**Pre-RAN1#105-e offline discussion on issue 1 of multi-beam enhancements**

## QCL for CA

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| 1.8 | [Based on offline discussion, cf. Yuki, *reformulated for better clarity*] Carrier aggregationFor TCI state(s) shared across a set of CCs (that is associated with the same gNB beam):* Alt1: CC-specific QCL-TypeD RS can be determined from the shared TCI state(s). The determined QCL-TypeD RSs for the set of CCs are further associated with a same QCL-TypeD RS.
* Alt2: A single QCL-TypeD RS is determined from the shared TCI state(s), and support enhanced QCL chain: support “i) only”, “ii) only”, or “both i) and ii)” from the following:
	+ i) the QCL type A TRS and, if any, QCL type D TRS, in the same/different CSI-RS resources
	+ ii) the QCL type A TRS and, if any, QCL type D SSB
 | **Alt1 (11)**: Nokia/NSB, NTT Docomo, Intel, Apple, APT/FGI, CATT, , Ericsson**Alt2 (8)**: vivo, Samsung (OptA and B), ZTE, MTK, Sony (OptA only), Qualcomm (OptA and B), Spreadtrum, OPPO (OptA only) |

From the latest discussion moderated by Yuki (Alt1/2 description from x3559, I edited this to avoid using “common TCI” per Xi’s previous comment):

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| 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.

---Example of QCL chain for both Alt.1 and Alt.2 are illustrated in the below Fig.1-2. Alt.1 has no impact on Rel.15 QCL chain, and Alt. 2 will introduce the new QCL chain (red allows in Fig.2).Figure 2-1: Example of QCL chain of Alt. 1 (same QCL chain as Rel.15)  a) Opt. A b) Opt. BFigure 2-2: QCL chain of Alt. 2 (Red part is new QCL chain from Rel.15) As commented by Yushu, when we select from the Alt.1 and Alt.2, we should also consider RLM/BFR. Note that usually RLM/BFD RS are not RRC configured, and implicitly derived as “Type D RS for CORESET”, otherwise it is not possible to update RLM/BFD RS by MAC CE). Alt.1 has no problem on this (because the QCL chain is the same as Rel.15).In Alt. 2, * RLM: as long as “Single QCL-TypeD RS” is configured on PCell/PSCell, we can derive PCell/PSCell RS as RLM RS. (seems no problem)
* BFD: if we assume “Single QCL-TypeD RS” is configured on PCell/PSCell, all SCell BFD RSs are implicitly derived as the same PCell/PSCell RS. So, it seems SCell BFR does not work in Alt. 2. (Note: in the QCL chain of Alt. 2 in Fig.2, BFD RSs of all SCells are implicitly derived as TRS on CC#0 (PCell/PSCell).)
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Table 1 Companies’ inputs: QCL for CA

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| **Please share your view on the following questions*** **Q1. What’s your view on/response to Yushu’s argument on RLM/BFR in favor of Alt1?**
* **Q2. Given that it is not very likely to support new QCL chaining rules in Rel-17 (OptA and OptB), can Alt2 proponents accept Alt1? If not, what’s the reason?**
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| **Company** | **Input** |
| MediaTek | On Q1, to our understanding, when NW configures “common beam operation” for a set of intra-band CCs, UE will apply the same Rx beam for control channels in all of the configured CCs all the time. We are wondering separate BFRs are still needed for these configured CCs even they share identical beam operation? It seems SCell BFR is not quite useful for this case.On Q2, due to the above understanding, we still prefer Alt2 with least Opt. A. Since using TRS as TypeD source RS is already support in Rel-15/16, we don't see implementation issue on this. |
| OPPO | Q1: Re the issue of RLM/BFR, Alt2 with single QCL-TypeD RS seems no problem for RLM/BFR. Actually, Alt2 with single QCL-TypeD RS can even reduce the UE complexity for beam failure detection because the UE monitor the same BFD RS for all the CCs.Q2: We are ok with Alt2 but the Opt.A need to be revised as follows:* Opt. A: The QCL-Type A TRS and, if any, QCL-Type D ~~TRS~~ CSI-RS, in ~~the same/~~different CSI-RS resources.

The reason for deleting “the same”: for one CC, the QCL-Type A TRS must be in that CC. Thus if the same CSI-RS is used for both QCL-TypeA and TypeD, it is impossible to support “single QCL-Type D RS for the set of the CCs” |
| Ericsson | Just for clarification, we have not agreed that the TCI states can be shared across CCs, have we?Q1: It would seem that Alt2 is not complete. We also have the FR1-FR2 CA case, where there is no QCL-TypeD on the PCell. Q2: Overall, the Rel-15 solution with TCI states defined per serving cell works fine. There seems to be little point in changing that how the TCI states are defined.  |
| Samsung | Q1: With a common beam across a group of CCs (that can share the same beam, i.e. TCI state with QCL Type-D), it would seem natural to use the same RS for BFD in all CCs. As Oppo pointed out, this could save UE complexity, it also saves overhead. For SCell BFR, the underlying assumption is that a separate beam is used in each cell and hence the need for a separate BFD RS associated with each cell.Q2: Given the argument in Q1, using a common QCL Type D source RS for a group of CCs sharing the same beam can reduce UE complexity, as the UE tracks only a single RS for the set of carriers. Therefore, we support Alt 2. Opt B seems to require an additional QCL Type D relation (for the SSB to be a source RS for PDSCH/PDCCH), therefore, we should at least support Opt A, we also like to be able to support Opt B. |
| Mod V5 | Modified Opt A per OPPO’s comment.Re Ericsson’s question, we have the following agreement (in short, TCI states could differ across CCs but they would ultimately refer to the same QCL Type-D RS – cf. Alt1 (either directly or indirectly)): On Rel-17 unified TCI framework, support common TCI state ID update and activation to provide common QCL information and/or common UL TX spatial filter(s) across a set of configured CCs:* ...
* Just as Rel.16, the RS in the TCI state that provides QCL-TypeA [or QCL-TypeB] shall be in the same CC as the target channel or RS
* The common TCI state ID implies that the same/single RS determined according to the TCI state(s) indicated by a common TCI state ID is used to provide QCL Type-D indication and to determine UL TX spatial filter across the set of configured CCs
* …
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| MediaTek | Re the modified Opt. A, we agree that “the same” should be deleted. But does changing “QCL-Type D TRS” to “QCL-Type D CSI-RS” mean any type of CSI-RS (BM, TRS, or CSI) can be supported as TypeD source in Opt.A?  |
| Apple | We support Alt1.For Alt2 OptA and OptB, in addition to the RLM/BFD issues, it is possible the beam for source RS for QCL-TypeA indication and QCL-TypeD indication are with different, which would complicate UE implementation.  |
| Docomo | We support Alt.1.Re the modified Opt. A, we don’t agree that “the same” should be deleted. Strictly speaking, for a CC with QCL-type D RS, QCL type A RS and QCL type D RS should be the same; for other CCs, QCL type A RS and QCL type D RS should be different. (Note: There is no need to assumer different QCL type A RS and QCL type D RS on a CC with QCL type D RS)We don’t understand clearly why Alt.2 can save UE complexity. Alt.1 assumes the common root SSB as QCL type D source of TRS on each CCs. UE can determine Rx beam based on the root SSB reception. This is also aligned with TS38.133. TS38.133 says when UE is indicated new TCI state by MAC CE, UE shall wait next SSB reception to apply the new TCI state, which means UE is allowed to wait next root SSB reception to determine Rx beams.We also need to discuss the issue of Alt.2 which Ericsson raised: *We also have the FR1-FR2 CA case, where there is no QCL-TypeD on the PCell*. We also don’t understand how Alt.2 works in FR1-FR2 CA. |
| Huawei, HiSilicon | 1. “TCI state(s) shared across a set of CCs” have not been agreed. What was agreed is to use “common TCI state ID update”. We suggest revising Alt1 as below to make this clear. * Alt1: CC-specific QCL-TypeD RS can be determined from the ~~shared~~ indicated common TCI state~~(s)~~ ID. The determined QCL-TypeD RSs for the set of CCs are further associated with a same QCL-TypeD RS.

2. We failed to understand how Opt A/B under Alt-2 can provide a technical advantage over Alt-1. If it is about UE complexity/overhead for BFD, the NW can simply choose not to configure SCell BFR. In our view, going with Opt A/B under Alt-2 will add extra complexity to UE, as it will now need to handle different sources for QCL TypeA and TypeD.3. In our understanding, for CA within an FR2 band, as the two CC(s) can be distantly separated (e.g., 700MHz) and gNB may use different Tx panel/beam(s) to transmit different CC(s), there is use case to configure SCell BFR when the UE is expected to apply the same Rx beam to receive multiple CC(s). 4. The comment/question from Ericsson/DOCOMO on FR1+FR2 CA is also valid. In this case, TCI states for FR1 CC(s) and FR2 CC(s) are typically different, and it is not well-motivated to “share” TCI states across CC(s).  |
| Sony | Regarding Q1, we think the answer from OPPO and Samsung could address the question. Instead of monitoring BFD RS per BWP per CC, if one single BFD RS on a CC can be shared among multiple CCs, UE’s complexity on measuring BFD RS (at least from this aspect) can thus be reduced. As for Q2, since Q1 seems not insolvable question, we would stick to Alt 2-1. Moreover, we share the same view with Docomo that for Opt. A, there is one case (circled in figure below) that QCL-TypeA RS and QCL-TypeD RS could be the same RS on a CC. For FR1-FR2 CA case, we tend to agree that QCL-TypeD RS on PCell (FR1) is typically not suitable to provide spatial Rx reference to other CCs (FR2). From this sense, Alt.1 seems a better choice, with common root SSB cut off as below. Specifically, one common TCI state ID in each CC points to different TCI states. It looks like (perhaps I am wrong) we are not stepping forwarding and just reusing Rel.16 X-CC beam indication mechanism. As for Alt.2, hopefully NW would not make such configuration.  |
| ZTE | Regarding Q1, we share the same views with Sony, OPPO and Samsung that the UE can share the same BFD-RS in such case, like CC-group specific BFR with a transparent manner. Regarding Q2, we strongly support Alt2 due to the fact that we have the following agreement. Using a same/single RS as for determining spatial relation should be a basic principle for unified TCI framework. It seems to revert this agreement if going with Alt1, to be honest.On Rel-17 unified TCI framework, support common TCI state ID update and activation to provide common QCL information and/or common UL TX spatial filter(s) across a set of configured CCs:* ...
* Just as Rel.16, the RS in the TCI state that provides QCL-TypeA [or QCL-TypeB] shall be in the same CC as the target channel or RS
* The common TCI state ID implies that the same/single RS determined according to the TCI state(s) indicated by a common TCI state ID is used to provide QCL Type-D indication and to determine UL TX spatial filter across the set of configured CCs
* …

If really need to go with Alt-1, as a compromise, we think that a single RRC pool of TCI states should be supported for CA case for saving the gNB RRC configuration overhead and UE memory/storage. We do not want to make the duplicated TCI configuration in all CCs. |

### How unified TCI is applied to other signals/channels

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| 1.4 | Whether Rel-17 DL and, if applicable, joint TCI also applies to the following signals. * If not applicable, how to provide DL QCL information for those signals

Note: UE-dedicated reception on PDSCH and all/subset of CORESETs have been agreed | CSI-RS resource for CSI:* **Yes (21)**: Lenovo/MoM, Ericsson, Nokia/NSB, OPPO, Spreadtrum, MTK, APT/FGI, Intel, Convida, AT&T, Samsung, Apple (at least for default AP-CSI-RS beam), Sony, Qualcomm, Xiaomi, NTT Docomo, Intel, CATT
* **No (3)**: Huawei, HiSi, Futurewei (need further discussion)

Some CSI-RS resource(s) for BM (if so, which one(s), e.g. aperiodic, repetition ‘ON’)* **Yes (16)**: Ericsson, Nokia/NSB, OPPO, MTK, APT/FGI, Intel, AT&T, Samsung, Apple (at least for default AP-CSI-RS beam), Sony (at least for repetition ‘ON’), Qualcomm, Xiaomi, NTT Docomo, Intel
* **No (5)**: Huawei, HiSi, Futurewei (need further discussion, depending on whether the resource is repeated or not), Spreadtrum, vivo

CSI-RS for tracking:* **Yes (10)**: Lenovo/MoM, Ericsson, Spreadtrum, AT&T, Nokia/NSB, Sony, Qualcomm, CATT
* **No (5)**: Huawei, HiSi, MTK, Futurewei, NTT Docomo
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| 1.5 | Whether Rel-17 UL and, if applicable, joint TCI also applies to the following signals. * If not applicable, how to provide UL TX spatial reference information for those signals
 | Some SRS resources or resource sets for BM:* **Yes (14)**: Lenovo/MoM, Ericsson, OPPO, MTK, Intel, APT/FGI, Nokia/NSB, Sony, Qualcomm, Xiaomi, Convida
* **No (4)**: Huawei, HiSi, Futurewei (need further discussion) , Spreadtrum (reuse R15 TCI framework)
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| 1.12 | TCI for non-UE-dedicated reception on PDSCH and all/subset of CORESETsAlt1: Extend (use) Rel-17 unified TCI Alt2: Reuse Rel-15/16 TCI | **Alt1**: vivo, Samsung, Qualcomm, Futurewei, , Ericsson**Alt2**: Apple (modify Alt2 as “reuse Rel-15/16 QCL assumption”, since many cases are for idle mode UE and there is no TCI), Huawei, HiSi |

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| The following questions are pertinent to sub-issues 1.4, 1.5, and 1.12:* QA. Does Rel-17 unified TCI apply to a channel, a CORESET, or a signal *other tha*n the ones already agreed.
	+ 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
* QB. If the answer to QA is yes for any of those channels/signals, how does this apply?
* QC. If the answer to QA is no for any of those channels/signals, how does the system provide DL QCL or UL TX spatial reference information to the channel/signal?

In regard to QB, it was pointed out (by Claes) that two possible interpretations exist. 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 requires M>1 and/or N>1.
	+ 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.
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Table 2 Companies’ inputs: unified TCI applied on other signals/channels

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| **~~Please share your view on the following questions~~*** **~~Q1. Regardless your views on 1.4/1.5/1.12, which interpretation do you hold?~~**

**See the modified question after Mod V5 comment** |
| **Company** | **Input** |
| MediaTek | On QA: Our understanding on “applying Rel-17 unified TCI” is always Interpretation 1, and we are okay to support Rel-17 unified TCI “optionally” apply to at least CSI-RS resource for CSI, i.e., it shares the same TCI state machine as that for UE-dedicated reception on PDSCH and all/subset of CORESETs.On QB: Interpretation 1On QC: For those signals and non-UE-dedicated channels not applying Rel-17 unified TCI, separate “TCI state machines” are needed, and legacy Rel-15/16 signaling mediums are used for them (no new signaling mechanism). However, these “TCI state machines” still can share the same TCI state pool used for Rel-17 unified TCI (not sure whether this is Interpretation 2). |
| OPPO | QA: For DL, yes to CSI-RS for CSI and one set of CSI-RS set with repetition = ‘ON’, For UL: Yes to one SRS resource set for BM.QB: Interpretation 1. QC: For the channels/signals with No in QA, the scheme specified in rel-15/16 is applied. |
| Ericsson | QA: Our understanding is that “applying Rel-17 unified TCI” is Interpretation 2. Hence “unified TCI” means unified across UL and DL. “Common beam operation” is a very important special case of unified TCI. QB: Interpretation 2. We understand how this would imply M>1 and N>1. Rel-15/16 signalling/configuration mechanisms would be reused when needed, but would indicate a R17 TCI state.On the common beam operation: In Rel-15, aperiodic CSI-RS for CSI can use a default beam when the triggering offset of the CSI-RS is smaller than the UE capability. The same rule was introduced for aperiodic CSI-RS for BM in Rel-16. Reporting using a default beam is very useful in practice, and reduces the number of aperiodic triggering states. We propose that such common beam operation is supported also for R17 TCI states. |
| Samsung | QA: CSI-RS for CSI should perform measurements on a CSI-RS resource with the same beam as that of the corresponding PDCCH/PDSCH. Same common beam as that used for PDCCH/PDSCH.CSI-RS for beam management with repetition on, should have the same beam as that of the corresponding PDCCH/PDSCH for Rx beam refinement. Same common beam as that used for PDCCH/PDSCH.CSI-RS for tracking can itself be a source RS for PDCCH/PDSCH, using a common beam would create a circular relation and hence should be avoided.QB: Interpretation 1.QC: If a channel is not part of a common beam used for PDCCH/PDSCH, its beam is signalled separately, we are open to consider the following options:* Signalling based Rel-17 TCI states.
* Signalling based on Rel-15/16 TCI states, this might increase the configuration overhead, as the UE would need to be configured with the Rel-15/16 TCI states and Rel-17 TCI states.
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| Mod V5 | For brevity, I will use the term **‘other signals/channels’** to refer to those mentioned in QA below* *QA. Does Rel-17 unified TCI apply to a channel, a CORESET, or a signal other than the ones already agreed.*
	+ *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*

From the above comments, I observe the following additional points:* [MTK, Ericsson] It should be possible to use Rel-17 TCI states for all ‘other signals/channels’. The question, for a given ‘other signal/channel’, is whether Interpretation 1 or Interpretation 2 is possible for the signal/channel of interest.
* [MTK, Ericsson] Corollary: with Interpretation 2, the ‘other signal/channel’ of interest will use a TCI state update signaling/configuration mechanism different from that used for PDSCH/UE-dedicated CORESET/PUSCH/PUCCH. That signaling mechanism could be a separate Rel-17 MAC CE/DCI based (e.g. M/N>1), or even Rel-15/16 (TBD). But this ‘other signal/channel’ still uses Rel-17 TCI states.

So we can reorient the discussion assuming only Rel-17 TCI states are used for all the ‘other signals/channels. The question can be reframed below. |
| **Please share your view on the following questions****Given that all the ‘other signals/channels’ (listed in QA above) configured with Rel-17 unified TCI states, for each of those ‘other signals/channels’*** **Q1. Which ones of the ‘other signals/channels’ should be able to share the same Rel-17 “TCI state machine” as PDSCH/UE-dedicated CORESETs/PUSCH/PUCCH (i.e. Interpretation 1)?**
* **Q2. For the ‘other signals/channels’ that do not admit Interpretation 1 (therefore, admit only Interpretation 2), what TCI state update signaling/configuration mechanism(s) should be used?**
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| OPPO | Q1: CSI-RS for CSI, one CSI-RS resource set with repetition = ‘On’ and one SRS resource set for BMQ2: the rel15/re16 TCI update signaling/configuration mechanism shall be used. |
| MediaTek | Q1: “Optionally” apply to at least CSI-RS for CSI. In Rel-15/16, the common beam operation is only valid for AP CSI. We see it is also beneficial to allow such common beam operation for P and SP CSI-RS.Q2: By assuming only Rel-17 TCI states are used, Rel-15/16 signaling/configuration mechanism for TCI/spatial relation should be used.  |
| Apple | Q1: At least aperiodic CSI-RS for CSI and BM, which is to avoid default beam issue – potential default beam mismatch between A-CSI-RS and PDSCH. In addition, AP-TRS can also be considered, then the AP-TRS can be triggered with a small scheduling offset. But if all types of AP-CSI-RS are included, it is better to revise the agreement a little bit to include TRS only as the source RS. We are also open to extend unified TCI for P/SP-CSI-RS with separate signaling (legacy RRC/MAC CE by using unified TCI), so that UE does not need to maintain two TCI states pools: R17 TCI and R16 TCI. Q2: It seems there will be no other signals/channels. |
| Huawei, HiSilicon | The term of “TCI state machine” is confusing to us. In R15/R16, there is a TCI state pool configured under PDSCH config, where PDCCH and CSI-RS can be configured/assigned/indicated with a TCI state from this TCI state pool. In UE feature discussion, when defining active TCI states for PDCCH/PDSCH, the TCI states configured for CSI-RS is not considered. The “TCI state machine” here seems to refer to the pool of active TCI states for PDCCH/PDSCH in R15/R16, and we failed to understand why the configured/indicated TCI states for CSI-RS should follow that for PDCCH/PDSCH. For example, there can be up to 192 CSI-RS resources for BM, CSI, and tracking purposes, it is unclear which of them should follow the active beam pair for PDCCH/PDSCH transmission, and how the gNB would know if whether to apply is optionally configured by RRC in advance, especially for periodic CSI-RS and when UE is moving around. We are not sure whether the underlying assumption here is that gNB can change the Tx beam of periodic CSI-RS when UE moves around. If that is the case, we suggest explicitly listing it out for consideration. In addition, in a typical QCL chain that comes with explicit TCI indication, it is PDCCH/PDSCH to follow CSI-RS, not the other way around. Similar to Ericsson, we are supportive to inherit the R15/R16 mechanism that aperiodic CSI-RS can use a default QCL (following lowest CORESET) when the triggering offset is smaller than the UE capability. We believe this is an implied behavior, once the joint or DL TCI in R17 is applied to PDCCH reception, and no further agreement is needed. So far, R17 TCI is mainly for data/control channels, which is aligned with the WID (focusing on data/control channels), and we haven’t agreed that R17 TCI will be extended and applied to all other channel/signal(s). If the proposal here is that R17 TCI will essentially replace R16 TCI and spatial relation and then be applied everywhere, it is better to spell it out so that we can assess the impacts to the system and discuss whether to do it this way.  |
| Sony | Q1: CSI-RS for CSI, CSI-RS for tracking, and CSI-RS for BM with repetition ON. In Rel.15/16 QCL rules, various types of CSI-RS can leverage TCI states for UE to retune Rx beam for its DL reception on CSI-RS. In Rel.17, if we stick to only DL channels, rather than DL signals, then UE may have to maintain two parallel TCI state pools, one for Rel.15/16 and the other one for Rel.17.Q2: If any, what we have is only to reuse Rel.15/16 signaling mechanism(s) on TCI states.  |
| ZTE | Q1: Aperiodic CSI-RS for CSI and aperiodic CSI-RS for BM. * Besides, it is noted that periodic and semi-persistent CSI-RS for CSI, for BM and periodic TRS should be precluded in our views. Periodic DL RS are usually cell-specific for saving RS overhead, and dynamically updating the TCI state of the RS means that we have to provide UE-specific periodic RS with huge RS overhead from gNB perspective.

Q2: Then, we share the same views with OPPO, MTK and Sony that Rel-15/16 TCI configuration mechanism should be reused accordingly.  |