**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. |
| MediaTek | Q1a: Support of Alt1 is natural since we already agree the following in the previous meeting:  Previous agreements:   * 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   NW usually configures different TCI states for different gNB beams, where each TCI state associates one or two source RSs transmitted from a same NW beam. For Alt2, when the TCI states with a same ID are configured for a set of CCs, QCL-TypeD source RS shall be the same on one of the CCs, which means TCI states with a same ID configured in the CCs are associated with a same NW beam.  For Alt1**, a CC ID for QCL-TypeA source RS can be absent in a TCI state of the TCI state pool and the CC ID for QCL-TypeA RS is determined according to the target CC.** If NW can properly allocate the RS IDs for QCL-TypeA source RS, it is possible that a single TCI state can include all the required source RSs from the CCs. Thus, Alt1 is a better choice to avoid unnecessary configuration overhead and required UE memory.  For UL PC, we don't think this will be an issue in Alt1.  Q1b: For UL, there is no QCl-TypeA RS issue. Thus, it natural to use Alt1.  Q2a: For Alt1, we don't think that the TCI states for joint DL/UL beam indication has to be a subset of those for UL-only beam indication. NW can configure a pool of TCI states for different gNB beams, and joint DL/UL beam indication and UL-only beam indication can use the same pool of TCI states. If a TCI state is indicated/activated/configured for joint DL/UL beam indication, then common QCL and UL spatial Tx filter can be determined according to the previous agreement. If a TCI state is indicated/activated/configured for UL-only beam indication, UL spatial Tx filter still can be determined from the RS of DL QCL Type D in the TCI state.  Q2b: Separate pools are not necessary since NW only has to configure a pool of TCI states each corresponds to a gNB beam. Alt2 will cause unnecessary configuration overhead and required UE memory.  **Possible proposal:**  On Rel.17 unified TCI framework, UL TCI of separate DL/UL TCI and joint DL/UL TCI share a same pool of TCI states   * For UL TCI of separate DL/UL TCI, UL spatial filter is derived from the RS of DL QCL Type D |
| TCL | 1b: Our view is similar to that of LG;  2b: For Alt 2, gNB may need to configure multiple TCI states, which would lead to latency and signaling overhead. |
| Xiaomi | 1a, share same view as ZTE and MTK  1b, no  2a, we don’t see the limitation here. We think TCI state in the joint TCI state pool is enough for separate UL-only TCI because of beam correspondence. Even with MPE impact, two different TCI states in joint TCI state pool can be indicated for separate DL TCI state and separate UL TCI state respectively.  2b, the advantage is the lower RRC signaling overhead with Alt 1. |
| Docomo | 1a: Firstly, we would like to clarify that QCL Type-D RS also must be CC-specific for some cases (As shown below, it says QCL Type-A RS and QCL Type-D RS should be the same resource). QCL Type-D RS can be CC common or CC specific. So, this question (and potential FL proposal) should also cover QCL type Type-D RS (if CC specific).  ----  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.  ----  The necessary information for the target cell is combination of RS index and cell index. We can assume the same RS index is applied for each CC for QCL type A RS (i.e. if unified TCI is TRS#2, TRS#2 of CC#1 is used for QCL type A on CC#1, and TRS#2 of CC#2 is used for QCL type A on CC#2, and so on). We don’t need to explicitly configure the CC index for type A. On the other hand, QCL type D RS can be CC common or CC specific. Hence, we should be able to configure CC index for QCL type D RS.  One example of RRC structure is:  Unified TCI state (common for CCs):{   * QCL type A RS index for each CC = {RS#1, RS#2, …, RS#64} * QCL type D RS index for each CC = {RS#1’, RS#2’, …, RS#64’} * Cell index of QCL type D RS = {target cell, CC#1, CC#2, …}   }  Following figure illustrates the example of following configuration:   * QCL type A RS index for each CC = RS#2 * QCL type D RS index for each CC = RS#2’ * Cell index of QCL type D RS = CC#1     1b: We think no. |
| Ericsson | 1a: We do not see a good solution to this. The solution that ZTE mentions is indeed similar to the cross-CC TCI state activation. That solution has the drawback that the configurations on the carriers need to be identical. For TCI states, this restriction can be handled, but for TRS, this would mean a tougher restriction.  1b: Can’t see any  2a: One solution would have been not to allow SRS for BM for UL TCI, but that would require reverting agreement  2b: No. The RRC overhead issue is complicated, and the design should be left to RAN2. |
| vivo | 1a: The QCL Type-A reference is implicitly determined based on target serving CC.  1b: there seems to be no advantage.  2a: Application of TCI state for UL may not necessarily to be applied for DL through configuration or implementation.  2b: save RRC overhead. |
| Sony | 1a: same view with ZTE/MTK that QCL-TypeA RS without CC index configured in TCI state can be a valid solution. Moreover this solution is depicted in Docomo’s figure.  1b: Alt.2 could be more flexible than Alt.1 with per CC configured TCI state pool which comes at the cost of large signaling overhead. If PC and/or TA parameters are included in TCI states (pending issue), but not associated with TCI state, Alt.2 may result in more proper UL power control and/or time advancing.  2a:  2b: |
| Fraunhofer IIS/HHI | 2a: This is one issue that may leave Alt-1 with more spec impact than Alt-2. Specific procedures to classify UL and DL TCI states and its impact on existing TCI state based procedures are a concern. Although there are merits to both Alt-1 and 2, due to such issues we slightly prefer Alt-2 over Alt-1. |
| Nokia | 1a: We agree that Alt1 needs further clarification on how to configure QCL type-A  1b: Sharing similar view with CATT. Same TCI across multiple/all CCs would not be valid always. So we expect Alt 2 is more general approach.  2a:  2b: We don’t see clear benefits. But may less overhead on RRC configuration can be achieved. |
| Samsung | 1a: Indeed, QCL Type-A must be CC specific. As described by several companies, the cell index for QCL Type-A can be absent from the TCI state, and inferred by the target cell. QCL-Info for QCL Type-D can include a cell index to identified the cell of the source RS.  1b: For UL Tx spatial reference, it would seem natural to have the same beam applied to a group of cells. This saves RRC configuration overhead – this is advantage of Alt1 over Alt2.  2a: The norm for beam indication is to have the same beam for DL and UL, i.e. joint beam indication. Separate beam indication is for handling special cases, which we believe are not frequent. Given this view, we don’t think that it is prudent to over design the system for the special case especially when there is downside associated with this overdesign (see answer to 2b). If we allow an UL TCI state for separate DL/UL beam indication to have a different source RS type there should be justification for that. We would like the proponents of a separate UL TCI state pool for the separate DL/UL beam indication to state the justification of having a separate source RS type.  2b: Alt1 has less RRC overhead over Alt2. Alt1 can potentially simplify the UE implementation as the same source RS Type is used for separate and joint beam indication. |
| OPPO | 1a: That is the reason why we prefer Alt2.  1b: we do not see benefit of Alt1. Alt2 is a more general method and it does not need changing the TCI state framework.  2a/2b: Using common pool for separate DL and UL TCI state would increase the high layer signalling overhead in some aspect. |

### 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. |
| MediaTek | Q1: Yes  Q2a/Q2b: all RSs based on legacy QCL rule can be allowed. Necessary extension can be considered, especially for TypeA/C QCL. |
| TCL | Q1: Yes  Q2: All RSs are allowed, but the priority of these RSs needs further discussion. |
| Xiaomi | Q1: Yes  Q2: when CSI-RS configured as a source RS, is it necessary to let UE know the CSI-RS refer to serving cell or non-serving cell? |
| Docomo | Q1: Yes  Q2a: all RSs based on legacy QCL rule can be allowed  Q2b: it would be ok as long as QCLtype D is supported, to determine UL spatial domain filter. |
| Ericsson | Q1: Yes  Q2: all RS allowed for the legacy QCL provision. For DL QCL, these rules have been confirmed for unified TCI as well.  To progress the discussion, perhaps we can start from this proposal:  Support the following TCI state update (beam indication) mechanism based on the Rel.17 unified TCI framework:   * Support the use of non-serving SSB at least as an indirect QCL assumption for reception of PDCCH /PDSCH * Support the use of SSB (s) of non-serving cell(s) for determining common UL TX spatial filter for transmission of PUCCH /PUSCH * Note: an SSB is an indirect QCL source of PDCCH /PDSCH if the SSB is the QCL source of a CSI -RS that is the QCL source of the PDCCH /PDSCH DMRS |
| vivo | Q1: Positive, but restrictions may be put on cases where such beam indication would need more discussion. For example whether such beam indication for all channels;  Q2: We don’t see necessity to change compared to already agreed ones for the serving cell RS. |
| Sony | Q1: Yes  Q2a/Q2b: CSI-RS for mobility along with SSB can be used as source RS of QCL/spatial relation for DL reception and UL transmission |
| Nokia | Q1: Yes  Q2: We do not think RAN1 agreed to support PDSCH/PUSCH or PUCCH from/toward non-serving cell yet. And we consider SSB as the only QCL source for non-serving cell. |
| Samsung | Q1: Yes, based on the Rel-17 beam indication scheme for serving cell.  Q2: In the context of the unified TCI state framework, the baseline should be that the same source RS types agree for serving should be supported for non-serving cell. There is no clear motivation to add or remove source RS types. This applies to QCL Type-D for DL channels as well as UL TX spatial filter for UL channels. It is too early to say that the SSB has to be an indirect source, as it is still open whether the SSB can be a source RS for the serving cell case. |
| OPPO | Q1: it is too early to discuss that now. We still have so many open issue on FFS on RRC and use case assumptions. The agreement made in RAN1#103e is copied here. Before we can align and conclude on those FFS point, we do not suggest to discuss the detailed design of beam indication of non-serving cell SSB. The conclusion on RRC/use case have critical impact on the design. Different conclusion would result in different designs.  Q2: we do not support to discuss Q1 before we can verify those FFS point.   |  | | --- | | **Agreement**  On Rel-17 enhancements to enable L1/L2-centric inter-cell mobility:   * The following use cases are assumed:   + Network architecture:     - NSA, i.e. LTE PCell and NR-PSCell     - SA   + Intra-band CA     - FFS: If inter-band CA is also included   + Intra- RAT (excluding inter-RAT)   + Intra-frequency scenario:     - The SSBs of non-serving cells have the same center frequency and SCS as the SSBs of the serving cell     - An SSB of a non-serving cell is associated with a PCI different from the PCI of the serving cell     - FFS: Support for inter-frequency scenario   + FFS: Whether to support intra-DU only operation, or whether inter-DU is also allowed * The following enhancement scope is assumed:   + Facilitating measurement and reporting of non-serving RSs via incorporating non-serving cell info with some TCI(s), along with the necessary measurement and reporting scheme(s)     - FFS: Detailed/exact method(s)     - FFS: Whether this also implies the support of beam indication (TCI state update along with the necessary TCI state activation) for TCI(s) associated with non-serving cell RS(s)     - FFS: Metric for the measurement and reporting, e.g. L1-RSRP or L3-RSRP or time- or spatial-domain-filtered L1-RSRP     - FFS: Beam-level event-driven mechanism, using serving cell RS and/or non-serving cell RS   + Facilitate serving cell to provide configurations for non-serving cell SSBs via RRC     - FFS: details for the configurations, e.g. time/frequency location, transmission power, etc.     - FFS: other information needed for inter-cell mobility   + Note: In RAN1's understanding, non-serving cell SSB and non-serving cell RS can be part of the serving cell configuration * FFS: The following enhancement scope is assumed by RAN1:   + Whether RRC reconfiguration signaling is needed or not when a TCI associated with non-serving cell RS is indicated     - A non-serving cell RS is an RS that is or has an SSB of a non-serving cell as direct or indirect QCL source     - This implies no C-RNTI update when UE receives DL channel RS associated to non-serving cell RS as QCL source.     - FFS whether TCI associated with non-serving cell can be indicated to or are applicable for all channels.   + Whether some RRC parameters need to be updated without additional RRC signaling, e.g. some RRC parameters are pre-configured, which are associated with TCI states with neighbor cell RS as QCL source   + Whether UE needs/can change serving cell during L1/L2-centric inter-cell mobility.   + The above assumption to be verified by RAN2 | |  | |

### Issue 3 (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. |
| MediaTek | For Alt1B, we don’t see the difference between Alt1B and Alt2, where the BAT is still after the acknowledgement. It is not a compromised solution between Alt1A and Alt2, right? We don't think it is helpful to add this alternative at this moment. |
| TCL | In our opinion, Alt 1A is still needed, and similar to ZTE, the Alt 1B is similar to Alt 2 in general. So, we support Alt1. |
| Xiaomi | For Alt 1B, in our understanding “the UE may assume that the (gNB-)configured application time is after the acknowledgement” does not preclude the case that gNB configured application time is before the acknowledgement. If my understanding is correct, can we change to “the UE may assume that the (gNB-)configured application time is after or before the acknowledgement”? And we can support Alt 1B if my understanding is correct. Else, we prefer Alt 1A.  We think the difference between Alt 1A and Alt 2 is the TCI state for PDSCH scheduled by the DCI and the HARQ ACK/NACK feedback. As noted by LG, the TCI state in a DCI can apply to the scheduled PDSCH in R15/16 and there is no misalignment between UE and gNB. Thus why not allow UE to apply the TCI state to the scheduled PDSCH before acknowledgement? |
| Docomo | Agree with Apple’s suggestion (But, in that case, it seems we need to change “DCI” into “last symbol of DCI”, because DCI may be on multiple symbols).  If we discuss BAT in next meeting, is it possible to add the following option?   * Alt2B: the first slot that is at least X ms or Y symbols after the acknowledgment of the joint or separate DL/UL beam indication, where the new beam is applied to the PDSCH (scheduled by the beam indication DCI) and corresponding HARQ transmission before updating the unified TCI state.   Our preference is Alt.2B (1st priority), and Alt. 2 (2nd priority). |
| Ericsson | We do not see the point of Alt1B, and we do not see the relation to other DCI format, so we would propose to make the decision already in RAN1#104-e.  As we stated before, if the NW wants to perform the beam switch before the ACK, that should be up to the NW: the NW would take all aspects into account, both regarding design complexity, speed and risk for beam misalignment. With a DCI format that is robust enough, that risk can be managed, in case a super-fast beam switch is required.  We were thinking about an Alt1C, which utilizes the already agreed UE capability:   * Alt1C: the first slot that is at least X ms or Y symbols after the DCI with the joint or separate DL/UL beam indication   + At least one of the candidate values of the UE capability implies that the beam switch happens after the acknowledgement   With Alt1C, there is a guarantee that the UE is not forced to perform a beam switch before the ACK – the UE would simply advertise a capability that is large enough. |
| vivo | Support Alt2. |
| Sony | We share the same observation from FL that the beam applicable timing also depends on the pending DCI format (e.g. UL DCI or new dedicated DCI) for conveying TCI. So it’s okay to decide the BAT when DCI formats are finalized as predicated in RAN1#105e.  One concern on Alt1B is that if the acknowledgement to scheduled PDSCH or SPS PDSCH release is NACK, then would the BAT still valid? If yes, there might be beam misalignment between NW and UE which is also applicable to Alt.1A in previous email discussion. |
| Nokia | We prefer Alt 2. But can be open for further discussion. |
| Samsung | As comment by several companies we don’t see the value of adding Alt1B. It should be up to the network to decide whether the beam application time is after or before the corresponding HARQ-ACK.  We would like to motivate Alt1A based on the following example:   * Scenario 1: Single transmission of PDSCH: gNB sends PDCCH with TCI state scheduling a PDSCH. There are no other uplink or downlink transmissions before the PUCCH with the corresponding HARQ-ACK. In this case, with Alt1A, the network can set the beam application time to be before the start of the corresponding PDSCH, the UE can apply the new beam to PDSCH – this is already support in Rel-15/16, it would be a pity not to support in Rel-17. There is no misalignment as there are no other uplink or downlink transmissions before the PUCCH with the corresponding HARQ-ACK. This is not possible with Alt2 or Alt1B. * Scenario 2: There are other uplink or downlink transmissions between the time the PDCCH with the TCI state is sent and its corresponding acknowledgement. In this case, the network can choose whether to apply the beam before the acknowledgement and handle the consequences of misalignment, or set a beam application time to be large enough to occur after the acknowledgment, and there will be no misalignment.   With Alt1A, scenarios 1 and 2 are supported and it would be up to the network to set the value of the BAT. |
| OPPO | We suggested another option which shall consider the requirement from both UE and gNB. That option is missing from the proposal:  We suggest to update Proposal 3.1 by adding a Alt3.  **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 * Alt3: the first slot that is at least X1 ms or Y1 symbols after the DCI with beam indication and X2 ms or Y2 symbols after the acknowledgment of the beam indication. |

### 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. |
| MediaTek | Support Alt2 – A panel entity corresponds to a group RS resources   * + For beam indication, the RS is a source RS for UL TX spatial filter information   + For CSI/beam reporting, the RS is a measurement RS   In beam management framework, RS (whether it is measurement RS in beam reporting or source RS in beam indication) is the only medium that can be used for exchanging information between NW and UE. Therefore, it is natural to use RS to as the medium to deliver panel-related information.  However, whether and how to introduce a panel entity in signaling should be further discussed. We just reached the agreement for studying this in this week. |
| TCL | Support Alt1. |
| Xiaomi | Prefer Alt 2. |
| NTT Docomo | We share similar view with LG that how to introduce a panel is related to where the panel information is to be used e.g. for PUSCH/PUCCH/SRS, or for DL measurement and report. And we also agree with LG that introducing a new ID for panel is a clean solution, otherwise, it will be complicated how each panel is mapped to each channels/RSs. |
| Ericsson | Prefer Alt2  Alt2 is a functional definition. It describes how the panel would be used, both regarding beam indication/scheduling and measurements. In that sense, Alt2 is complete.  Alt1 does not bring any functionality: how it would be used in measurement reporting and scheduling is completely open. It is thus difficult to see what is gained by agreeing on Alt1. |
| vivo | Prefer Alt2.  Functionality need to be streamlined for how to use this panel ID.  A little bit confused by the following wording in Alt2. Our understanding is that the mapping of RS to panel is determined by UE in the CSI/beam reporting. Prefer not include the following if intention is not clear.  ~~The RS For CSI/beam reporting, is a source RS for UL TX spatial filter information~~ |
| Sony | Support Alt2.  Similar view with MTK that from specification perspective, RS or RS sets can be a proper signaling medium for panel-specific information changed between NW and UE. |
| Fraunhofer IIS/HHI | Support Alt. 2 |
| Nokia | Support Alt2. As a question for the clarification, in Alt 1, would we define 1-to-1 mapping between port and UE panel entity or each antenna port can be mapped on multiple of UE panel entity? |
| Samsung | Support Alt2  Alt1 introduces a new entity, which is not necessary. Also, in some sense, Alt2 includes Alt1 since a measurement RS is associated with a group of ports, isn’t it? |
| OPPO | We do not support to introduce explicit panel ID. That was discussed a lot in rel16 and it turned out we can not find good justification for that.  In beam indication, the gNB indicates one RS as the downlink QCL or UL TCI. Which panel(s) and Beams are used for reception and transmission is UE implementation.  Particularly:  Re Alt1: antenna port is unique term. We can not use it here.  Re Alt2: RS is the signaling we used for beam indication. So it seems we do not need to discuss how to how to map UE panel to RS. |

### 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 |
| MediaTek | Support Proposal 5.1 with one minor correction as follows:   * + FFS: Whether/how to enhance existing beam reporting format to support Option 2A   However, we tend to agree with ZTE that Option 1c and Option2c may not needed. |
| TCL | We support the proposal with Intel’s version. |
| Xiaomi | For the first main bullet, we think it can be divided into two cases:  Case 1: {Rel.16 P-MPR based (beam-level)} + {A}, where A is either Opt1A, Opt1B, or Opt1C  Case 2: {Rel.16 P-MPR based (panel-level)} + {A}, where A is either Opt1A, Opt1B, or Opt1C.  For case 1, we prefer Opt 1C since beam level based P-MPR + existed beam measurement report can provide enough information to gNB for selection beams without MPE impact.  For case 2, we prefer Opt 1B since panel level based P-MPR+ SSBRI(s)/CRI(s) and panel indication + existed beam measurement report can provide enough information to gNB for selection beams without MPE impact.  For the second main bullet, if the {SSBRI(s)/CRI(s) and/or panel indication} related to SSBRI(s)/CRI(s) without MPE impact, we prefer Opt 2C since SSBRI(s)/CRI(s)+ existed beam measurement report can provide enough information to gNB for selection beams without MPE impact.  We also want to clarify that why Option 2A is needed, is it assumed that there is no existed beam measurement report? |
| NTT Docomo | For option1B, we think whether additional quantity associated with each feasible beam/panel (SSBRI/CRI and/or panel indication) is reported can be further studied. We are fine with adding “option 1B” from ZTE in addition to  option1A/1B/1C in latest Intel’s version. For example,   * {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: {SSBRI(s)/CRI(s) and/or panel indication} + Virtual PHR or a modified version associated with each of the reported SSBRI(s)/CRI(s) and/or panel indication (if configured)   + Option 1D: No additional reporting quantity |
| Ericsson | We prefer Intel’s version – it is clearer. We still have concerns on using the term L1-RSRP in the main bullet in 2A: L1-RSRP is L1-RSRP, and MPE cannot affect that – the second FFS bullet would seem meaningless. The MPE effect should be in the main bullet. Could we use   * + Option 2A: L1-RSRP [L1-SINR] potentially affected by MPE 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 |
| vivo | Support Intel’s version. Based on agreed Rel-16 based P-MPR solution, we can naturally expand the PHR MAC CE to panel specific report, where only panel ID needs to be added but without additional reporting quantity, i.e. {Rel.16 P-MPR based (beam/panel-level)} + {Opt1C}. |
| Sony | Support the proposal from Intel. |
| Nokia | Support 5.1 with the latest Intel’s version |
| Samsung | Support Intel’s version.  We are supportive of ZTE’s proposal which is essentially Opt1A+1B. We prefer to add this as a new option, instead of replacing Opt1B  Re E/// comment on Option 2A, we prefer the original wording since E/// proposal means that the existing (R15/16 based) beam report is precluded from Opt 2A. In our view, E/// proposal is another option, which is included in the original wording. |
| OPPO | Support the latest 5.1 |

### 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 |