alt 2-2**:  **Alt 2-3**: vivo, Samsung, ZTE, Qualcomm, MTK (1st) |
| 1.2 | Setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index):   * AltA. The setting of (P0, alpha, closed loop index) is also associated with UL or (if applicable) joint TCI state * AltB. The setting of (P0, alpha, closed loop index) is also included with UL or (if applicable) joint TCI state * AltC. The setting of (P0, alpha, closed loop index) is neither associated with nor included in UL or (if applicable) joint TCI state   Note: It has been agreed that the setting of (P0, alpha, closed loop index) is associated with UL channel or UL RS (therefore the setting is channel- and signal-specific). | **AltA**: Lenovo/MoM, Spreadtrum, CMCC (PUSCH/PUCCH), Nokia/NSB, Futurewei, Fraunhofer IIS/HHI, ZTE, CATT (MAC CE update), OPPO (PUSCH, PUCCH), Apple, NTT Docomo, MTK, Intel (2nd preference)  **AltB**: Nokia/NSB, Samsung, IDC, Apple, Qualcomm, NTT Docomo (2nd pref), LG, Intel  **AltC**: vivo, Ericsson (P0 and alpha), Huawei/HiSi, OPPO (SRS, per resource set), Sony |
| 1.3 | Path-loss measurement (PL RS):   * AltA. PL-RS can be included in UL TCI state (or, if applicable, joint TCI state). * AltB. PL-RS can be associated with (but not included in) UL TCI state (or, if applicable, joint TCI state)   + FFS: Exact association mechanism * AltC. UE calculates path-loss based on periodic DL RS configured as the source RS for determining spatial TX filter in UL or (if applicable) joint TCI state   + FFS: If a PL RS is not included in or associated with the UL TCI state (or, if applicable, joint TCI state), whether the UE can estimate path-loss based on the PL-RS of an UL RS provided in an UL TCI state (or, if applicable, joint TCI state) as a source RS for determining the spatial TX filter. | **AltA**: Nokia/NSB, Ericsson, IDC, Fraunhofer IIS/HHI, Samsung (2nd preference), OPPO, Qualcomm, AT&T, NTT Docomo, LG, Intel  **AltB**: Lenovo/MoM, Spreadtrum, CMCC, Futurewei, ZTE, CATT (MAC CE update), Huawei/HiSi, Sony, MTK  **AltC**: vivo, Nokia/NSB (if not configured in TCI state), Samsung, ZTE (if not configured in TCI state), Apple  **One solution only** (no mixture optional/default): NTT Docomo, Ericsson, Samsung, Qualcomm |
| 1.4 | See table below (cf. offline discussion [1])  Do the following ‘other signal(s)/channel(s)’ admit Interpretation 1 when operating with Rel-17 unified TCI? | CSI-RS resource for CSI:   * **Yes**: Lenovo/MoM, Spreadtrum, Nokia, Ericsson, Samsung, Fraunhofer IIS/HHI, ZTE (only AP), OPPO, Apple (at least AP), Convida, APT * **No**: vivo, Huawei/HiSi   Some CSI-RS resource(s) for BM (if so, which one(s), e.g. aperiodic, repetition ‘ON’)   * **Yes**: Nokia/NSB, Ericsson, Samsung, Fraunhofer IIS/HHI (rep ON), OPPO (one resource with rep ON), Apple (at least AP), APT (rep ON), ZTE(only AP) * **No**: vivo, Spreadtrum, Huawei/HiSi   CSI-RS for tracking:   * **Yes**: Lenovo/MoM, Ericsson * **No**: vivo, Spreadtrum, Samsung, Huawei/HiSi, MTK, ZTE     Some SRS resources or resource sets for BM:   * **Yes**: Ericsson, OPPO, ZTE * **No**: Huawei/HiSi   Non-UE-dedicated reception on PDSCH and all/subset of CORESETs:   * **Yes**: vivo * **No**: Huawei/HiSi |
| 1.5 | See table below (cf. offline discussion [1])  For ‘other signal(s)/channel(s)’ which do not admit Interpretation 1 when operating with Rel-17 unified TCI (i.e. only Interpretation 2 is applicable), what TCI state update/configuration mechanism is used? | **Rel-15/16 update/configuration mechanism**: Fraunhofer IIS/HHI, Samsung, OPPO, ZTE, MTK  **Rel-17 update/configuration mechanism (using M>1 or N>1)**: vivo |
| 1.6 | For separate TCI, UL TCI state pool  Alt1: Shared pool with joint/DL TCI state  Alt2: Separate pool | **Alt1**: vivo, Spreadtrum, Samsung, Xiaomi, ZTE, Qualcomm, MTK, Convida, NTT Docomo, Intel  **Alt2**: CMCC, Ericsson, Futurewei, Huawei/HiSi, Fraunhofer IIS/HHI, OPPO |
| 1.7 | TCI state pool for CA  Alt1: Separate, per CC  Alt2: Shared among all CCs  Note: This is related to 1.1. | **Alt1:** Nokia/NSB, Huawei/HiSi, OPPO, LG  **Alt2:** vivo, Spreadtrum, Apple, Samsung, Xiaomi, Sony, Qualcomm, NTT Docomo, MTK, Intel, ZTE |
| 1.8 | Maximum value of M (DL) and N (UL) along with the use case(s) | Max M:   * **1 for sTRP**: Spreadtrum, ZTE, Samsung, Convida, NTT Docomo, MTK, OPPO * **>1 only for mTRP**: Samsung (M=2), Apple (M=2), LG, OPPO (M = 2) * **>1 for uses other than mTRP (specify)**: Futurewei, CATT, Qualcomm, LG   Max N:   * **1 for sTRP**: Spreadtrum, ZTE, Samsung, Convida, NTT Docomo, MTK, OPPO * **>1 only for mTRP/panel**: Samsung (N=2), Apple (N=2), LG, OPPO (N = 2) * **>1 for uses other than mTRP (specify)**: Futurewei, CATT, Qualcomm, LG |
| 1.9 | If M>1 and/or N>1 are supported, whether this implies simultaneous reception with different DL QCL(s) or transmission with different UL spatial filter(s) | **Yes**: Apple  **No**: |
| 1.10 | 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  Note: There are currently two interpretations on the agreement regarding CSI-RS for CSI: 1) Agreeing on reusing Rel-15/16 QCL rules implies CSI-RS for CSI is also agreed, 2) Only CSI-RS for tracking and BM were listed in the agreement, so CSI-RS for CSI is not yet agreed | SSB, with TRS as QCL Type-A source RS   * **Yes:** vivo, Samsung, ZTE, MTK, NTT Docomo * **No:** Spreadtrum, OPPO, Apple, Intel   SRS for BM, optionally with TRS as QCL Type-A source RS   * **Yes:** vivo, Spreadtrum, Nokia/NSB, Samsung, IDC, ZTE, Convida * **No:** Ericsson, Fraunhofer IIS/HHI, OPPO, LG   CSI-RS for CSI   * **Yes:** CMCC, ZTE, Sony * **No:** vivo, Spreadtrum, Samsung, OPPO |
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**From offline discussion on how Rel-17 unified TCI applies to ‘other signals/channels’ (1-4 and 1-5):**

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| For discussion purposes, the term ‘other signal(s)/channel(s)’ refers to channel(s), CORESET(s), or a signal(s) *other than* (DL) UE-dedicated reception on PDSCH and all/subset of CORESETs), as well as (UL) dynamic-grant/configured-grant based PUSCH and all of dedicated PUCCH resources. That is:   * For DL: CSI-RS resource for CSI, some CSI-RS resource(s) for BM, CSI-RS for tracking, non-UE-dedicated reception on PDSCH and all/subset of CORESETs * For UL: Some SRS resources or resource sets for BM   Two possible interpretations on how Rel-17 unified TCI applies to ‘other signal(s)/channel(s)’. We use CSI-RS resource for CSI as an example to illustrate the point.   * Interpretation 1: The CSI-RS resource for CSI shares the same (Rel-17 DL or, if applicable, joint) TCI state machine (hence ‘DL RX beam tracking loop’) as that for UE-dedicated reception on PDSCH and all/subset of CORESETs. This works regardless of the values of M and/or N.   + In this case, the Rel-17 DL or, if applicable, joint TCI state used for the CSI-RS resource for CSI needs to be associated with some UE-dedicated reception on PDSCH and all/subset of CORESETs. * Interpretation 2: The CSI-RS resource for CSI uses a different (Rel-17 DL or, if applicable, joint) TCI state machine (hence ‘DL RX beam tracking loop’) as that for UE-dedicated reception on PDSCH and all/subset of CORESETs. This [may] require M>1 and/or N>1 [if Rel-17 TCI state update/configuration mechanism is used].   + In this case, a separate Rel-17 DL or, if applicable, joint TCI state dedicated to the CSI-RS resource for CSI can be used without any association with any UE-dedicated reception on PDSCH and all/subset of CORESETs. |

The following observation can be made:

* (1.2, 1.3) These two issues have bene discussed since RAN1#103-e (11/2021) and need to be concluded. Preferences from companies do not change significantly although they are better understood. In general, a number of companies prefer not to support two-scheme (default/optional) solutions as those would impose complication on both NW and UE implementation.
  + On PL-RS, detailed aspects of the PL-RS can be further discussed after proposal 1.2 is agreed.
* (1.1/1.7) From offline discussion [1], proposals 1.3 (on CA QCL) is a good compromise between Alt1 and Alt2 proponents (Alt1 represents slight majority view).
* (1.4, 1.5) From offline discussion [1], proposals 1.4 (on applicability and use of Rel-17 TCI states) may be agreed after some discussion. Proposal 1.5 and 1.6 are good starting points for finalizing the issue in this meeting.
* (1.10) The situation has not changed since RAN1#103-e. It is time to conclude.

Based on the above observation, the following moderator proposals can be made:

**Proposal 1.1**: On the setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index) for Rel.17 unified TCI framework, the setting is either included in or associated with UL TCI state or (if applicable) joint TCI state.

* Whether it is ‘included in’ or ‘associated with’ (including the manner it is performed) is up to RAN2

**Proposal 1.2**: On path-loss measurement for Rel.17 unified TCI framework, a PL-RS (configured for path-loss calculation) is either included in or associated with UL TCI state or (if applicable) joint TCI state.

* If theDL RS in the UL or (if applicable) joint TCI state to provide spatial relation indication is different from PL-RS, path-loss measurement is up to UE implementation
* Whether it is ‘included in’ or ‘associated with’ (including the manner it is performed) is up to RAN2
* FFS: detailed aspects of PL-RS, e.g. CSI-RS type(s), time-domain behavior(s), restriction on configuration

**Proposal 1.3**: On Rel.17 unified TCI framework, [a single RRC pool of TCI states is used] for 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/BWPs

* A CC~~-~~specific source RS can be determined from the indicated common TCI state ID to provide QCL Type-D indication and to determine UL TX spatial filter. The determined CC-specific source RSs for the set of configured CCs/BWPs are further associated with a same QCL-TypeD RS.
  + Note: From a previous agreement, 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/BWPs
  + [FFS: how to provide the CC/BWP-specific RSs in a TCI state of the single RRC TCI state pool shared among the set of configured CCs/BWPs, e.g., the BWP/CC ID for the source RS for QCL Type-D reference and/or UL TX spatial reference can be absent in a TCI state]
* “A set of configured CCs/BWPs” includes all the BWPs in the set of configured CCs in one band

**Proposal 1.4**: On Rel.17 unified TCI framework,

* Any DL RS or DL physical channel that is a valid target signal/channel within the Rel-15/16 QCL rules can be configured as a target signal/channel of a Rel-17 DL TCI (hence the Rel-17 DL TCI state pool)
* Any UL RS or UL physical channel that is a valid target signal/channel within the Rel-15/16 UL spatial relation rules can be configured as a target signal/channel of a Rel-17 UL TCI (hence the Rel-17 UL TCI state pool)

**Proposal 1.5**: On Rel.17 unified TCI framework, in RAN1#105-e, discuss and decide

* Whether each of the following DL RSs and channels can share the same Rel-17 TCI state as UE-dedicated reception on PDSCH and for UE-dedicated reception on all or subset of CORESETs in a CC
  + CSI-RS resources for CSI
  + Some CSI-RS resources for BM, if so, which ones (e.g. aperiodic, repetition ‘ON’)
  + CSI-RS for tracking
  + Non-UE-dedicated reception on PDSCH and all/subset of CORESETs
* Whether each of the following UL RSs and channels can share the same Rel-17 TCI state as dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC
  + Some SRS resources or resource sets for BM

**Proposal 1.6**: On Rel.17 unified TCI framework, for the following (‘other’) signal/physical channel:

* Any DL RS or DL physical channel that does not share the same Rel-17 TCI state as UE-dedicated reception on PDSCH and for UE-dedicated reception on all or subset of CORESETs in a CC
* Any UL RS or UL physical channel that does not share the same Rel-17 TCI state dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC,

Discuss and down-select in RAN1#105-e between the following two alternatives:

* Alt1. Rel-15/16 TCI state and, if applicable, UL spatial relation update signaling/configuration mechanism(s) are reused to update/configure the Rel-17 TCI state
* Alt2. New TCI state update signaling/configuration mechanism(s) are used, e.g. using M>1 and/or N>1 with Rel-17 MAC-CE/DCI-based beam indication for Rel-17 joint/separate TCI

**Conclusion 1.7**: On Rel.17 unified TCI framework, in RAN1#105-e, there is no consensus on supporting the following source RS types for DL QCL Type-D reference for DL common UE-dedicated reception on PDSCH and all/subset of CORESETs:

* SSB
* SRS for BM
* CSI-RS for CSI

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 1**  **2) Share your inputs on the above FL proposals** |
| MediaTek | P1.1 and P1.2: Support. We would like to further check whether the signaling (RRC or MAC-CE) to provide the association is also decided by RAN2 if ‘associated with’ is adopted by RAN2. If so, we prefer to further clarify it in the proposal. For example,   * Whether it is ‘included in’ or ‘associated with’ (including the manner it is performed and the signaling) is up to RAN2   P1.3: We can support the proposal if the brackets of [a single RRC pool of TCI states is used] are removed. Regarding how to provide the “CC-specific” RSs in a TCI state for multiple CCs, the BWP/CC ID for the source RS can be absent in a TCI state, and RS will be located in the active BWP in each CC by default.  P1.4: We prefer not to introduce any new signaling mechanism for “other” signals/channels not applying Rel-17 TCI state machine. However, it may not be possible to reuse Rel-15/16 UL spatial relation update signaling/configuration mechanism(s) to update/configure the Rel-17 TCI state for “other” UL signals/channels not applying Rel-17 TCI state machine. Since RS index is directly provided as spatial relation, it is quite different from TCI state. Thus, for UL part in P1.4, we prefer to leave it for further study.  P1.5: Support  P1.6: For Alt1, as mentioned above, we see it may not be possible to reuse Rel-15/16 UL spatial relation update signaling/configuration mechanism(s) to update/configure the Rel-17 TCI state for “other” UL signals/channels not applying Rel-17 TCI state machine.  P1.7: Support |
| Nokia/NSB | Proposal 1.1  Open for further discussion  Proposal 1.2  Not support subbullets. We don’t think PL measurement can depend on UE implementation. It should be clarified in the spec. We can only accept the main bullet only.  And for the clarification, in our understanding, when we say association to TCI state, we may consider association to the TCI index not to the TCI state itself. Can we confirm the general understanding?  **Proposal 1.2**: On path-loss measurement for Rel.17 unified TCI framework, a PL-RS (configured for path-loss calculation) is either included in TCI state or associated with index/codepoint of UL TCI state or (if applicable) joint TCI state.   * ~~If the DL RS in the UL or (if applicable) joint TCI state to provide spatial relation indication is different from PL-RS, path-loss measurement is up to UE implementation~~ * ~~Whether it is ‘included in’ or ‘associated with’ (including the manner it is performed) is up to RAN2~~ * ~~FFS: detailed aspects of PL-RS, e.g. CSI-RS type(s), time-domain behavior(s), restriction on configuration~~   Proposal 1.3: We slightly prefer separated TCI pool per CC, but can be open for further discussion.  Proposal 1.4: Support  Proposal 1.5: Support  Proposal 1.6: Support |
| Intel | Proposal 1.1: OK. Also OK with Mediatek’s clarification  Proposal 1.2: OK with the main bullet and 2nd sub-bullet. Share Nokia’s concern on UE implementation based PL measurement. Would be good have further discussion on this case. We can keep it as FFS for now.  Proposal 1.3: OK in principle.  Proposal 1.4 – 1.6: Our general preference is to implement a clean design of Rel-17 unified TCI framework which replaces the spatial relation information signaling from Rel-15/16. To this end, leaving some configurations to re-use old framework while some use the new framework is not preferable. The two frameworks should not co-exist down the road making the whole design more complicated. As a result, in Proposal 1.6, we are not sure how Alt.1 works, especially since the Rel-17 UL TCI state definition and contents are not finalized yet. |
| Qualcomm | For Proposal 1.1, Suggest the following wording for potential RRC+MAC-CE based PL RS update, similar to R16  **Proposal 1.1**: On the setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index) for Rel.17 unified TCI framework, the setting is ~~either~~ included in and/or associated with UL TCI state or (if applicable) joint TCI state.   * Whether it is ‘included in’, ~~or~~ ‘associated with’ (including the manner it is performed), or both (e.g. MAC-CE updates the one configured in TCI state) is up to RAN2   For Proposal 1.2, same wording suggestion  **Proposal 1.2**: On path-loss measurement for Rel.17 unified TCI framework, a PL-RS (configured for path-loss calculation) is ~~either~~ included in and/or associated with UL TCI state or (if applicable) joint TCI state.   * If theDL RS in the UL or (if applicable) joint TCI state to provide spatial relation indication is different from PL-RS, path-loss measurement is up to UE implementation * Whether it is ‘included in’, ~~or~~ ‘associated with’ (including the manner it is performed), or both (e.g. MAC-CE updates the one configured in TCI state) is up to RAN2 * FFS: detailed aspects of PL-RS, e.g. CSI-RS type(s), time-domain behavior(s), restriction on configuration   For Proposal 1.3, suggest the following wording for the following reasons:   * I guess the bracket in the main bullet is because one or multiple pools is still FFS. So suggest to reword the main bullet and add the FFS as a sub-bullet; * Common TCI state ID may or may not provide common beam in R16. So suggest to remove it from main bullet; * Modified the original 1st sub-bullet to emphasize at least a single common beam indication RS can be indicated for all BWPs/CCs; I guess that is the intention. * Removed the bracket for FFS and clarify that it is for the case each BWP/CC has its own source RS, especially for TypeA RS, which must be different for different BWP/CC   **Proposal 1.3**: On Rel.17 unified TCI framework, ~~[a single RRC pool of TCI states is used]~~ each configured RRC pool of TCI states is used for 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/BWPs   * FFS: whether a single or multiple RRC pools can be configured across a set of configured CCs/BWPs * At least a common ~~A CC-specific~~ source RS can be determined from the indicated common TCI state ID to provide common QCL Type-D indication and/or to determine common UL TX spatial filter across the set of configured CCs/BWPs. ~~The determined CC-specific source RSs for the set of configured CCs/BWPs are further associated with a same QCL-TypeD RS.~~   + […]   + ~~[~~FFS: how to provide the CC/BWP-specific source RSs from ~~in~~ a TCI state of one ~~the single~~ RRC TCI state pool shared among the set of configured CCs/BWPs, e.g., the BWP/CC ID for the source RS for QCL Type-A/D reference and/or UL TX spatial reference can be absent in a TCI state~~]~~ * […]   For Proposal 1.4, suggest the following wording to include joint TCI  **Proposal 1.4**: On Rel.17 unified TCI framework,   * Any DL RS or DL physical channel that is a valid target signal/channel within the Rel-15/16 QCL rules can be configured as a target signal/channel of a Rel-17 DL or joint TCI (hence the Rel-17 DL and joint TCI state pool(s)) * Any UL RS or UL physical channel that is a valid target signal/channel within the Rel-15/16 UL spatial relation rules can be configured as a target signal/channel of a Rel-17 UL or joint TCI (hence the Rel-17 UL and joint TCI state pool(s))   For Proposal 1.5, fine to discuss. Our preference is allow sharing same configured TCI for any RS/channel  For Proposal 1.6, suggest to discuss after Proposal 1.5. Because it would be more efficient to reuse/share same R17 TCI for any DL/UL RS/channel. |
| Apple | Proposal 1.1: Support  Proposal 1.2: We can compromise to consider PL-RS with one of the additional bullets   * Option 1: Introduce a UE capability to report whether it beam alignment between PL-RS and DL-RS for beam indication * Option 2: Enhance FG 2-4 and 2-62 that PL-RS is counted for active TCI * Option 3: Pathloss measurement is up to UE implementation if beam mismatch happens * Beam alignment/mismatch can be defined based on whether the DL-RS for beam indication and PL-RS is the same or whether there is direct/indirect QCL relationship between DL-RS for beam indication and PL-RS.   We are also fine without any consensus for PL-RS, which means the SSB for MIB decoding would be used.  Proposal 1.3: OK. We support single TCI state pool, which can save overhead. R15 design unnecessarily requires large UE memory.  Proposal 1.4: As downlink QCL indication is a 2-stage approach, does this mean we need at least 2 types of unified TCI – one for CSI-RS, the other for PDSCH/PDCCH? Similarly uplink spatial relation indication for PUSCH is based on a 2-stage approach, does it mean SRS for CB/NCB can be included in UL TCI, and there would be two types of UL TCI – one for SRS/PUCCH, the other for PUSCH?  Proposal 1.5: Support in principle.  Proposal 1.6: We suggest we first identify what “other signal/channel” is, and decide the solution later.  Proposal 1.7: Support |
| Samsung | Proposal 1.1: Support  Proposal 1.2: We share Apple’s view that the PL RS and the beam RS should be aligned to the same QCL source. However, the current wording of the first sub-bullet seems to imply that the PL RS and beam RS should be the same. We suggest the following update:  “A UE expects that the DL RS in the UL or (if applicable) joint TCI state providing spatial relation indication and the PL-RS are aligned to the same QCL source”.  Proposal 1.3: We agree with the direction of the proposal as a compromise, but we would like to remove the square brackets around “a single RRC pool of TCI states is used”  Proposal 1.4: Support with a small wording update   * Any DL RS or DL physical channel that is a valid target signal/channel ~~within the~~ of a Rel-15/16 TCI state QCL rules can be configured as a target signal/channel of a Rel-17 DL TCI (hence the Rel-17 DL TCI state pool)   Proposal 1.5: Support  Proposal 1.6: Support slight preference for Alt1, as we have limited TCI state indication capability in release 17 (with no repurposing) |
| OPPO | Proposal 1.1: Only support it for PUSCH and PUCCH. But not support it for SRS. For SRS, the (P0, alpha, closed loop index) shall be configured to the set and they shall not change along with the TCI state switch  Proposal 1.2: Support  Proposal 1.3: The proposal contradict with the previous agreement. In previous agreement, the QCL-TypeRS is a “same/single RS”. But this proposal proposes to use CC-specific RS, which are definitely not same/single RS. The reason for agreed “same/single RS” is to ensure same beam on those CC. The new description of “CC-specific source RS… with a same QCL-TypeD RS” can not ensure the same beam on multiple CCs because from the perspective of PDCCH and PDSCH, only the indirect QCL is same and that does not mean same beam.  Proposal 1.4: The proposal is confusing. For example, regarding the SRS of BM, does the proposal mean that we are going to just replace the “spatial relation info” with ‘TCI state’ but still use the beam indication control signaling specified in rel15/16? If so, why we bother to repeat the same function here? If not so, does the proposal mean the indicated “common TCI” in rel17 unfied TCI framework will be applied to all the channel and reference signals?  Proposal 1.5: Ok  Proposal 1.6: For ‘other signal/channels’: we suggest to reuse whatever is specified in rel15 and rel16 and do not repeat the same function by replacing “spatial relation info” with “UL TCI”.  Conclusion 1.7: Ok |
| ZTE | Proposal 1.1: Support. We are also fine with MTK’s or QC’s clarification.  Proposal 1.2: Support  Proposal 1.3: As we mentioned before as in offline discussion, it is a compromise solution that the Alt1 + a single RRC pool, and the bracket for a single RRC pool should be removed. Otherwise, we need to go Alt2, and to be honest, we do believe that Alt1 is to revert the previous agreement.   * **Alt1**: Separate QCL-Type D RS for each of the CCs can be determined from the TCI state(s). The determined QCL-Type D RSs for the set of CCs are further associated with a same QCL-Type D RS. * **Alt2**: A single QCL-Type D RS for the set of the CCs is determined from the TCI state(s), and support enhanced QCL chain:   Proposal 1.4: A little bit confusing. If our understanding is correct, we only need to clarify which types RSs/channels can be assumed as target ones of unified TCI framework in the spec, and if unified TCI framework is enabled, then the UE need to follow the specified UE behavior corresponding unified TCI framework rather than Rel-15/16. If so, it seems that this proposal is not needed unless we would like to clarify some ambiguities among companies.  Proposal 1.5: Support. Our preference can be found in the above tables.  Proposal 1.6: Support.  Proposal 1.7: Considering that we already supported that CSI-RS for CSI can be configured as source RS in Rel-15/16 QCL chain, we slightly prefer to keep CSI-RS for CSI as source RS in Rel-17 unified TCI framework also. |
| LG | Proposal 1.1: Support  Proposal 1.2: Support the main bullet but we share a similar view with Nokia on the first sub-bullet that it needs further discussion for how to handle the case.  Proposal 1.3: It is preferred to remove ‘a single RRC pool of TCI state is used’ in main bullet and discuss further on that as FFS. As Huawei and CATT mentioned in offline discussion, it would lead the same UL PC across CCs by taking PC setting included in/associated with UL TCI into account.  Proposal 1.4, 1.5, 1.6 and Conclusion 1.7: Support |

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

Table 3 Summary: issue 2

|  |  |  |
| --- | --- | --- |
| **#** | **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**: Lenovo/MoM, Huawei/HiSi, Sony, LG, ZTE * **No**: Nokia/NSB, Samsung, OPPO, MTK   CSI-RS for BM configured for NSC:   * **Yes**: Nokia/NSB, Ericsson, AT&T, ZTE * **No**: Samsung, OPPO, MTK   CSI-RS for tracking (TRS) configured for NSC:   * **Yes**: -- * **No**: Samsung, OPPO, MTK |
| 2.2 | Maximum value of K (beams associated at least with non-serving cell(s) reported in a single CSI reporting instance), i.e. KMAX  Note: UE capability of supporting < KMAX is neither ruled out nor within the scope of 2.2 | **4**: vivo, Spreadtrum, MTK (if cell = 1),OPPO  **8**: Nokia/NSB, Ericsson, AT&T, CATT (at least), MTK (if cells > 1)  **16**: Huawei/HiSi, Samsung, ZTE |
| 2.3 | How to set the value of K≤ KMAX  Alt1: RRC configured (based on UE capability)  Alt2: Dynamically selected by UE (indicated in CSI reporting, two-part UCI) | **Alt1**: OPPO, MTK, CATT, Intel, ZTE  **Alt2**: Samsung |
| 2.4 | The maximum value of NMAX (number of non-serving cell(s) RRC configured for measurement/reporting)  Note: UE capability of supporting <Nmax is neither ruled out nor within the scope of 2.4 | **1**: Spreadtrum, OPPO  **>1 (specify)**: Ericsson (FFS the maximum value), CATT, Samsung (4), Xiaomi (3) , ZTE |
| 2.5 | Whether to support the following reporting behavior | Periodic**:**   * **Yes**: Nokia/NSB, MTK, Samsung (with restriction), Spreadtrum, ZTE * **No**:   Semi-persistent**:**   * **Yes**: Nokia/NSB, MTK, Samsung, ZTE, Spreadtrum * **No**:   Aperiodic**:**   * **Yes**: Nokia/NSB, MTK, Samsung, ZTE, Spreadtrum * **No**:   Event-driven**:**   * **Yes (specify event)**: Nokia/NSB, Xiaomi (L3 Events A2~A6 or Event B1 or new L1 event), ZTE (event triggered by L3 mobility measurement), Apple (L1-RSRP of NSC is beyond L1-RSRP of SC plus an offset), AT&T, Sony (L1 metric of NSC is beyond L1 metric of SC plus an offset), Qualcomm, Samsung, LG * **No**: MTK |
| 2.6 | 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:   * *SSB associated with NSC as direct QCL source:*    + **Yes**: Nokia/NSB, Samsung, MTK, NTT Docomo, ZTE   + **No**: * *SSB associated with NSC as indirect QCL source (therefore any CSI-RS resource using NSC SSB can be used as a source RS):*    + **Yes**: CMCC, Nokia/NSB, Samsung, Sony, Ericsson, MTK, NTT Docomo, ZTE, LG   + **No**: * *CSI-RS for RRM:*    + **Yes:** Sony, LG   + **No:** Samsung, MTK   UL TX spatial reference:   * *SSB associated with NSC as direct QCL source:*    + **Yes**: CMCC, Samsung, Sony, Ericsson, MTK, ZTE   + **No**: * *SSB associated with NSC as indirect QCL source (therefore any CSI-RS resource using NSC SSB can be used as a source RS):*    + **Yes**: CMCC, Samsung, Sony, Ericsson , MTK, ZTE, LG   + **No**: * *CSI-RS for RRM:*    + **Yes**: Sony, LG   + **No**: Samsung, MTK |
| 2.7 | Whether to support the following Rel-17 unified TCI types for L1/L2-centric inter-cell mobility | Joint TCI:   * **Yes**: Samsung, vivo, Nokia/NSB, MTK, ZTE, LG * **No**:   Separate DL/UL TCI (including DL-only, UL-only, and [DL+UL]):   * **Yes**: vivo, Nokia/NSB, MTK * **No**: Samsung (FFS), ZTE(FFS is needed) |
|  |  |  |

The following observation can be made:

* (2.6, 2.7) For beam indication, at the minimum, indirect QCL with SSB from NSC seems agreeable as a method for spatial reference. In addition, joint TCI can be agreed.
* (2.1) This issue has been discussed for several meetings and there is no consensus (the situation hasn’t changed)
* (2.2) Kmax=8 represents the majority view
* (2.5) No objection to support P/SP/AP, and the majority supports L1-based event-driven reporting

Based on the above observation, the following moderator proposals can be made:

**Proposal 2.1**: On Rel.17 beam indication enhancements for L1/L2-centric inter-cell mobility, support the following:

* Rel-17 DCI-based beam indication (using DCI formats 1\_1/1\_2 with and without DL assignment, including the associated MAC-CE-based TCI state activation) with the TCI field used to update joint TCI state
  + FFS (to be decided in RAN1#106-e): The use of the TCI field to update separate DL/UL TCI states
* The DL QCL and UL spatial relation rules already agreed for intra-cell scenario, also allowing the use of SSB associated with a physical cell ID different from that of the serving cell as an indirect QCL source
  + FFS (to be decided in RAN1#106-e): Whether SSB associated with a physical cell ID different from that of the serving cell can also be used as a direct QCL source (source RS)

**Conclusion 2.2**: On Rel.17 multi-beam measurement/reporting enhancements for L1/L2-centric inter-cell mobility and inter-cell mTRP, there is no consensus on supporting the following measurement RS types in RAN1#105-e:

* CSI-RS for mobility/RRM associated with non-serving cell
* CSI-RS for BM configured for non-serving cell
* CSI-RS for tracking configured for non-serving cell

**Proposal 2.3**: On Rel.17 multi-beam measurement/reporting enhancements for L1/L2-centric inter-cell mobility and inter-cell mTRP,

* Support at least K=4 and 8, where K is defined as the number of beams associated at least with non-serving cell(s) reported in a single CSI reporting instance
  + The maximum value of supported K is a UE capability
  + FFS: The support of K=16
* Support NW-controlled periodic, semi-persistent, and aperiodic reporting
  + FFS: Restriction for periodic reporting, e.g. smaller value(s) of K, number of non-serving cells
* Support L1-based event-driven reporting
  + FFS: Definition of L1-based event

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 3**  **2) Share your inputs on the above FL proposals** |
| MediaTek | P2.1: Support  P2.2: Support  P2.3: Support in principle. Regarding K=8, we prefer to support it only when a reporting is associated with more than cells (NSCs and/or SC). Otherwise, we don't see the need to support more than four if a reporting is associated with only one NSC. |
| Intel | Proposal 2.1: Not ok with the first sub-bullet. MAC-CE activation and TCI state mapping to codepoints for intra-cell is not finalized. For example, if dynamic indication is agreed where both joint and separate DL/UL TCI can be mapped to codepoints, only joint TCI state update is an added constraint and it is not clear why we should agree to this at this point. We can put the entire MAC-CE based codepoint activation part in the FFS.   * Rel-17 DCI-based beam indication (using DCI formats 1\_1/1\_2 with and without DL assignment~~, including the associated MAC-CE-based TCI state activation) with the TCI field used to update joint TCI state~~   + FFS (to be decided in RAN1#106-e): MAC-CE-based TCI state activation and the use of the TCI field to update joint or separate DL/UL TCI states |
| Qualcomm | For Proposal 2.1   * Suggest to add “at least”   + Rel-17 DCI-based beam indication (using DCI formats 1\_1/1\_2 with and without DL assignment, including the associated MAC-CE-based TCI state activation) with the TCI field used to update at least joint TCI state * Suggest to add “for PDCCH/PDSCH”, because SSB should be allowed to be as direct QCL source at least for CSI-RS. Otherwise, it is unclear how this indirect QCL for any channel/RS works.   + The DL QCL and UL spatial relation rules already agreed for intra-cell scenario, also allowing the use of SSB associated with a physical cell ID different from that of the serving cell as an indirect/direct QCL source, except for a direct QCL source for PDCCH/PDSCH     - FFS (to be decided in RAN1#106-e): Whether SSB associated with a physical cell ID different from that of the serving cell can also be used as a direct QCL source for PDCCH/PDSCH (source RS)   For Conclusion 2.2: Support  For Proposal 2.3: Support |
| Apple | Proposal 2.1: one minor suggestion as follows, since we also support MAC CE based beam indication in R17  **Proposal 2.1**: On Rel.17 beam indication enhancements for L1/L2-centric inter-cell mobility, support the following:   * Rel-17 MAC CE and DCI-based beam indication (using DCI formats 1\_1/1\_2 with and without DL assignment, including the associated MAC-CE-based TCI state activation) with the TCI field used to update joint TCI state   + FFS (to be decided in RAN1#106-e): The use of the TCI field to update separate DL/UL TCI states * The DL QCL and UL spatial relation rules already agreed for intra-cell scenario, also allowing the use of SSB associated with a physical cell ID different from that of the serving cell as an indirect QCL source   + FFS (to be decided in RAN1#106-e): Whether SSB associated with a physical cell ID different from that of the serving cell can also be used as a direct QCL source (source RS)   Proposal 2.2: Support  Proposal 2.3: We have concerns for aperiodic report. UE has to measure corresponding SSB to get ready for potential beam report triggering, but UE does not know when this report would be triggered. This waste UE power quite a lot. So, we suggest the following change.  **Proposal 2.3**: On Rel.17 multi-beam measurement/reporting enhancements for L1/L2-centric inter-cell mobility and inter-cell mTRP,   * Support at least K=4 and 8, where K is defined as the number of beams associated at least with non-serving cell(s) reported in a single CSI reporting instance   + The maximum value of supported K is a UE capability   + FFS: The support of K=16 * Support NW-controlled periodic, and semi-persistent reporting   + FFS: Restriction for periodic reporting, e.g. smaller value(s) of K, number of non-serving cells * Support L1-based event-driven reporting   + FFS: Definition of L1-based event |
| Samsung | Proposal 2.1: In general, the direction of the proposal is fine. We have not, based on my knowledge, define indirect SSB. I think we should define if we include in proposal to be clear. Alternatively we can avoid this wording as follows:   * The DL QCL and UL spatial relation rules already agreed for intra-cell scenario, also allowing the use of ~~SSB~~ at least a reference signal associated with an antenna port of a physical cell ID different from that of the serving cell as ~~an indirect~~ QCL source   + FFS (to be decided in RAN1#106-e): Whether SSB associated with a physical cell ID different from that of the serving cell can also be used as a direct QCL source (source RS)   At least is added to cover the FFS which would be an additional RS  Conclusion 2.2: Support  Proposal 2.3: Support direction of proposal. We think that the last bullet should be FFS in its entirety as we have not define what the event is:   * FFS: Support L1-based event-driven reporting   + ~~FFS:~~ Definition of L1-based event |
| OPPO | 2.1：The main purpose of this proposal is to reuse the agreed DCI-based beam indication for inter-cell mobility. Then we only need to say this and the details for joint TCI or separate TCI can be removed for current moment. And as in Conclusion 1.7, there is no consensus to support SSB as direct QCL, we do not see why we need the second FFS.  **Proposal 2.1**: On Rel.17 beam indication enhancements for L1/L2-centric inter-cell mobility, support the following:   * Rel-17 DCI-based beam indication (using DCI formats 1\_1/1\_2 with and without DL assignment, including the associated MAC-CE-based TCI state activation) with the TCI field is used ~~to update joint TCI state~~   + ~~FFS (to be decided in RAN1#106-e): The use of the TCI field to update separate DL/UL TCI states~~ * The DL QCL and UL spatial relation rules already agreed for intra-cell scenario, also allowing the use of SSB associated with a physical cell ID different from that of the serving cell as an indirect QCL source   + ~~FFS (to be decided in RAN1#106-e): Whether SSB associated with a physical cell ID different from that of the serving cell can also be used as a direct QCL source (source RS)~~   Conclusion 2.2: suggest to remove “in RAN1#105-e”. Let us make a conclusion and stop discussing it.  2.3: we have concern on K =8. There is no justification to support so many. Suggest to only support K = 4. |
| ZTE | Proposal 2.1: Support. Also we are fine with Apple’s update for MAC-CE based beam indication  Proposal 2.2: Definitely not our preference, but we can live with this proposal for progress.  Proposal 2.3: We suggest to support K=16 in this proposal from spec perspective, and UE vendor can report capability signaling of the maximum number of K to be supported. Meanwhile, we can NOT live with K=4 only as OPPO suggested, and it significantly weakens the benefits of NSC-measurement (also relevant to spec forward compatibility) from gNB vendor perspective. |
| LG | For Proposal 2.1: Support in principle. However, the DCI format 0\_1/0\_2 for Rel-17 beam indication also can be considered, which is up to the result of Issue#3.  For Proposal 2.3, it seems too early to support K>4 until details of reporting method is fixed. If we simply reuse existing beam reporting, K=4 may be sufficient. |

### Issue 3 (beam indication signaling medium)

Table 5 Summary: issue 3

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| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | Whether both DL TCI and UL TCI states can be signaled in one instance of beam indication DCI formats 1\_1/1\_2 (with and without DL assignment) | **Yes (one TCI field codepoint represents both DL and UL TCI states)**: Nokia/NSB, Ericsson, Samsung, Xiaomi, OPPO, Fujitsu, Intel  **No**: |
| 3.2 | 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, Xiaomi, Convida  **Alt2A**: Lenovo/MoM, CMCC, Fujitsu, Samsung (2nd preference), IDC, Spreadtrum, ZTE, CATT, Huawei/HiSi, Apple, Sony, Qualcomm, NEC, NTT Docomo (2nd preference), APT, MTK , Intel, OPPO (2nd preference: Alt2B+ meet the UE capability) , ZTE  **Alt2B**: Nokia/NSB, Samsung (1st preference), Xiaomi, NTT Docomo (1st preference), LG  **Alt2C:**  **Alt3**: OPPO |
| 3.3 | For a UE configured with (supporting/capable of) both joint TCI and separate DL/UL TCI (including DL-only TCI, UL-only TCI, [or DL+UL TCI]), how to signal the switching between joint TCI and separate DL/UL TCI:   * AltA. Either joint TCI, DL-only TCI, UL-only TCI, [or DL+UL TCI] can be dynamically indicated via beam indication DCI (i.e. the 8 available TCI codepoints are partitioned for all the TCI “types”) * AltB. Either joint DL/UL TCI or separate DL/UL TCI can be activated via MAC CE signaling (included in the TCI state activation)   + When separate DL/UL TCI is activated, either DL-only TCI, UL-only TCI, [or DL+UL TCI] can be indicated via beam indication DCI   Note: The UE capability/optionality/FG issue is beyond the scope of 3.2 | **AltA**: Lenovo/MoM, Nokia/NSB, ZTE, OPPO (only for the UE with UE capability supporting both joint and separate TCI state), Sony, Convida, APT , Intel (TCI state usage indication via MAC-CE and dynamic switching using DCI)  **AltB**: Spreadtrum, CATT, Ericsson, Huawei/HiSi, Samsung, Xiaomi, Apple, Qualcomm, MTK, NTT Docomo, LG |
| 3.4 | Additional support for DCI ACK/NAK for DCI formats 1\_1/1\_2 with DL assignment when used for beam indication | **Yes:** Lenovo/MoM (dedicated ACK/NACK bit in codebook), Xiaomi (separate HARQ-ACK bit), Samsung, CATT (only ACK), OPPO (only ACK), Apple, NEC (only ACK)  **No:** ZTE(FFS is needed) |
| 3.5 | Support for additional DCI formats for Rel-17 unified TCI framework beam indication (TCI state update) beyond the agreed DCI formats 1\_1/1\_2 with + without DL assignment | **No additional DCI format is supported for beam indication:** Convida, OPPO  **DCI formats 0\_1/0\_2 with UL grant (for UL-only TCI of separate DL/UL TCI)**: IDC, Sony, NEC, MTK, LG, Intel, ZTE |
| 3.6 | When more than one TCI codepoints are activated by MAC CE, the activated TCI state(s) for the lowest codepoint is/are applied. | **Yes:** Huawei, HiSilicon  **No:** Intel, OPPO, ZTE |
| 3.7 | When UE is configured with two HARQ priorities, the HARQ ACK/NACK feedback for beam indication DCI is always mapped to high priority codebook with PUCCH resource associated to priority index 1 | **Yes:** Intel  **No:** |

The following observation can be made:

* (3.1) Majority support for signaling both DL and UL TCI in one beam indication instance for separate TCI
* (3.2) Alt2A seems to be the alternative acceptable to (almost) all companies
* (3.3) AltB (MAC-CE-activation based) represents the majority viee and the middle ground between RRC-based (too slow) and codepoint-based (over-partitioning the max 8 available codepoints into joint and separate TCIs – 4 “types” of TCI) switching between joint and separate TCI. It also accommodates (partially) the view of those preferring fully dynamic switching (since the switching among DL, UL, and DL+UL is done via TCI field codepoints)

Based on the above observation, the following moderator proposals can be made:

**Proposal 3.1**: On Rel-17 unified TCI, for separate DL/UL TCI, both DL-only TCI and UL-only TCI states can be updated in one instance of beam indication using DCI formats 1\_1/1\_2 (with and without DL assignment)

**Proposal 3.2**: On Rel-17 DCI-based beam indication, regarding application time of the beam indication, the first slot that is at least X ms or Y symbols after the last symbol of the acknowledgment of the joint or separate DL/UL beam indication.

**Proposal 3.3**: On Rel-17 unified TCI, for a UE configured with both joint TCI and separate DL/UL TCI (including DL-only TCI, UL-only TCI, or DL+UL TCI), either only joint DL/UL TCI states or only separate DL/UL TCI states can be activated via MAC-CE-based TCI state activation

* When joint TCI states are activated, only joint TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication
* When separate DL/UL TCI states are activated, either DL-only TCI state, UL-only TCI state, or DL+UL TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication

Table 6 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 5**  **2) Share your inputs on the above FL proposals** |
| MediaTek | P3.1: Support  P3.2: Support  P3.3: Support. Regarding how to activate joint TCI or separate TCI via MAC-CE-based TCI state activation can be left to RAN2 design.   * *How to activate either only joint DL/UL TCI states or only separate DL/UL TCI states is up to RAN2* |
| Nokia/NSB | Proposal 3.1: Support  Proposal 3.2: Support  Proposal 3.3: We prefer no ‘mode like’ separation between indication of joint/separated TCI, since it can be up to gNB which TCI to be associated to each of TCI index. But as our 2nd preference, we can be open for MAC CE based switching. We do not support any slower changes, e.g., RRC. |
| Intel | Proposal 3.1: Support  Proposal 3.2: Support  Proposal 3.3: Do not support this proposal. We don’t see the need to limit the configurable codepoints to one type of TCI states. As we outlined in our paper, MAC-CE configuring the TCI codepoints can also configure the usage i.e., what type of TCI state the codepoint maps to. In this case, the DCI indication can choose any of the 8 codepoints and they can map to either joint or separate TCI states. Requiring MAC-CE to reconfigure codepoints if gNB needs to indicate separate TCI states is not desirable.  We also added Issue 3.7 to the Table 5. In our understanding, the ACK/NACK for beam indication is a very important UCI which is needed to ensure UE and gNB are aligned on which beam is used. In this case, this ACK/NACK feedback should not be dropped in favor of other UCI i.e., prioritization is needed. For the case when a UE is configured with two HARQ codebook priority indices, the beam indication ACK/NACK should always be mapped to the high priority HARQ/ACK codebook. |
| Qualcomm | For Proposal 3.1: Can more details be provided? How?  For Proposal 3.2: Support  For Propoal 3.3: Suggest the following clarification if that is the intention  **Proposal 3.3**: On Rel-17 unified TCI, for a UE configured with both joint TCI and separate DL/UL TCI (including DL-only TCI, UL-only TCI, or a pair of DL+UL TCIs if supported), either only joint DL/UL TCI states or only separate DL/UL TCI states can be activated via MAC-CE-based TCI state activation   * When joint TCI states are activated, only joint TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication * When separate DL/UL TCI states are activated, either a single DL-only TCI state, a single UL-only TCI state, or a pair DL+UL TCI states if supported can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication |
| Apple | Proposal 3.1: Support  Proposal 3.2: Support  Proposal 3.3: For separate DL/UL, we suggest one code-point is always mapped to a pair of DL+UL TCI. So we suggest the following change:  **Proposal 3.3**: On Rel-17 unified TCI, for a UE configured with both joint TCI and separate DL/UL TCI (including DL-only TCI, UL-only TCI, or DL+UL TCI), either only joint DL/UL TCI states or only separate DL/UL TCI states can be activated via MAC-CE-based TCI state activation   * When joint TCI states are activated, only joint TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication * When separate DL/UL TCI states are activated, DL+UL TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication |
| Samsung | Proposal 3.1: Support  Proposal 3.2: Support  Proposal 3.3: Support |
| OPPO | Proposal 3.1: The wording is confusing a little bit. Does the proposal intent to say that a single DCI can indicate one DL TCI state and one UL TCI state? Suggest to change as follows:  **Proposal 3.1**: On Rel-17 unified TCI, for separate DL/UL TCI, ~~both DL-only TCI and UL-only TCI states can be updated in~~ one instance of beam indication using DCI formats 1\_1/1\_2 (with and without DL assignment) can indicate one DL TCI state and one UL TCI state.    Proposal 3.2: We prefer to add a note that the gap between the beam indication DCI and that first slot shall satisfy the UE capability.  **Proposal 3.2**: On Rel-17 DCI-based beam indication, regarding application time of the beam indication, the first slot that is at least X ms or Y symbols after the last symbol of the acknowledgment of the joint or separate DL/UL beam indication.   * The gap between the last symbol of the beam indication DCI and that first slot shall satisfy the UE capability   Proposal 3.3: support in principle. But prefer to clarify that in one single MAC CE, all the activated TCI states shall be the same type: all are joint TCI states or all are separate TCI states.  **Proposal 3.3**: On Rel-17 unified TCI, for a UE configured with both joint TCI and separate DL/UL TCI (including DL-only TCI, UL-only TCI, or DL+UL TCI), either only joint DL/UL TCI states or only separate DL/UL TCI states can be activated via MAC-CE-based TCI state activation   * When joint TCI states are activated, only joint TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication, here all the activated TCI states are joint TCI states. * When separate DL/UL TCI states are activated, either DL-only TCI state, UL-only TCI state, or DL+UL TCI state can be updated via the TCI field in DCI formats 1\_1/1\_2 used for beam indication, here all the activated TCI states are separate DL/UL TCI states. |
| ZTE | Proposal 3.1: Support  Proposal 3.2: Support. Xms is slightly preferred considering that different SCS may be configured for different CCs in CA case.    Proposal 3.3: Support. We think that for separate beam indication mode (as a super mode compared with joint TCI indication), we also need to support a beam state that can be applied to both DL and UL as a joint TCI state by default. |
| LG | Proposal 3.1: Suggest to discuss whether to support DCI format 0\_1/0\_2 for UL TCI update before discussing this proposal. If it is supported, it seems not needed to use DL DCI format (i.e. 1\_1/1\_2) for UL TCI update in case of separate DL/UL TCI.  Proposal 3.2: We have strong concern on this proposal. The main difference between Alt2A and Alt2B is whether to apply the indicated TCI in DCI to the scheduled PDSCH. Could someone explain why the indicated TCI by DCI should NOT be applied to the scheduled PDSCH, which is an existing functionality? Alt2A will lead to worse performance than Rel-15/16, i.e. PDSCH beam application timing is delayed after sending HARQ-ACK for the scheduled PDSCH, which is very strange design.  Proposal 3.3: Support in principle. Need to remove ‘DL+UL TCI state’ by DCI 1\_1/1\_2 for now due to the reason commented on 3.1 |

### Issue 4 (MP-UE)

Table 7 Summary: issue 4

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| **#** | **Issue** | **Companies’ views** |
| 4.1 | Whether to support the following measurement/reporting scheme for UE-initiated panel activation/selection:   * Opt1-1: A panel entity corresponds to a reported CSI-RS and/or SSB resource index in a beam reporting instance   + The correspondence between a panel entity and a reported CSI-RS and/or SSB resource index is informed to NW   + Note: the correspondence between a CSI-RS and/or SSB resource index and a panel entity is determined by the UE (analogous to Rel-15/16) * Opt1-2: A panel entity is referring to a new panel ID within CSI/beam reports   + FFS: Detailed design of the new panel ID including the information conveyed by the new panel ID   + Note: The association between the new panel ID and the panel entity is determined by the UE * Opt1-3: No additional specification support | **Opt1-1:** Huawei/HiSi, Apple (if capable), Sony (2nd pref), MTK  **Opt1-2:** IDC, vivo, Lenovo/MoM, Spreadtrum, CMCC, Samsung (resource set ID), ZTE (global ID), Huawei/HiSi, Sony, Fraunhofer IIS/HHI, Xiaomi, AT&T, NTT Docomo, LGE  **Opt1-3:** CATT, OPPO, Ericsson, Apple, APT, Intel |
| 4.2 | Whether to support CB-based SRS resources with different numbers of ports | **Yes**: ZTE, Samsung, CATT, OPPO (different sets have different number of ports), Qualcomm, NTT Docomo, LGE, MTK  **No**: vivo, APT , Intel |
| 4.3 | Whether to support NCB-based SRS resource sets with different numbers of resources | **Yes**: ZTE, Samsung  **No**: |
| 4.4 | Support of NW-initiated panel activation/selection | **Yes**: IDC (TCI state group indication + gNB confirmation), vivo (TCI state update), Huawei/HiSi (handshake), Qualcomm (handshake), Fraunhofer IIS/HHI  **No**: Spreadtrum, Sony, Xiaomi, OPPO |
|  |  |  |

The following observation can be made:

* (4.1) Opt1-2 represents the super-majority view
* (4.2) The additional support for having different # ports for SRS resources represents the majority view

Based on the above observation, the following moderator proposals can be made:

**Proposal 4.1**: On Rel.17 enhancements to facilitate UE-initiated panel activation and selection, a panel entity is referring to a new panel ID within CSI/beam reports

* FFS: Detailed design of the new panel ID including the information conveyed by the new panel ID
* Note: The association between the new panel ID and the panel entity is determined by the UE

**Proposal 4.2**: Support configuring a UE with SRS resources having different numbers of ports for codebook-based UL transmission

Table 8 Additional inputs: issue 4

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 7**  **2) Share your input on the above FL proposals** |
| Nokia/NSB | Proposal 4.2: Support. Can we clarify that SRS resources within the same resource set can have different number of ports?  **Proposal 4.2**: Support configuring a UE with SRS resources having different numbers of ports within the same resource set for codebook-based UL transmission |
| Qualcomm | For Proposal 4.1: Suggest to add the following FFS  FFS: Details for reporting the new panel ID within CSI/beam reports.  For Proposal 4.2: Support |
| Apple | Do not support proposal 4.1 and 4.2.  Proposal 4.1 and 4.2 prohibits flexibility for UE to change panel at any time. |
| Samsung | Proposal 4.1: Support  Proposal 4.2: Support |
| MediaTek | P4.1: We have concern on Opt1-2. For Opt1-2, if a new panel ID is associated with a beam reporting, which means UE can only initiate one UE panel for that beam reporting. If NW would like to check the link qualities from multiple UE panels, multiple beam reports with different IDs have to be configured. We fail to see why separate reports are needed for each UE panel. Furthermore, if multiple CSI/beam reports with different IDs are configured to UE, UE is required to initiate multiple UE panels, which is not aligned with the spirit of “UE-initiated” panel activation and election. In our opinion, for Opt1-1, only one beam report is needed since SSBRSs/CRIs can correspond to one or multiple UE panels, and UE can decide to activate how many UE panels.  To address the comments from Apple, Qualcomm and MediaTek, suggest the following changes to the proposal:   * Allow UE to determine new panel ID and inform to NW per reporting instance. UE can change the panel across different reporting instances. Details for reporting the new panel ID(s) within a CSI/beam reporting instance can be further discussed, as suggested by Qualcomm. * Allow one or more activated panels per reporting instance, instead of only one. * Clarify what information is conveyed by new panel ID in this proposal. If no information is conveyed by new panel ID, the need to introduce such ID in specification is unclear. At least we see a panel active state should be supported for the case if UL panel(s) are not the same set of DL panel(s), as agreed in previous RAN1 meeting. Other information is not precluded.   **Proposal 4.1**: On Rel.17 enhancements to facilitate UE-initiated panel activation and selection, at least one panel entity is referring to a new panel ID within a CSI/beam reporting instance   * The new panel ID(s) within CSI/beam reporting instance is determined by the UE and reported to NW   + FFS: Details for reporting the new panel ID(s) within a CSI/beam reporting instance * The new panel ID(s) is used to convey at least the following information:   + A panel active state either DL reception only or both DL reception and UL transmission   + Other information is not precluded * FFS: Detailed design of the new panel ID * Note: The association between the new panel ID and the panel entity is determined by the UE   P4.2: Support |
| OPPO | Proposal 4.1: do not support. We do not see the need for specification support  Proposal 4.2: we support to configure two SRS resource set with different number of antenna ports for CB. Suggest to change the proposal as follows:  **Proposal 4.2**: Support configuring a UE with two SRS resource sets having different numbers of ports for codebook-based UL transmission |
| ZTE | Proposal 4.1 Support. We think that we need to make final decision this meeting, otherwise to be honest, we do not think that we can have sufficient time budget/meetings for complete this issue 4 MPUE.  Proposal 4.2: OPPO’s update is better in our views, and we also support to extend this issue to NCB case, e.g., two SRS resource sets that may have same or different numbers of SRS resources. |
| LG | Support Proposal 4.1 and 4.2  On Proposal 4.1, prerequisite for this proposal would be a UE report regarding the number of DL/UL panel entities accompanied by their properties. Essential information for gNB would be whether reported CRI/SSBRI is measured from DL only panel or from DL/UL shared panel. If it is from DL only panel, gNB can use the CRI/SSBRI as DCI TCI but not for UL TCI, otherwise it can use it for both DL TCI and UL TCI. Thus, it would be good to add ‘UE capability report on panel-specific information is supported including at least supported number of DL/UL panel IDs’ as a subbullet.  On Proposal 4.2, detailed signaling can be discussed later (e.g. different number of ports within a same resource set as Nokia or across different resource sets as OPPO). |

### Issue 5 (MPE mitigation)

Table 9 Summary: issue 5

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| **#** | **Issue** | **Companies’ views** |
| 5.1 | Whether to support:   * Opt 1A. {Rel.16 P-MPR based (beam/panel-level)} + Virtual PHR or a modified version   + The modified version may be associated with each activated UL TCI or, if applicable, joint TCI, or associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured) from candidate pool, if reported.   + The reporting reuses the event-driven mechanisms from the Rel-16 P-MPR reporting * Opt 1D. {Rel.16 P-MPR based (beam/panel-level)}   + The reporting reuses the event-driven mechanisms from the Rel-16 P-MPR reporting * Opt 2A. {SSBRI(s)/CRI(s) and/or panel indication} + 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: Whether the reporting is UE-initiated (event-driven) and/or NW-initiated   + FFS: If Opt2A is selected and there is no consensus on a modified L1-RSRP definition, at least the Rel-15 L1-RSRP definition is reused and virtual PHR may be added | **Option 1A**: ZTE, Lenovo/MoM, Apple, OPPO (via MAC CE), Qualcomm, Nokia/NSB, MTK, Convida, NTT Docomo  **Option 1D**: vivo (add panel ID in PHR MAC CE), Spreadtrum, Huawei/HiSi, Sony, Xiaomi  **Option 2A**: CATT, Apple, Sony, Lenovo/MoM, CMCC, Samsung, Qualcomm, Nokia/NSB, MTK, NTT Docomo, LGE, Ericsson |
| 5.2 | If Opt1A/D in 5.1 is supported:   * Alt1. Beam-level reporting * Alt2. Panel-level reporting | **Alt1**: Qualcomm, Nokia/NSB, Convida, MTK, Intel, ZTE(1st preference)  **Alt2**: vivo, Spreadtrum, Huawei/HiSi, Xiaomi, Sony, NTT Docomo, ZTE(2nd preference) |
| 5.3 | If Opt2A 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**: CATT, Nokia/NSB, Intel, ZTE  **Alt2**: Lenovo/MoM, Samsung, LG |
|  |  |  |

The following observation can be made:

* (5.1) Opt2A represents the majority view, followed by Opt1A

Based on the above observation, the following proposal can be made:

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

* Opt1A. {Rel.16 P-MPR based (beam/panel-level)} + Virtual PHR or a modified version
  + The modified version may be associated with each activated UL TCI or, if applicable, joint TCI, or associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured) from candidate pool, if reported.
  + The reporting reuses the event-driven mechanisms from the Rel-16 P-MPR reporting
* Opt2A. {SSBRI(s)/CRI(s) and/or panel indication} + 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: Whether the reporting is UE-initiated (event-driven) and/or NW-initiated
  + FFS: If Opt2A is selected and there is no consensus on a modified L1-RSRP definition, at least the Rel-15 L1-RSRP definition is reused and virtual PHR may be added

Table 10 Additional inputs: issue 5

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 10**  **2) Share your inputs on the above FL proposals** |
| MediaTek | Support in principle. But prefer to support Opt2A as NW-initiated since event-driven mechanism is already supported by Opt1A, and Opt2A can be an enhanced beam reporting format. We don't see the need to introduce two schemes with the same reporting types. |
| Nokia/NSB | Support in principle |
| Qualcomm | Support as a starting point |
| Apple | Support |
| Samsung | Support as a compromise |
| OPPO | Ok in principle. Suggest to remove the wording “beam” and “panel” because in the spec, we eventually use the RS ID or TCI state for those reports and there will be no beam or panel in the spec.  **Proposal 5.1**: On Rel.17 enhancements to facilitate MPE mitigation, support the following schemes:   * Opt1A. {Rel.16 P-MPR based ~~(beam/panel-level)~~} + Virtual PHR or a modified version   + The modified version may be associated with each activated UL TCI or, if applicable, joint TCI, or associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured) from candidate pool, if reported.   + The reporting reuses the event-driven mechanisms from the Rel-16 P-MPR reporting * Opt2A. {SSBRI(s)/CRI(s) ~~and/or panel indication~~} + 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: Whether the reporting is UE-initiated (event-driven) and/or NW-initiated   + FFS: If Opt2A is selected and there is no consensus on a modified L1-RSRP definition, at least the Rel-15 L1-RSRP definition is reused and virtual PHR may be added |
| ZTE | Support as a compromise.  Just to clarify our preference: if Alt-2 is supported, we think that it should be NW-initialized and be performed based on Rel-15 L1-RSRP + virtual PHR rather than a modified definition. |
| LG | Support as a starting point |

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

Table 11 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   * Opt 1-1A: Beam measurement/reporting/refinement/selection triggered by beam indication (without CSI request) * Opt 1-1B: UE-initiated beam selection/activation based on beam measurement and/or reporting (without beam indication or activation from NW) * Opt 1-2: Semi-static NW-configured beam selection (without beam indication and measurement/reporting) * Opt 1-3: SSB grouping to reduce beam training * Opt 1-4: Aperiodic beam measurement/reporting based on multiple resource sets for reducing beam measurement latency | **Opt 1-1A**: IDC, Nokia/NSB (refinement), Samsung (refinement, M/R)  **Opt 1-1B**: IDC (with beam group indication), Nokia/NSB, Futurewei, Ericsson, OPPO, MTK, LG  **Opt 1-2**: NTT Docomo  **Opt 1-3**: Apple, Ericsson  **Opt 1-4**: Nokia/NSB (BFR), ZTE, Samsung |
| 6.2 | Group 2: Reducing activation delay of TCI states and PL-RSs (including other WGs, e.g. RAN4)   * Opt 2-1A: Latency reduction for MAC CE based TCI state activation, or frequency/time/beam tracking * Opt 2-1B: Latency reduction for MAC CE based PL-RS activation * Opt 2-1C: Latency reduction for MAC CE based PUCCH resource/resource group activation * Opt 2-2: Direct SCell TCI state activation * Opt 2-3: Replacing RRC-based with MAC CE (or DCI) based for DL QCL or UL information update * Opt 2-4: One-shot timing update for TCI state update   Note: A number of companies argued that most of the schemes in this category can be handled exclusively in RAN4 | **Opt 2-1A**: vivo (A-TRS), Ericsson, ZTE, Apple (AP CSI-RS triggering via MAC CE/DCI), NTT Docomo  **Opt 2-1B**: vivo, ZTE  **Opt 2-1C**: vivo   * Other views: Ericsson (under issue 1)   **Opt 2-2**: Qualcomm   * Other views: Ericsson (out of scope, CA AI)   **Opt 2-3**: IDC, Lenovo/MoM (associated CSI-RS for SRS resource for NCB)   * Other views: Ericsson (unclear target)   **Opt 2-4**: Ericsson |

The following observation can be made:

* (6.1, 6.2) Opt1-1B and Opt 2-1A represent the majority views for Group 1 and 2, respectively. Note that the agreement says “strive for at most one per group”

Based on the above observation, the following proposal can be made:

**Proposal 6.1**: On Rel.17 enhancements to facilitate advanced beam refinement/tracking, focus study and, if needed, specification effort on the following options:

* Group 1: UE-initiated beam selection/activation based on beam measurement and/or reporting (without beam indication or activation from NW)
* Group 2: Latency reduction for MAC CE based TCI state activation, or frequency/time/beam tracking

Table 12 Additional inputs: issue 6

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 12**  **2) Share your inputs on the above FL proposals** |
| MediaTek | Support the proposal  For G1, we see UE-initiated beam selection/activation could be one alternative to reduce the beam activation latency. Based on beam measurements, UE can select one (i.e., beam selection) or more (i.e., beam activation) TCI states as active and reports it/them to NW. Since the TCI state(s) is selected/activated by UE, UE is responsible to remember the QCL properties of DL RS(s) associated with the selected/activated TCI state(s). Thus, the one SSB measurement for beam activation is not needed anymore. Once NW response to the report is received by UE, the selected/activated TCI states can be immediately used for DL reception (or UL transmission in unified TCI framework). |
| Qualcomm | Support |
| Apple | Support in principle. One quick question for clarification, for group 1, is it correct understanding that PRACH like beam report is not precluded? |
| Samsung | Not support   * FL proposal for Group 1 is too premature since we haven’t even listed the pros and cons of each scheme. In fact, the benefit of opt 1-1B over beam indication based scheme is unclear. Without gNB confirmation we have misalignment, and with gNB confirmation there is no latency/overhead saving from beam indication based beam selection (at the expense of more spec impact). * For group 2, Samsung believes this is something to be discussed in RAN4, not in RAN1. So the second bullet from FL proposal is not needed and should be removed. |
| ZTE | We support second bullet (Group-2), but not for first bullet (Group-1).  In our views, the FL proposal for Group 1 should be well justified firstly due to that, from gNB perspective, we can NOT live with a solution of totally up to UE reporting without any gNB confirmation that seems to reverts the basic assumption for UE-initialized behavior, e.g., for BFR, in 3GPP 5G-NR. If with gNB confirmation, we are wondering the benefits compared with the normal procedure of beam indication/activation and reporting. |
| LG | Support |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | R1-2105296 | Moderator summary for offline discussion on multi-beam enhancement: CA QCL and unified TCI for 'other signals/channels' | Moderator (Samsung) |
| 2 | R1-2104205 | Enhancement on multi-beam operation | FUTUREWEI |
| 3 | R1-2104266 | Enhancements on multi-beam operation | Huawei, HiSilicon |
| 4 | R1-2104292 | Remaining Issues on Rel-17 Multi-beam Operation | InterDigital, Inc. |
| 5 | R1-2104343 | Further discussion on multi beam enhancement | vivo |
| 6 | R1-2104404 | Enhancements on Multi-beam Operation | Lenovo, Motorola Mobility |
| 7 | R1-2104411 | Enhancements on Multi-beam Operation | Spreadtrum Communications |
| 8 | R1-2104484 | Enhancements on multi-beam operation | CATT |
| 9 | R1-2104585 | Enhancements on Multi-beam Operation | ZTE |
| 10 | R1-2104599 | Enhancements on multi-beam operation | CMCC |
| 11 | R1-2104654 | Enhancements on Multi-beam Operation | Qualcomm Incorporated |
| 12 | R1-2104732 | Enhancements on Multi-beam Operation | OPPO |
| 13 | R1-2104888 | Enhancements to Multi-Beam Operations | Intel Corporation |
| 14 | R1-2105058 | Enhancements on Multi-beam Operation | Fujitsu |
| 15 | R1-2105087 | Views on Rel-17 Beam Management enhancement | Apple |
| 16 | R1-2105151 | Further enhancement on multi-beam operation | Sony |
| 17 | R1-2105231 | Enhancements on multi-beam operation | Fraunhofer IIS, Fraunhofer HHI |
| 18 | R1-2105246 | Discussion on multi-beam operation | NEC |
| 19 | R1-2105273 | Enhancements on Multi-beam Operation | Nokia, Nokia Shanghai Bell |
| 20 | R1-2105291 | Multi-Beam Enhancements | Samsung |
| 21 | R1-2105353 | Enhancement on multi-beam operation | MediaTek Inc. |
| 22 | R1-2105540 | Enhancements on multi-beam operation | Xiaomi |
| 23 | R1-2105588 | Enhancements on Multi-beam Operation | Convida Wireless |
| 24 | R1-2105665 | Enhancements on Multi-Beam Operations | AT&T |
| 25 | R1-2105683 | Discussion on multi-beam operation | NTT DOCOMO, INC. |
| 26 | R1-2105779 | Enhancements on Multi-beam Operation | LG Electronics |
| 27 | R1-2105816 | Discussion on enhancements for Multi-beam Operation | Asia Pacific Telecom, FGI |
| 28 | R1-2105828 | Enhancements on Multi-beam Operation | Ericsson |
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