**3GPP TSG RAN WG1 #104-e R1-210xxxx**

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

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

**Title:** Moderator summary#5 for multi-beam enhancement: Round 3

**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 |

## Summary and proposals

The summary and proposals are based on the content of the previous FL summaries R1-2101185 (preparation) and R1-2101856 (round 1).

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

Table 1 Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.11 | TCI State pool for CA  Alt1: Shared among CCs  Alt2: Individually configured per CC | **Alt1 (14)**: Spreadtrum, Xiaomi, ZTE, vivo, MTK, Intel, Sony, NTT Docomo, Samsung, Qualcomm, Lenovo/MoM, Ericsson (UL TCI), IDC  **Alt2 (12)**: OPPO, Nokia/NSB, CMCC, Huawei/HiSi, CATT, APT, TCL, Ericsson (DL TCI), Futurewei, LG  **QCL Type-A implicitly determined based on CC:** Intel, Samsung, MTK, CATT, ZTE |
| 1.12 | For separate TCI, UL TCI state pool  Alt1: Shared pool with joint/DL TCI state  Alt2: Separate pool | **Alt1 (12)**: Spreadtrum, Xiaomi, ZTE, CATT, vivo, MTK, Intel, Convida, Qualcomm, Samsung, CATT, NTT Docomo  **Alt2 (15)**: Futurewei, OPPO, Lenovo/MoM, Nokia/NSB, CMCC, Ericsson, Huawei/HiSi, AT&T, Sony, Lenovo/MoM, APT |

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| Previous agreements:   * 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 |

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| Action: Please answer the questions below.   1. TCI state pool for CA (for common signaling of TCI state ID across CCs):    1. Since QCL Type-A reference must be CC-specific (unlike QCL Type-D), Alt1 can work only if QCL Type-A reference can be inferred via other means, e.g. “implicitly determined based on CC” (there might be other means). Could Alt1 proponents explain how QCL Type-A reference be obtained?    2. For UL TX spatial reference, is there any advantage of Alt2 over Alt1 (since Alt1 seems a natural choice)? 2. TCI state pool for separate DL/UL TCI: Considering the supported source RS types for joint TCI are a subset of those for UL-only TCI (since joint TCI applies to both DL and UL),    1. How would Alt1 overcome this limitation (otherwise the choice of UL TCI source RS types for Alt1 would be limited to that of joint TCI)?    2. Is there any advantage of Alt1 over Alt2 that justifies the potential drawback in 2a?   Goal: Finalize the proposal to be ready for endorsement |

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

Table 2 Inputs: issue 1

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| **Company** | **Input** |
| Moderator | Please provide inputs for the questions |
| Apple | 1a: It is true that there could be a problem for QCL-TypeA for Alt1.  1b: It seems not. I am not sure whether power control could be a problem.  2a: Indeed, some rules need to be defined for Alt1, like TCI selection for CORESET0, where only the first 64 valid TCI states can be indicated  2b: I guess the potential advantage could be RRC overhead reduction. gNB does not need to configure the same RSs in different TCI states. |
| CATT | 1a: Agree that QCL-typeA RS derivation may need to be addressed for alt-1.  1b: It is preferable the CA framework is band-agnostic at least from RAN1 perspective. For (future potential) inter-band application, common pool may mandate the same QCL-typeD RS (assuming same TCI-ID) for each CC and same DL/UL spatial filter for CCs in different bands, thereby limiting its use case. Alt-2 avoids this issue.  2a:  2b: Unclear. We don’t think RRC overhead is a major optimization area. |
| APT | 1a. indeed, how to derive QCL-typeA for Alt1 is unclear to us.  1b.  2a. it is not clear if Alt-1 can be applied for separate DL/UL case.  2b. similar to CATT, we don’t think RRC overhead is an issue here. |
| ZTE | 1a: The straight-forward solution for deriving QCL Type A RS is: when a CC ID for QCL-Type A RS can be absent in a TCI state in a reference cell, the CC ID for QCL-Type A RS is determined according to a target CC of the TCI state.   * In our opinion, this way of “applying the same QCL Type-A RS ID to the CCs in the same CC group” in Alt-1 seems to be similar to “applying the same activated TCI state ID to the CCs in the same CC group” in Alt-2. The only enhancement of Alt-1 over Alt-2 is to change the level/requirement of same ID from TCI state to QCL Type-A RS resource, and huge RRC overhead can be saved accordingly.   1b: It seems not. If going with Alt-2, the rule of PL RS determination should be considered to satisfy the rule of up to 4 PL RS(s) for a UE.  2a: Introducing SRS for BM into TCI state is a natural solution for handling this limitation. Alternatively, we can further support to have association signalling between TCI state and SRS. When is applied, the SRS is used for determining spatial filter of UL transmission, and herein we can have a condition that the SRS should share the same spatial domain filter as QCL-TypeD RS in the TCI state, if any.  2b: RRC overhead can be saved significantly, especially considering cross-CC case as mentioned in 1a and 1b. |
| LG | 1a: agree that this is the problem of Alt1  1b: UL TCI can include other than beam RS such that power/timing control related in this or later releases. So, Alt2 is more futureproof design. |
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### Issue 2 (L1/L2-centric inter-cell mobility)

Table 3 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.5 | Source RS type(s) applicable for L1/L2-centric inter-cell mobility  Note: currently there is no agreement on supported source RS type(s) for L1/L2-centric inter-cell mobility | SSB:   * **Yes**: * **No**:   CSI-RS for mobility:   * **Yes**: Lenovo/MoM, Huawei/HiSi, LGE, Sony. CATT, ZTE * **No**: Samsung, Qualcomm, Intel, MTK, Apple, OPPO, Nokia/NSB, Futurewei   CSI-RS for tracking:   * **Yes**: Samsung, ZTE, Futurewei, Huawei/HiSi * **No**: Qualcomm, Intel, MTK, OPPO, Nokia/NSB   CSI-RS for BM:   * **Yes**: Futurewei * **No**: |

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| Previous agreement (RAN1#103-e)   * 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   + … |

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| Action: Interested companies are encouraged to share their views on the following questions:   1. Supporting beam indication (TCI state update along with the necessary TCI state activation) for TCI(s) associated with non-serving cell RS(s) – yes or no? 2. If #1 is affirmative, what type(s) of source RS shall be supported for providing:    1. QCL information for UE-dedicated PDSCH/PDCCH reception?    2. UL TX spatial filter information for PUSCH/PUCCH?   Goal: Finalize the proposal to be ready for endorsement |

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

Table 4 Inputs: issue 2

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| **Company** | **Input** |
| Moderator | Please provide answers to the questions |
| Apple | Q1: Yes  Q2a/Q2b: all RSs based on legacy QCL rule can be allowed |
| CATT | Q1: Yes  Q2: all RS allowed in legacy QCL provision (unless there is good reason for their exclusion) |
| APT | Q1: yes  Q2: all RS allowed in legacy QCL provision. The RSs should have QCL source configured, except for SSB. |
| ZTE | Q1: Not sure. Currently we only agree that SSB can be used for non-serving cell measurement. But, since according to legacy QCL rule, SSB can NOT be applied to PDCCH/PDSCH reception, we need to consider whether CSI-RS for tracking/CSI as QCL Type-A can be from non-serving cell or serving cell firstly.   |  | | --- | | For the DM-RS of PDCCH, the UE shall expect that a TCI-State indicates one of the following quasi co-location type(s):  - 'QCL-TypeA' with a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured with higher layer parameter trs-Info and, when applicable, 'QCL-TypeD' with the same CSI-RS resource, or  - 'QCL-TypeA' with a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured with higher layer parameter trs-Info and, when applicable, 'QCL-TypeD' with a CSI-RS resource in an NZP-CSI-RS-ResourceSet configured with higher layer parameter repetition, or  - 'QCL-TypeA' with a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured without higher layer parameter trs-Info and without higher layer parameter repetition and, when applicable, 'QCL-TypeD' with the same CSI-RS resource. |   Q2: CSI-RS for BM without QCL assumption, CSI-RS for CSI and CSI-RS for tracking can be supported. |
| LG | Q1: Yes  Q2: Type of source RSs can be same as Rel-15/16 for PDSCH/PDCCH/PUCCH/PUSCH. Only change would be to allow NSC SSB or mobility CSI-RS as top QCL source. |
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### Issue 3 (beam indication signaling medium)

Table 5 Summary: issue 3

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| **#** | **Issue** | **Companies’ views** | **Moderator notes** |
| 3.1 | Beam application time definition:  Alt1: Measured from DCI reception  Alt2: Measured from ACK transmission | **Alt1 (DCI) (7):** Spreadtrum, Xiaomi, Ericsson, CATT, MTK, NEC, Samsung  **Alt2 (ACK) (17):** IDC, Lenovo/MoM, Fujitsu, Nokia/NSB, CMCC, Apple, Huawei/HiSi, ZTE, vivo, Intel, Sony, Qualcomm, NTT Docomo, APT  **Alt1 and Alt 2:** OPPO (Since Alt1 considers the requirement of UE and Alt2 considers the requirement of gNB side), LG (Alt1 for DL assignment/PDSCH of the DCI, Alt2 else) | |

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| Previous agreement (RAN1#103-e):  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) |

From round-2B discussion, the following proposal for refining Alt1 was made (Qualcomm, Spreadtrum: reworded from UE perspective):

* 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
  + The UE may assume that the (gNB-)configured application time is after the acknowledgement.

Some companies also commented that the decision on beam application time (BAT) should be dependent on the decision whether an additional DCI format for beam indication is supported or not.

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| **Proposal 3.1**: On Rel.17 DCI-based beam indication, regarding application time of the beam indication: if beam indication is received, down-select (no later than RAN1#105-e) from the following:   * Alt1A: the first slot that is at least X ms or Y symbols after the DCI with the joint or separate DL/UL beam indication * Alt1B: the first slot that is at least X ms or Y symbols after the DCI with the joint or separate DL/UL beam indication   + In addition, the UE may assume that the (gNB-)configured application time is after the acknowledgement * 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) |

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| Action: Interested companies are encouraged to provide their inputs on the proposal.  Goal: Finalize the proposal for endorsement |

Table 6 Inputs: issue 3

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| **Company** | **Input** |
| Moderator | Proposal 3.1 is essentially the previous agreement with Alt1B added and a deadline for decision. The new part is highlighted in blue |
| Apple | For both Alt1B and Alt2, we suggest to change “acknowledgement” into “last symbol of the acknowledgement”. |
| APT | We wonder if Alt1A is still needed since it does not address the concern of mis-alignment issue between gNB and UE on the beam to be used. We suggest to remove Alt1A to avoid similar argument in next meetings. |
| ZTE | Alt2 is supported.  In our views, the Alt 1B is similar to Alt 2 in general, but we do not want to have a complicate timeline for gNB implementation. |
| LG | First of all, as commented/questioned multiple times, there is no strong need to define a unified BAT for different DL/UL channels because UE cannot receive or transmit them simultaneously anyway. More importantly, the TCI in a DCI should be able to apply to the scheduled PDSCH by the DCI as Rel-15/16 (**same behavior as when TCI is present in DCI**). So, we have strong concern on Alt1B and Alt2 because it precludes the use of indicated TCI for the scheduled PDSCH. If we’d like to go with Alt2, the scheduled PDSCH should be an exception as in Rel-15/16. |
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### Issue 4 (MP-UE)

Table 7 Summary: issue 4

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| **#** | **Issue** | **Companies’ views** | **Moderator notes** |
| 4.1 | Entity pertaining to an UL panel for the purpose of UE-initiated panel selection (of one) and activation (of ≥1)  Note: support for UE-initiated panel selection/activation was agreed (but spec support is still FFS – see 4.2) | Alternatives:   * Newly defined panel ID(s): Lenovo/MoM (study), LGE, Xiaomi, NTT Docomo, Qualcomm, Spreadtrum, ZTE, Huawei/HiSi (virtual concept without mandating physical UE panel implementation), IDC, APT, CMCC   + Not needed: AT&T, CATT, Ericsson, OPPO, Nokia/NSB * SSBRI(s)/CRI(s) or CSI-RS resource set ID(s): IDC, Samsung, MTK(SSBRI(s)/CRI(s)), Xiaomi, CATT * SRI(s) or SRS resource set ID(s): vivo, Qualcomm, Xiaomi, Sony (SRS resource set ID(s)), Fraunhofer IIS/HHI, Huawei/HiSi, APT * Antenna port group: Apple, Qualcomm, Nokia/NSB | |

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| Previous agreement (RAN1#102-e):   * The following assumptions are used:   1. 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) |

Regardless of whether a newly defined panel ID is needed or not, (from the above summary) there are two main categories on what constitutes a panel:

* A group of antenna ports
* A group of RS resources (abstraction of “analog beam”)
  + For beam indication, the RS is a measurement RS
  + For CSI/beam reporting, the RS is a source RS for UL TX spatial filter information

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| Action: Interested companies are encouraged to provide their inputs on the following alternatives:   * Alt1. A panel entity corresponds to a group of antenna ports * Alt2. A panel entity corresponds to a group RS resources   + For beam indication, the RS is a measurement RS   + For CSI/beam reporting, the RS is a source RS for UL TX spatial filter information   Goal: Finalize the proposal to be ready for endorsement |

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| **Proposal 4.1**: On Rel.17 enhancement for facilitating fast uplink panel selection,   * … |

Table 8 Inputs: issue 4

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| **Company** | **Input** |
| Moderator | Please provide answers to the question |
| Apple | Support Alt1 |
| APT | Prefer Alt2 |
| ZTE | Support Alt2. Also we can support a new ID for panel/UE antenna group. |
| LG | Conceptually, each panel can represent either or both a group of antennas(alt1) or a group of beams(alt2).  From specification point of view, Alt1 would work only for PUSCH to our understanding while Alt2 would work for PUCCH, PRACH, and SRS.  For PUSCH, it is true that a group of antenna ports can be mapped to a panel in Rel-15/16, e.g. for non/partial-coherent CB based PUSCH transmission and for 2 port PTRS transmission.  Meanwhile, for PUCCH and SRS, a group of resources can be mapped to a panel in Rel-15/16, e.g. for BM SRS resource set transmission and for PUCCH resource group based simultaneous spatial relation update.  In summary, it is our understanding that Alt1 is for PUSCH and Alt2 is for PUCCH, SRS, PRACH from target RS/channel perspective.  If Alt1 vs Alt2 is intended to define granularity of the reference RS, not the target RS/channel. We think Alt2 fits better because a group of SRS, CSI-RS, or SSB resources can be a source RS for panel indication rather than a group of antenna ports of each SRS resource and/or a group of antenna ports of each CSI-RS resource. Only exception may be the SRS for CB based PUSCH transmission where a subset of SRS antenna ports can represent each panel, e.g. for non/partial-coherent CB based PUSCH transmission.  Overall, this would be one of the reasons that introduction of a new ID for panel is a clean solution because it is now very complicated and ambiguous on how each panel can be mapped to each resource or antenna ports in current specification. |
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### Issue 5 (MPE mitigation)

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| Latest version of proposal 5.1 (FL):  **Proposal 5.1**: On Rel.17 enhancements to facilitate MPE mitigation:   * Decide in RAN1#104bis-e whether the following combinations should be further studied (not necessarily, but can be, in one reporting instance):   + {Rel.16 P-MPR based (beam/panel-level)} + {A}, where A is either Opt 2 or Opt3 or Opt4   + {SSBRI(s)/CRI(s) and/or panel indication} + {A}, where A is either Opt1 or Opt2 or both (Opt1 and Opt2) or Opt4 * Option 1: L1-RSRP [L1-SINR] associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)   + FFS: How panel-level L1-RSRP [L1-SINR] is calculated if L1-RSRP [L1-SINR] is associated with panel   + FFS: Whether/how to include MPE effect in L1-RSRP [L1-SINR], e.g. by using scaled or modified L1-RSRP [L1-SINR]   + FFS: Whether/how to enhance existing beam reporting format to support Option 1 * Option 2: Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured) * Option 3: Virtual PHR or a modified version associated with each activated UL TCI or, if applicable, joint TCI * Option 4: No additional report   Intel’s version of proposal 5.1:  **Proposal 5.1**: On Rel.17 enhancements to facilitate MPE mitigation:   * Decide in RAN1#104bis-e whether the following ~~combinations~~ should be further studied (not necessarily, but can be, in one reporting instance):   + {Rel.16 P-MPR based (beam/panel-level)} + {A}, where A is either Opt1A, Opt1B, or Opt1C:     - Option 1A: Virtual PHR or a modified version associated with each activated UL TCI or, if applicable, joint TCI     - Option 1B: {SSBRI(s)/CRI(s) and/or panel indication}     - Option 1C: No additional reporting quantity   + {SSBRI(s)/CRI(s) and/or panel indication} + {A}, where A is either Opt2A, Opt2B, Opt2A+ Opt2B, or Option 2C     - Option 2A: L1-RSRP [L1-SINR] associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)       * FFS: How panel-level L1-RSRP [L1-SINR] is calculated if L1-RSRP [L1-SINR] is associated with panel       * FFS: Whether/how to include MPE effect in L1-RSRP [L1-SINR], e.g. by using scaled or modified L1-RSRP [L1-SINR]       * FFS: Whether/how to enhance existing beam reporting format to support Option 1     - Option 2B: Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)     - Option 2C: No additional reporting quantity |

Intel’s version disseminates each reporting format more clearly. We will use that as a starting point for this round and refine it while being mindful of the latest FL version (in terms of content):

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| **Proposal 5.1**: On Rel.17 enhancements to facilitate MPE mitigation, decide in RAN1#104bis-e whether the following should be further studied (not necessarily, but can be, in one reporting instance):   * {Rel.16 P-MPR based (beam/panel-level)} + {A}, where A is either Opt1A, Opt1B, or Opt1C:   + Option 1A: Virtual PHR or a modified version associated with each activated UL TCI or, if applicable, joint TCI   + Option 1B: {SSBRI(s)/CRI(s) and/or panel indication}   + Option 1C: No additional reporting quantity * {SSBRI(s)/CRI(s) and/or panel indication} + {A}, where A is either Opt2A, Opt2B, Opt2A+ Opt2B, or Option 2C   + Option 2A: L1-RSRP [L1-SINR] associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)     - FFS: How panel-level L1-RSRP [L1-SINR] is calculated if L1-RSRP [L1-SINR] is associated with panel     - FFS: Whether/how to include MPE effect in L1-RSRP [L1-SINR], e.g. by using scaled or modified L1-RSRP [L1-SINR]     - FFS: Whether/how to enhance existing beam reporting format to support Option 1   + Option 2B: Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)   + Option 2C: No additional reporting quantity |

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| Action: Interested companies are encouraged to provide their inputs on the proposal  Goal: Finalize the proposal to be ready for endorsement |

Table 9 Inputs: issue 5

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| **Company** | **Input** |
| Moderator | 5.1: Using the latest Intel’s version |
| Apple | Support 5.1 with the latest Intel’s version |
| ZTE | Firstly, we still prefer to go with original version that has been stable for a long period.  Then, if going with the new one, we think that   * Firstly, Option 1c and Option2c should be removed, considering that the main bullet is to study whether we need any additional report. * Then, Option 1B should be modified, like:   + Option 1B: {SSBRI(s)/CRI(s) and/or panel indication} + Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured) |
| LG | We support the proposal with Intel’s version |
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### Issue 6 (beam refinement/tracking)

This is the status after the second GTW (online) session 01/29/2021.

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| **Possible Agreement**  On Rel.17 enhancements based on the unified TCI framework, perform study and, if needed, specify the following:   * Beam management with reduced DL signaling to reduce latency * Reducing activation delay of TCI states and PL-RSs (including other WGs, e.g. RAN4)   + On RAN4-related matters, assessment/study phase can be done in RAN1. If RAN4-based enhancements are found necessary, a LS to RAN4 will be sent (to prepare RAN4 work)   Note: Given its dependence on the maturity of and lower priority compared to other issues (1 to 5), when to start the work and how much work is done on issue 6 should depend on the progress on the other issues.  **Objected by** Huawei/HiSi  **Support by** Futurewei (clarify 2nd bullet), MTK, Samsung, OPPO, Apple, Intel, NTT Docomo, Qualcomm (clarify 2nd bullet), Ericsson, IDC, Spreadtrum (after other issues progress enough), Xiaomi, Nokia/NSB (clarify 2nd bullet), Convida (after other issues progress enough), Lenovo/MoM, CATT, ZTE, NEC, Sony, Verizon Wireless, KT Corporation, KDDI |