**3GPP TSG RAN WG1 #102-e R1-2006985**

**e-Meeting, August 17th – 28th, 2020**

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

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

**Document for:** Discussion and Decision

1. Introduction

In this summary, the term “item 1” refers to the first item in the Rel.17 NR FeMIMO WID, i.e. multi-beam enhancement:

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| 1. Enhancement on multi-beam operation, mainly targeting FR2 while also applicable to FR1:
	1. 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)
	2. 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
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This summary includes the following:

* Categorization of proposals and issues in the submitted contributions
* Summary of current companies’ positions on each of the aspects within the category
* Moderator proposals
1. Categorization of issues

Based on the WID and plausible workflow throughout the WI, the proposals and/or issues raised by interested companies are organized as follows to identify pertinent aspects (including design components). This is not intended to be an exhaustive list of alternatives, but rather a skeleton to facilitate planning and progress tracking from meeting to meeting. The details on each item will be hashed out as the work progresses.

Table 1 Category of issues

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| 1. **Unified TCI framework** – by means of extending the Rel.15/16 DL TCI framework (e.g. TCI state definition)
	1. Design for UL common TCI
		1. Goal: utilize same unified design as DL TCI, specify UL TCI framework to facilitate common TCI state update for UL (data, PUCCH, SRS)
		2. Including UL PC, timing control, PL RS, and/or default UL common beam
	2. Design for DL common TCI
		1. Goal: identify and, if needed, specify potential refinement on Rel.15/16 DL TCI framework to facilitate common TCI state update for DL (data and DL assignment of the same UE)
		2. Including default DL common beam
	3. Additional QCL Type-D relations for TCI state definition
		1. Goal: if supported, facilitate extended use of DL RS (e.g. SSB, CSI-RS) for UL and UL RS (e.g. SRS) for DL
	4. Facilitating combined/joint and separate TCI for DL and UL:
		1. Goal 1: when beam correspondence is assumed (common scenario), specify TCI framework to facilitate common TCI state update for DL and UL
		2. Goal 2: when beam correspondence is not assumed (e.g. MPE event), facilitate separate TCI state updates for DL and UL

*Note: the following factors should be considered in the above design aspects** + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*
		- *Beam correspondence assumption*
		- *When applicable, performance assessment based on the agreed EVM*
1. **L1/L2-centric inter-cell mobility**
	1. The need for and/or the applicability and scope of L1-/L2-centric inter-cell mobility:
		1. Goal: assess the need for and/or the applicability (use cases) and scope of L1/L2-centric inter-cell mobility (as an enhancement on the Rel.15/16 L3-based approach)
	2. Method of enabling L1/L2-based inter-cell mobility:
		1. Goal: select the type of information pertinent to non-serving cell(s) in TCI state to facilitate inter-cell mobility operation, e.g. PCI, SSB/TRS indicator,TAGs, L1-RSRP report for RS in a neighboring cell

*Note: the following factors should be considered in the above design aspects** + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*
		- *Beam correspondence assumption*
		- *When applicable, performance assessment based on the agreed EVM*
1. **Dynamic TCI state update signaling medium** for common TCI state update operation
	1. Signaling medium: L1 control signaling (DCI-based on PDCCH) and/or MAC CE
		1. Goal: select the medium and the associated detailed design used for signaling TCI state update
		2. This includes DCI format when applicable, reliability (HARQ-ACK and/or repetition), UE-specific vs. UE-group, 1-part vs. 2-part signaling, timing aspect
	2. Exact content:
		1. Goal: define list of parameters included in the TCI state update (supporting multiple formats is possible)
		2. This includes (a) separate DL and UL (DL-only and UL-only), (b) Combined joint DL and UL

*Note: the following factors should be considered in the above design aspects** + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*
		- *Beam correspondence assumption*
		- *When applicable, performance assessment based on the agreed EVM at high-speed scenarios*
1. **Extension of UL TCI for UE with (capable of) multiple panels** to facilitate UL fast panel selection, given the unified TCI framework design (cf. the above aspect 1 and 3)
	1. Mechanism to identify a UE panel:
		1. Goal: Assess whether resource ID or resource set ID (SRS, CSI-RS, ...) is sufficient or an explicit (new) panel ID is needed
	2. Signaling mechanism to enable UL fast panel selection,
		1. Goal 1: assess needed signaling from UE to NW, e.g. to indicate multi-panel capability, UE reporting
		2. Goal 2: extending UL TCI state update mechanism for various scenarios for UL fast panel selection, e.g. if supported, DL and UL TCI state update are (a) common, (b) separate;
	3. The need for panel-specific timing and power control enhancements in relation to panel indication and unified TCI framework design
		1. Goal: assess the need for panel-specific timing and power control and, if needed, the associated specification features

*Note: the following factors should be considered in the above design aspects** + - *CA and cross-carrier scheduling operation (e.g. inter- and intra-band CA, FR1/FR2 CCS)*
		- *The use of UE panels for both DL reception and UL transmission, including the need for UE reporting and NW signaling*
		- *Beam correspondence assumption*
1. **MPE mitigation -** given the unified TCI framework design and multi-panel UE support (cf. the above aspect 1, 3, and 4)
	1. The need for enhancement(s) to reduce UL coverage loss due to meeting MPE regulation
		1. Goal: assess the need based on a list of candidate schemes
	2. Method of enabling MPE mitigation:
		1. Goal: scheme selection for MPE mitigation

*Note: the following factors should be considered in the above design aspects** + - *Beam correspondence assumption*
		- *Performance assessment based on the agreed EVM*
		- *Support for fast panel selection on MP-UE*
1. **Miscellaneous enhancements**
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1. Observation and proposals

From the above summary and inputs, the moderator makes the following **observations**:

* Issue 1:
	1. Issue 1.4, especially on supporting both joint and separate TCI for DL and UL, takes logical precedence over the other within issue 1 category.
		+ The term “TCI” comprises a TCI state that includes at least one source RS associated with a TX spatial filter linked with a target RS.
		+ Separate TCI is thought to be relevant when, e.g. MPE event occurs, thereby DL TX and U TX spatial filter are not assumed to be DL-UL reciprocal.
		+ However, at least one company (e.g. OPPO) points out that it is possible to utilize the same TCI state to represent both DL TX and UL TX spatial filters regardless whether they are assumed DL-UL reciprocal or not.
		+ In this sense, it seems natural to use the same TCI pool for both DL and UL
	2. Issue 1.1 requires defining the use case of UL common TCI relative to the channels/signals, i.e. PDSCH, PUCCH, SRS. That is, whether UL common TCI refers to a common TCI state shared by PDSCH, PUCCH, and SRS.
	3. On issue 1.3, supporting the use of SSB/CSI-RS and SRS as source RS for UL TCI (basically UL TX spatial filter) seems agreeable to all, but supporting the use of SRS as source RS for DL TCI needs further discussion
* Issue 2:
	1. It is pointed out that L1/L2-centric inter-cell mobility is a part of the scope (identify and specify). Therefore, a proper prelude to this work is to identify the scope (e.g. the extent of RAN2 impact) and use cases (e.g. this method may have limited application, if any, for inter-RAT handover or NR network anchored to a legacy RAT)
	2. Candidates for PHY layer components have been proposed. This issue can be finalized in RAN1#103-e
* Issue 3:
	1. Each of the two alternatives (DCI and MAC CE) receives good support. Since the medium for dynamic common TCI update precedes some other issues, it is important to decide this issue in RAN1#103-e.
	2. At least one company points out that the two alternatives may not be entirely exclusive of each other – depending on use cases, e.g. Intel
* Issue 4:
	1. A proper starting point for this issue can be the final outcome of Rel.16 discussion. To ensure that participating companies are on the same page, some basic assumptions on MP-UE should first be agreed.
	2. It was pointed out that deciding whether an explicit/new panel ID is needed or not is dependent on some other issues such as MPE mitigation. Therefore, this issue can be deferred. Some progress can still be made by discussing potential NW-to-UE and UE-to-NW signaling.
* Issue 5:
	1. A proper starting point for this issue can be the final outcome of Rel.16 discussion. To ensure that participating companies are on the same page, some basic assumptions on MPE mitigation should first be agreed.
	2. As pointed out by at least one company (e.g. Futurewei) there are 3 sub-categories associated with MPE mitigation: MPE event detection, UE report of an MPE event, NW signaling in response to the MPE event.
* Issue 6:
	1. Issue 6.2 is supported by 7 companies, stressing that the latency due to beam switching is not only attributed to beam indication, but also beam acquisition/tracking – which is a valid point.
	2. Issue 6.6 is supported by 7 companies. To avoid overlap with ITEM 2c (BM for mTRP), this item should be handled within the scope of ITEM 2c

Based on the above observation the following moderator **proposals** are made:

* [Issue 1] For Rel.17 NR FeMIMO, on the unified TCI framework
	1. Support joint/combined TCI for DL and UL, as well as joint TCI pool for DL and UL
		+ The term “TCI” comprises a TCI state that includes at least one source RS associated with a common TX spatial filter linked with a target RS
		+ The joint TCI corresponds at least to the case when DL common TX and UL common TX spatial filters are assumed DL-UL reciprocal.
		+ The DL common TX spatial filter corresponds at least to UE-dedicated transmission on PDSCH and UE-dedicated DL control on PDCCH
		+ The UL common TX spatial filter corresponds at least to UE-dedicated transmission on PUSCH, UE–dedicated control on PUCCH, and SRS
		+ FFS (RAN1#103-e): Extension to intra- and inter-band CA
	2. In RAN1#103-e, select one of the following alternatives for accommodating the case when DL TX and UL TX spatial filters are assumed non-DL-UL reciprocal (e.g. MPE event)
		+ Alt1. Utilize the joint TCI
			- Note: One (joint) TCI state can include at least two links: 1) one DL target RS linked with at least one source RS, and 2) one UL target RS linked with at least another source RS
		+ Alt2. Support separate DL and UL TCIs
		+ FFS (RAN1#103-e): Extension to intra- and inter-band CA
	3. Support the use of SSB/CSI-RS and/or SRS as source RS to represent a UL TX spatial filter in the unified TCI framework
		+ Whether the UL TX spatial filter corresponds to UL TCI (separate from DL TCI) depends on the outcome of 1b) above
	4. In RAN1#103-e, decide if SRS can be configured as a source RS to represent a DL TX spatial filter in the unified TCI framework
	5. In RAN1#103-e, decide/finalize all other parameters included in the TCI, e.g. UL-PC-related parameters, UL-timing –related parameters, PL RS
	6. In RAN1#103-e, identify issues pertaining to alignment between DL common and UL common default beam assumptions
* [Issue 2] For Rel.17 NR FeMIMO, on L1/L2-centric inter-cell mobility:
	1. In RAN1#103-e, finalize scope and use cases for L1/L2-centric inter-cell mobility, including:
		+ Applicability in various CA setups such as intra-band and inter-band CA
		+ Use cases in comparison to Rel.15 L3-based handover (HO) taking into account DAPS-based Rel.16 mobility enhancement
		+ The extent of RAN2 impact (MAC CE, RRC)
		+ Network architecture, e.g. NSA vs. SA, inter-RAT scenarios
	2. In RAN1#103-e, depending on the outcome of 2a), further identify additional components –along with the associated alternatives –required for supporting inter-cell mobility based on the same unified TCI framework as that for intra-cell mobility (including dynamic TCI state update signaling), including
		+ Method(s) for incorporating non-serving cell information in the TCI
		+ Method(s) for DL measurements and UE reporting associated with non-serving cell(s)
		+ UL-related enhancements, e.g. related to RA procedure including TA
* [Issue 3] For Rel.17 NR FeMIMO, on dynamic TCI state update signaling medium:
	1. In RAN1#103-e, select between the following alternatives (based on at least the agreed EVM):
		+ Alt1. DCI
		+ Alt2. MAC CE
		+ Note: Combination between DCI and MAC CE for, e.g. different use cases or control information partitioning can also be considered
	2. In RAN1#103-e, depending on the outcome of a), identify more detailed design issues for the dynamic TCI state update, e.g.
		+ Exact content
		+ Signaling format, including the support of UE-group (in contrast to UE-dedicated) signaling
		+ Reliability aspects including the support of retransmission
* [Issue 4] For Rel.17 NR FeMIMO, on MP-UE assumption to facilitate fast UL panel selection:
	1. The following assumptions are used:
		+ In terms of RF functionality, a UE panel comprises a collection of TXRUs that is able to generate one analog beam (per polarization if dual-polarized array is used)
		+ All the UE panels constitute the same number of antenna ports
	2. In RAN1#103-e, identify candidate signaling schemes for the following (taking into account potential extension of the unified TCI framework in issue 1):
		+ NW to MP-UE
		+ MP-UE to NW
* [Issue 5] For Rel.17 NR FeMIMO, on MPE mitigation (that is, minimizing the UL coverage loss due to the UE having to meet the MPE regulation), in RAN1#103-e:
	1. Decide on the need for MPE mitigation: companies are encouraged to submit evaluation results based on the agreed EVM
	2. If needed, identify candidate solutions to be down-selected in future meeting(s). The following sub-categories can be used:
		+ CAT0. The need for specification support for MPE event detection and, if needed, candidate solutions
		+ CAT1. UE reporting associated with an MPE event
		+ CAT2. NW signaling in response to the reported MPE event
* [Issue 6] For Rel.17 NR FeMIMO,
	1. Add another category for beam acquisition (including beam tracking and refinement) latency reduction –especially in high-speed scenarios – which includes performing study and, if needed, specifying at least the following:
		+ Joint DL TX/RX beam refinement (P2/P3) and beam sweeping using ‘group TCI’
			- Note: The relation with existing features such as beam-group reporting should be considered
		+ Predictive TCI state update
		+ Enabling DL TX/RX beam refinement (P2/P3) via additional QCL with A-TRS
		+ SSB-based beam indication via MSG3 on PRACH to facilitate beam refinement during initial access
		+ Dynamic TCI for periodic RS
	2. Partial BFR will be handled in ITEM 2c (BM enhancement for mTRP)
1. Summary of companies’ inputs based on the issue category in Table 1

In the following subsections, companies’ views from the submitted contributions are summarized. Note that the **titles** used below for each numeration (e.g. 1.1, 1.2, ...) are merely *shorthand* of **more detailed descriptions given in Table 1**. For instance, the term “common TCI” refers to commonality between data and dedicated control (DL and/or UL). Likewise, the term “common TCI state update” refers to update mechanism of the said common TCI state shared by the data and dedicated control (DL and/or UL).

* 1. Unified TCI framework

Table 2 Summary of issues raised in RAN1#102-e for unified TCI framework

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| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 1.1 | Design of UL common TCI: * 1.1.1: support UL common TCI for PUSCH/PUCCH/SRS based on analogous design to Rel.15/16 DL TCI
* 1.1.2: Content of UL TCI state: QCL type (cf. 1.3) or spatial relation,, reference signalresource or port for spatial relation, PC parameters (including P0/alpha, PL RS, closed loop index)
* 1.1.3: Alternative UL PC scheme concurrent with (but not included in) UL common TCI
 | 1.1.1: Ericson, Fraunhofer IIS/ HHI, Futurewei, Lenovo/MotM, MediaTek, Nokia/NSB, NTT Docomo, OPPO, Qualcomm, Samsung, Spreadtrum, ZTE, Xiaomi, CATT, Sony, AT&T, Intel, IDC1.1.2: OPPO, ZTE, Qualcomm, Samsung, Ericsson, Lenovo/MotM, Intel, IDC1.1.3: MediaTek | Per WID (identify and specify), UL TCI for PUSCH/PUCCH/SRS will be supported. The format (e.g. analogous design to Rel.15/16 DL TCI, in what sense, issue 1.1.1) can be confirmed in RAN1#103-e or even RAN1#102-e. A few companies point out that the ise cases of UL TCI (including the applicable UL channels) needs to be decided – with a number of companies pointing out that UL TCI should provide additional functionality over Rel.15/16 UL spatial relation.The content of TCI state (issue 1.1.2) can be finalized in RAN1#103-e. |
| 1.2 | Design of DL common TCI: -- | -- | Currently no input, but some work may be done later, e.g. default common beam for DL, after issue 1.4.x is more mature |
| 1.3 | Source RS used for QCL Type-D relations in DL or UL TCI* 1.3.1: SRS for DL TCI
* 1.3.2: SSB/CSI-RS for UL TCI
* 1.3.3: SRS for UL TCI
 | 1.3.1: * Support: CATT, IDC, Samsung, vivo
* Need more discussion: Huawei/HiSi, Qualcomm, ZTE, Ericsson, LG, MediaTek, Intel

1.3.2: CATT, Fraunhofer IIS/HHI, IDC, Intel, MediaTek, Samsung, vivo, Qualcomm, Xiaomi, ZTE, Sony, Lenovo/MotM, AT&T1.3.3: Qualcomm, CATT, ZTE, Samsung, MediaTek, Sony, Lenovo/MotM, Fraunhofer IIS/HHI, Intel, IDC | This issue can be finalized in RAN1#103-e. |
| 1.4 | * 1.4.1: Whether to support both combined/joint and separate TCI for UL and DL
* 1.4.2. Common beam (QCL update) for intra- and inter-band CA (configurable)
* 1.4.3. Sharing the same TCI pool for DL and UL TCI
* 1.4.4. Alignment of UL and DL default beams
 | 1.4.1: * Support both: CMCC, Nokia/NSB, Samsung, ZTE, Xiaomi, Ericsson, Sony, Huawei/HiSi, Fraunhofer IIS/HHI
* Support separate: IDC
* Support combined: OPPO

1.4.2: Ericsson, Samsung, vivo, ZTE, Qualcomm, Xiaomi, Sony, OPPO1.4.3: LGE, OPPO, Samsung, Sony, MediaTek , Xiaomi, ZTE, vivo, Intel1.4.4: NTT Docomo, Ericsson, Qualcomm, vivo, Huawei/HiSi | 1.4.1 and 1.4.2 are fundamental and should be finalized in RAN1#103-e (including the CA issue). The rest can be finalized in later meetings.The moderator agrees with a few companies that at least 1.4.1 is more fundamental than the other, including 1.1, 1.2, and 1.3. |

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| **Company** | **Input** |
| NTT Docomo | Multiple companies propose to align default UL/DL beam in tdocs. (Ericsson also presented it in GTW session.) |
| MediaTek | Regarding Issue 1.1 and 1.2, since RAN1 doesn't decide whether to have separate or same TCI states for DL and UL, it would be better to change the wording “UL TCI” to “UL QCL relation” and “DL TCI” to “DL QCL relation”. [Moderator] Rel.15/16 supports DL TCI already. Rel.17 WID implies the support of UL TCI. The exact format is still to be completed and whether it can be separate or always common with DL TCI is to be discussed in 1.4. The categories for 1.1. and 1.2 are correct. TCI is an indicator QCL relation (since LTE). See also Table 1 for more detailed explanation of the categoryRegarding Issue 1.3 Additional QCL Type-D relations for TCI, we think this issue can be further categorized into the following components for discussion.* 1.3.1: SSB/CSI-RS as QCL Type-D source in TCI for UL
* 1.3.2: SRS as QCL Type-D source in TCI for UL
* 1.3.3: SRS as QCL Type-D source in TCI for DL

Regarding Issue 1.4.3 sharing the same TCI pool for DL and UL TCI, it should be discussed as a part of Issue 1.1 UL QCL relation. This is because if DL and UL don't share the same TCI pool, introducing a separate TCI pool for UL is needed but DL still can reuse the TCI pool as in Rel-15/16. [Moderator] See above commentRegarding Issue 1.1, we would like to add one more candidate for providing power control setting and SRS resource or port when an UL common TCI is activated/indicated for an UL transmission, instead of including them in the UL common TCI. Meanwhile, we also share the same view with ZTE that power control setting includes PL RS and other important parameters.* 1.1.3: Other mechanism to provide power control (including P0/alpha, PL RS, closed loop index) and SRS resource or port along with common TCI activation/indication
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| Samsung | For item 1.4, we suggest adding 1.4.5 for support of predictive TCI indication. A TCI state indicator can indicate current TCI state and future TCI State(s) [Moderator] This can be categorized under 6.2 as it is targeted to improve/optimize beam acquisition performance at high-speed (added to 6.2)**Update on Mon 24-Aug-20**For item 1.1.2, suggest to update as follows:1.1.2: Content of TCI state:QCL-Type (cf. 1.3), or spatial relation,~~power control and SRS~~ reference signalresource or port for spatial relation, Power control parameter and PLRS.In release 15/16, for uplink spatial relation indication, the PUSCH follows the SRI (SRS Resource Indicator), which is a double reference to the spatial RS. The PUSCH references a SRS resource, which in turn has its own reference for spatial relation. Using the UL TCI, will be a direct reference to the RS used as the spatial source. For PUCCH and SRS, the spatial relation information is already defined in Rel.15, so it could seem that introducing UL TCI is a bit redundant. However, the benefit is a common indication mechanism for all UL channels. The same indication can be used for PUSCH, PUCCH and SRS |
| Apple | We have one question on “UL common TCI” and “DL common TCI”, does it mean the TCI is only common for UL or DL, or the TCI is common for both UL and DL? Before we agree something like UL TCI, we suggest we discuss the functionality first on what should be additionally provided by TCI compared to spatial relation info. To be more specific, we need to make sure the TCI is not just a simple different terminology compared to spatial relation info.[Moderator] Please see Table 1 for more detailed description. A good starting point would be the example from Rel.16 provided by Nokia during the MB.1 discussion. Another key functionality (cf. Table 1) for UL TCI is to facilitate the so-called “common beam” (common TCI state update) operation for UL. |
| Qualcomm | For 1.1.2, we also support to define the UL TCI content. Also, should the TPMI signaled together with UL TCI state in DCI scheduling CB based PUSCH?For 1.3.1, SRS in DL TCI needs further discussion considering its impact on UE power consumptionFor 1.3.2 and 1.3.3, we support the proposalsFor 1.4.1, we prefer to investigate common beam based on existing mechanism, e.g. default UL beamFor 1.4.2, we support the proposalFor 1.4.4, we support DL default beam to be identical to UL default beam |
| vivo | It seems that common beam is now entangled with UL TCI. Our understanding is that these issues could be separately discussed: * Our understanding is that UL TCI is for more flexible UL multi-beam operation. There are in fact several different ways of interpreting UL-TCI. One of the interpretations is at higher layer signaling level: UL and DL channels/RS could share a common configuration pool, thus there is definition of UL-TCI. Related uplink design can be based on such UL-TCI framework to support more flexible UL multi-beam indication.
* For the common beam part, especially for single common beam operation, it seems we already support such behavior in Rel-16. Of course one of the discussion point is that whether we need to make such common beam operation more dynamic compared with Rel-16 schemes.

[Moderator] From the WID, it is the intention that unified TCI (including UL TCI analogous to DL TCI) is intended (only) to facilitate common beam operation. But of course companies can propose to expand the use case of UL TCI beyond common beam. |
| CATT | * We are supportive of introduction of UL TCI, and common beam functionality. Similar to DL, a pool of UL TCI states can be introduced for UL beam management. The benefits over Rel.15/16 spatial relation info are greater network scheduling flexibility and reduced radio overhead.
* We share similar views of vivo that Rel.17 specification should allow network implementation to configure UL TCI functionality and common beam functionality together, or separately. For instance there are cases where network may need to provide different beams for SRS pilots and PUCCH/PUSCH transmission, and separate UL TCI may be provided for SRS and PUCCH/PUSCH.
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| ZTE | Regarding 1.1.2, it should be noticed that UL power control parameter includes P0, alpha, closed loop process index, and PL RS, rather than PL RS only. For R16 default beam, we only need to further provide default pathloss RS that is NOT explicitly configured; but for R17 unified TCI, we try to explicitly indicate a TCI state which means that all above power control parameter should be mapped to the TCI in advance. Please check the following updated. Regarding QC comments, we think that TPMI field + TCI field is both in DCI, e.g., enhanced format 0\_1.* 1.1.2: Content of TCI state: QCL, spatial relation, power control (including P0/alpha, PL RS, closed loop index) and SRS resource or port~~, PLRS~~

Regarding 1.3, we can support to include SSB/CSI-RS/SRS as a reference RS, but are not sure for including SRS into DL-TCI. It is due to the fact that we need to carefully review the current definition of QCL type and “being inferred from the channel”.* Regarding 1.4.4, we are glad to have further solution of aligning the default beam between DL and UL. But it seems to be relevant to further enhancement of R16 default beam for PUCCH and SRS. If so, we prefer to treat this issue together with Issue 6.5 in Section 2.6 Miscellaneous enhancements
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| Ericsson | For 1.3.1: More discussion is needed, the precise use case must be described, taking mobility into account. Seems less urgent – this is quite separate and can be added at any point in time.For 1.3.2 and 1.3.3, this is part of 1.1 – we can hardly say “additional” for UL TCI, since UL TCI is not defined.As Docomo notes, we should also make a complete alignment of default beams – fix the few outstanding issues. Falls under 1.4..4 – if we could agree this in principle in #102-e, it would be good foundation to move on to UL TCI.Seems 1.4 is more basic than 1.1-1.3 |
| LG | For 1.1.1, similarly with Apple, we are open for UL TCI but it will be better to firstly clarify what functionality needs to be enhanced compared with Rel-15/16. In this sense, it seems that handling 1.4 is prerequisite for initial stage of TCI framework.For 1.1.2, what is the difference between spatial relation and QCL for UL TCI content?For 1.3.2 and 1.3.3, it is required to clarify how to extend and/or the difference from existing spatial relation. |
| Huawei/HiSilicon | Just minor update our positions: we support 1.4.1 and 1.4.4, rather than 1.1.1. We have similar understanding and preference as DOCOMO/Ericsson with regards to aligning default UL/DL beam. Although ‘UL TCI’ was discussed in Rel-15/16, we observed companies have different interpretations on what is the exact meaning. In this meeting, similar to the comment from MediaTek, it may be worth discussing, at high level without diving into details, the definition of ‘UL TCI’ first, for example, to which channel/signal(s) this ‘UL TCI’ may be applied to, effective for single transmission or certain duration, what can be put into this ‘UL TCI’, applicability to intra/inter band CA, etc.  |
| Sony | For 1.1.1, we prefer to have UL TCI with analogous function as its DL counterpart, i.e. TCI state (for DL) in Rel.15/16, rather than power control, port indication, etc. For 1.3.2 and 1.3.3, similar to spatial relation, we are supportive to include DL RS (SSB/CSI-RS) and UL RS (SRS) into UL TCI state. In this sense, the full function of spatial relation for UL beam management can be replaced by UL TCI.For 1.4.1, we are open to discuss either joint or separate TCI for DL and UL. For 1.4.2, we hope the common beam can be applied for either intra-band or inter-band cases, considering the similarity of beam management between bands at FR2. As a consequence, the overhead can be saved at maximum level.As for 1.4.3, it seems our preference was partially captured. In our Tdoc, we discuss the possibility of configuring a common pool of TCI states for DL and UL. Given the current background, we slightly prefer to have separate TCI state pools for DL and UL for flexibility reasons. |
| OPPO | On 1.1.1: As discussed in our Tdoc, it seems not necessary to introduce TCI framework for PUCCH and SRS resource. For SRS resource and PUCCH, *spatial relation info* is used for UL beam indication. The beam indication for PUCCH is provided by a PUCCH-SpatialRelationInfo, which contains one DL or UL RS providing Tx beam information and also the uplink power control parameters. The beam indication for SRS is provided by an SRS-SpatialRelationInfo which contains one DL or UL RS providing Tx beam information. From our perspective, one SpatialrelationInfo configured to PUCCH or SRS resource provide the same function as one UL TCI-state and it is equivalent to a UL TCI-state. I guess the usage for UL TCI shall be clarified first. If the “UL TCI state” is only used to replace the spatial relation info for PUCCH and SRS, it seems not necessary for SRS or PUCCH. On 1.4.1: What is the meaning of “combined/joint” and “separate”. Does it mean like that: “combined/joint” means a pool of TCI states that is used for both DL and UL, and ‘separate’ means that we have a pool of DL TCI states and another pool of UL TCI state?. We do not see the motivation for defining two separate pools of TCI states for DL and UL separately. If so, rel15/rel16 already supports that. In rel15/16, the DL beam indication is based on TCI state and UL beam indication for PUSCH is based on SRI. They are separate “TCI state” equivalently.On 1.4.2: we can support that.  |
| Lenovo/MotM | Regarding 1.1.2, all power control parameters including P0, alpha, closed loop index and PL-RS should be considered in the design of UL common TCI. So we support ZTE’s proposal* 1.1.2: Content of TCI state: QCL, spatial relation, power control (including P0/alpha, PL RS, closed loop index) and SRS resource or port.

Regarding common UL TCI (1.1.1) and common DL TCI (1.2), we should identify the scenario and requirement first. Regarding 1.3, we can support SSB/CSI-RS/SRS as the source RS for UL TCI similar with the spatial relation for PUCCH/SRS, while we should firstly identify the applicable scenario before the discussion of taking SRS as source RS for DL TCI.Regarding 1.4, the Rel-15/16 feature of default beam for PDSCH/CSI-RS reception and the default beam for SRS/PUCCH transmission should be firstly investigated before the discussion on the alignment of UL and DL default beams. Another general question is whether those features are designed for both single-TRP and multi-TRP scenarios? |
| Fraunhofer IIS/HHI | Issue 1.3 indicates ‘additional QCL-type D for TCI’ and includes UL TCI. It is unclear as UL TCI isn’t defined yet. It can instead say, “RSs used as references in TCI”. For this issue, we support sub-bullets 1.3.2 and 1.3.3 in the case of UL TCI, and would also go further in using DL channels, such as a CORESET, as reference for spatial relation in the UL TCI framework at least for UEs with beam correspondence, which could also be captured in the summary. It is incorrectly recorded that we support 1.3.1 and not support for 1.3.3, hence we have removed our name from the list of supporters of 1.3.1 and added our name to 1.3.3. We also support separate TCI for the DL and the UL, i.e., having a separate pool of TCI states for UL and DL – the second part of sub-bullet 1.4.1.  |
| Futurewei | We also think that predictive beam indication should be added to 1.4 since enhancement of BM for high-speed is an important aspect of the WID. We also have one clarification question: If we use default beam for DL/UL and data/control, does that mean that we can only have one beam direction hypothesis at a given time?[Moderator] It is now included in 6.2. The importance of 6.2 raised by Apple/Futurewei is valid from moderator’s point of view.  |
| Intel | In our understanding issue 1.4 is more fundamental and should be discussed first. To this end, we have the following comments:* 1.4.1 – we do not think beam correspondence and separate DL/UL TCI should be coupled. There could be other use cases for separate DL and UL beams e.g., MPE mitigation etc. Thus, the use cases can be further discussed, and beam correspondence can be removed at this stage.

[Moderator] Correct. ‘Beam correspondence’ is only associated with common/joint. But to avoid confusion this can be removed and will be included in se case discussion.* 1.4.2 – For common beam update, it should be ensured that the functionality works in sync with default beam indication across CCs i.e., there should not be any conflict between configured common beam and default beam. Any update to default beam indication should be taken into account.
* 1.4.3 – We think that shared DL/UL TCI pool is major motivation for specifying UL TCI.
* 1.4.4 – default beams for DL/UL currently are not aligned as pointed out in contributions and such alignment can be good for combined DL/UL TCI indication.

For 1.1 is ok in principle. We do not see the point in having separate indication of SRS resource and power control as in 1.1.3For 1.3, Intel does not support SRS as source RS for DL TCI (can be ok with further discussion). We are ok with proposals 1.3.2 and 1.3.3 for potential UL TCI indication.Overall, we agree with Apple’s comment that UL TCI should not simply be a replacement in terminology for spatial relation information and should provide additional functionality including OH/latency reduction on top of current functionality. |
| InterDigital | * 1.1.1 Just to double check the intention. In our understanding, this is proposing common TCI between uplink channels and signals, not between DL and UL, correct? If our understanding is correct, we also support 1.1.1.

[Moderator] Correct. Issue 1.1.1 is only for UL. * 1.1.2 We support this proposal.
* 1.3.3 We support this proposal.
* 1.4.1 We support separate TCI for UL and DL, i.e., having a separate pool for DL and UL, respectively.
 |

* 1. L1/L2-centric inter-cell mobility

Table 3 Summary of issues in RAN1#102-e for L1/L2-centric inter-cell mobility

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 2.1 | Need/applicability/scope2.1.1 Study latency reduction of 1st SSB transmission after MAC CE command with known TCI state and TL1-RSRP with unknown TCI state2.1.2 Deprioritize (need justification, separate from BM) 2.1.3: Need to define use cases, e.g. avoid duplication with L3-based mobility, intra- vs. inter-band, clarify/avoid RAN2 impact  | 2.1.1: ZTE, Samsung2.1.2: CMCC, Futurewei, Huawei/HiSi, Spreadtrum, MediaTek, LG2.1.3: Nokia/NSB, Samsung, Qualcomm, Ericsson, AT&T, Lenovo/MotM, ZTE | This issue can be decided in RAN1#103-b. Note that 2.1.1 can be understood as a condition whether L1/L2-based inter-cell mobility should be supported.One company prefers to discuss this after sub-item 1 (unified TCI). |
| 2.2 | Methods, if L1/L2-based inter-cell mobility is supported2.2.1 PCI of NSCell (non-serving cell) in TCI2.2.2 SSB indication of NSCell in TCI2.2.3 Multiple TAGs2.2.4 L1-RSRP reporting for CSI-RS/SSB in a neighboring cell | 2.2.1: CATT, Ericsson, Sony, vivo, Xiaomi, LG, OPPO, Lenovo/MotM, Intel2.2.2: Apple (SSB associated with one TCI group), IDC, Qualcomm, Samsung, ZTE, Xiaomi, vivo, Sony, OPPO, Lenovo/MotM, Intel2.2.3: Qualcomm2.2.4: ZTE, Samsung, vivo,OPPO | This issue can be decided in later meetings after issue 2.1 is finalized |

|  |  |
| --- | --- |
| **Company** | **Input** |
| InterDigital | Just for clarification. If our understanding is correct, 2.1.4 in Companies’ views needs to be updated to 2.1.3. |
| Apple | We are a little bit confused about 2.1.1. Our understanding is that common TCI framework is a sub-agenda under L1/L2 mobility. Is it correct understanding that we would like to clarify this first and then discuss all the sub-agenda under L1/L2 mobility?[Moderator] From the WID, notice intra-cell mobility is differentiated from L1/L2-centric inter-cell mobility (since intra-cell is handled by BM and always L1/L2-centric). This section (cf. Table 1 ☺) is intended only for inter-cell since this requires different discussion on use cases, applicability, and some companies are still skeptical. Having said that, a natural reading of the WID suggests that the same type of solution (unified TCI framework and signaling) should be used for intra- and L1/L2-centric inter-cell mobility. |
| Qualcomm | For 2.1, we believe this feature has evident benefit. We support to discuss the use cases at earliest time, including #102e |
| vivo | Share similar understanding that L1/L2 centric mobility is a useful feature. We are supportive to discuss this issue earlier.Moreover, 2.1.1 belongs to issue 2.2. |
| ZTE | For 2.1 we share the same views with QC and vivo that, if possible, we prefer to identify the usage or candidate methods for this essential issue in this eMeeting. Also, TL1-RSRP with unknown TCI state should be considered as I marked above.For 2.2, L1-RSRP reporting for beams in neighboring cell seems to be missing. So I add it back. In our views, if reducing the  |
| Ericsson | Note that the WID says “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” – so the plenary already decided that RAN1 should specify L1/L2-centric inter-cell mobility.We agree that we should avoid duplication of L3-functionalityThere may also be a need to clarify what is meant by “inter-cell”, to avoid RAN2 impact. |
| LG | We support 2.1.2. If the necessity of the L1/L2-based inter-cell mobility is justified, then the corresponding method can be considered based on PCI to improve the RS configuration on spatial relation info or UL TCI for multi-cell UL transmission. |
| Huawei, Hisilicon | For Issue 2.2.1, we suggest to discuss with our own RAN4 colleagues firstly in order to understand the rationality of additional delay of waiting for the 1st SSB occasion after MAC-CE indication. Otherwise RAN1 may override RAN4 design. It sounds to be a big restriction.  |
| Sony | For 2.2.2, we think SSB for mobility measurement can be configured in TCI state of non-serving cell. Because whether or not PCI can be included into TCI state, a UE has to measurement SSBs from non-serving cell for mobility reasons. |
| OPPO | We prefer to discuss this issue after we have discussed the unified TCI state and common beam.  |
| Lenovo/MotM | We also think that L1/L2 centric mobility is a useful feature. However, we should firstly identify the use cases before the discussion on 2.2. |
| AT&T | We agree with companies that L1/L2 centric mobility is an important feature that was already decided by plenary.  |
| Intel | For 2.1.1, our understanding is that this falls under a broader category of latency reduction and is beneficial for both intra and inter-cell mobility. Thus, we think the sub-bullet should be simplified to latency reduction schemes. Additionally, 6.2 also lists mechanisms for latency reduction and should be treated together since they benefit inter-cell mobility as well through faster beam acquisition, tracking and application.2.1.3 needs to be discussed first since it is unclear how this inter-cell beam management process works in conjunction with L3 Handover procedures. The use definition should further help clarify the applicability of proposals.We are ok in principal with 2.2.1 and 2.2.2. |

* 1. Dynamic common TCI state update signaling

Table 4 Summary of issues in RAN1#102-e for dynamic TCI signaling

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| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 3.1 | Signaling medium for TCI state update 3.1.1: DCI 3.1.2: MAC CE | 3.1.1: CATT, Fraunhofer IIS/HHI (PUSCH), Futurewei, NEC (consider HARQ), Nokia/NSB (consider HARQ), Qualcomm (consider UE-group), Samsung (consider UE-group and HARQ), ZTE, IDC, AT&T (consider UE-group), Intel (combination of DCI triggering + MAC-CE)3.1.2: Apple, CATT, Fraunhofer IIS/HHI (PUCCH, SRS), Futurewei, Huawei/HiSi, MediaTek, vivo, Xiaomi, LG, Sony, Lenovo/MotM | Signaling medium is also fundamental as it determines the reception of TCI update (latency, acceptable overhead, reliability). Whether DCI or MAC CE (or both, depending on use cases) is selected should be decided in RAN1#103-e.Next level of details such as, if DCI is selected, UE group and retransmission can be finalized in later meetings |
| 3.2 | Exact content | -- | This work can start after issue 3.1 is finalized |

|  |  |
| --- | --- |
| **Company** | **Input** |
| MediaTek | It is unclear to us what intension of issue 3.1 is. Signaling for PDCCH beam updating or other channel? The proposals from companies in this table have different intensions and quite diverse. It is better to clarify the use case first before discussion on what signaling medium should be used.[Moderator] See Table 1 for more detailed explanation. The above titles are shorthand. |
| Samsung | For item 3.1, we would like to investigate reliability enhancements of DCI-based beam indication, e.g. repetition, HARQ feedback etc. We would also like to investigate timing aspects, when to apply a TCI state at the gNB and UE in response to a beam indication signal to ensure beam alignment at gNB and UE.Regarding MediaTek’s comment, in our view, this section deals with the signaling mechanism for the beam indication (i.e. the signaling for the TCI state). One of the objectives of the work item is “Enhancement on signaling mechanisms for the above features to improve latency and efficiency with more usage of dynamic control signaling (as opposed to RRC)”. There are various tradeoffs to consider when enhancing signaling for beam indication, as an example you can refer to the discussion in our Tdoc R1-2006991.  |
| InterDigital | In our view, DCI based BWP switching mechanism is an obvious example that DCI based indication can provide enough reliability when the signaling mechanism is combined with HARQ feedback. Also, if enough reliability is provided, DCI based indication is most fast and efficient mechanism which is suitable to beam indication methods which require low latency. Therefore, we would like to support 3.1.1.  |
| Apple | As we discussed in our contribution, we have concern to use DCI based TCI indication. The beam indication latency does not come from the signaling latency but from the TCI action time. DCI based beam indication is not robust enough and we need to define the complicated default beam before action time for intra-CC scheduling and cross-CC scheduling. In addition, we also see different schemes under 3.1.1. |
| Qualcomm | For 3.1, we support DCI based TCI indication for control. It can have same reliability with shorter activation time than MAC-CE if DCI has its own A/N, which is already supported in current spec for some DCIs. In addition to TCI states, we should consider general proposals to reduce BM OH/latency, which is described in WID:1. Enhancement on multi-beam operation, mainly targeting FR2 while also applicable to FR1:
	1. 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:
 |
| vivo | Evaluation and analysis should be conducted on the exact reason why current framework does not work. The related optimization target should be set based on the analysis. |
| CATT | Functional wise both 3.1.1 and 3.1.2 can both achieve common beam update for different channels of the same UE. For high-speed train scenarios where a group of UE share the same beam, both L1/L2 work. 3.1.1 is preferable in terms of BM latency and processing complexity (e.g. omitted PDSCH decoding) compared to 3.1.2.  |
| ZTE | We share the same views with Samsung and Qualcomm. * Firstly, regarding A/N feedback, we can observe two candidate solution: #1, as QC mentioned, the DCI can has its won A/N; #2, the A/N corresponding DCI can be implicitly carried by PDSCH HARQ procedure when the unified TCI state is indicated by DCI format 1\_1, for instance.
* Secondly, high mobility scenario for vehicular or training is key usage for this WID, if our understanding is correct. In such case, the trajectory of a set of UEs may be very similar, and the group common DCI command can be considered for reducing latency and signaling overhead (MAC-CE is a UE specific signaling).
 |
| Ericsson | We are open to either solution. Providing that the signaling latency of MAC CE is the limiting factor of the beam indication, we should consider DCI. See also issue 6.2.Would seem appropriate to perform some evaluations before addressing the issue – not sure if we can conclude in RAN1#103-e. |
| LG | We have the similar view with Apple that the DCI based beam indication seems not robust and the accuracy is quite degraded. In the perspective of latency on beam indication, the main component is of TCI activation time not of signaling latency itself. |
| Huawei/HiSilicon | We have similar suggestion as MediaTek - it would be better to clarify the use cases and technique details before deciding which type of signaling is to be used.  |
| Sony | Firstly, we share the same view with Apple that the 3ms of MAC CE activation latency is only small portion of updating delay. In RAN4, it also depends on a) TCI state is known or unknown; b) whether or QCLed SSB has been measured. Secondly, we also think that given the activation function based on MAC CE, if one would like to introduce another same function, the benefits have to be well justified.So we would be supportive to 3.1.2. |
| OPPO | We can see the benefit and merit of supporting a common beam operation. So we can study/consider all the aspects, including which signaling method shall be used for the common beam operation: DCI or MAC CE.  |
| Lenovo/MotM | We share similar views with vivo, it should clarify why Rel-15/16 framework does not work well. Enhancement of PDCCH itself is out of scope for this sub-agenda item. If PDCCH needs to be enhanced for better reliability, it should be conducted in 8.1.2.1 if applicable. |
| Fraunhofer IIS/HHI | The decision of using DCI or MAC-CE for indicating an UL TCI for PUSCH, PUCCH or SRS should be approached on a case-by-case basis for each of them. |
| AT&T | We think it is important to consider aspects of DCI based signaling for common beam operation, especially related to UE-group updates, which is an important use case (e.g. mobile IAB). |
| Futurewei | We think that using DCI or MAC-CE is a tradeoff between signaling efficiency and reliability. Depending on the usage scenarios, both could have their ideal use cases and both should be supported.  |
| Intel | For 3.1, we think that DCI based signaling can help in further latency reduction. In our contribution, we have proposed latency reduction through flexible beam mapping which can be based on DCI based triggering of RSs. Therefore, we see benefit in reducing the usage of MAC-CE signaling with DCI based alternatives to reduce MAC-CE latency. However, some MAC-CE signaling is still necessary. Therefore, we propose that a combination of both be used in conjunction with latency reduction mechanisms.  |

* 1. Multi-panel UE (MP-UE)

Table 5 Summary of issues raised in RAN1#102-e for MP-UE

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 4.1 | UE panel identification:  | 4.1:* Explicit/new panel ID is needed: CMCC, Huawei/HiSi, Lenovo/MotM, LGE, NTT Docomo, Sony, Spreadtrum, vivo, ZTE, Xiaomi
* Explicit/new panel ID is not needed: AT&T, CATT, Fraunhofer IIS/HHI (RS resource ID), IDC (UE selection), Lenovo/MotM, MediaTek (UE selection), Samsung (RS resource ID), Qualcomm, Xiaomi, Ericsson, OPPO
 | Since this issue heavily depends on the outcome of unified TCI and signaling (issue 1 and 3), it can be finalized in later meetings.However, the moderator agrees that some fundamental issues such as panel assumptions can be started and finalized early. |
| 4.2 | Signaling for UL panel selection4.2.1: UE to NW4.2.2: TCI state update extension | 4.2.1: LG, ZTE4.2.2: LG, ZTE  |
| 4.3 | Panel-specific UL timing and power control | 4.3:* Needed: Huawei/HiSi, LGE, ZTE, Sony, Lenovo/MotM
* Not needed: OPPO
 |

|  |  |
| --- | --- |
| **Company** | **Input** |
| NTT Docomo | We think the need for panel ID can be discussed at earlier stage since it may also impact certain configuration signaling in other issues.  |
| MediaTek | First, we don't agree that MP-UE enhancement heavily depends on the outcome of unified TCI framework. They can be discussed in parallel. Even how to provide panel ID along with UL beam indication may be relevant to unified TCI framework, it can be discussed after RAN1 decides to introduce such panel ID, if needed. Furthermore, there are still several potential enhancements are proposed by companies to facilitate panel-specific UL beam selection, which fall within the scope and can be discussed separately from unified TCI framework. Second, before discussion on any possible enhancements to MP-UE over Rel-15/16, RAN1 should have and agree a common understanding or assumption for MPUE, and we see the MPUE-Assumtion3 agreed in Rel-16 could be a good starting point.

|  |
| --- |
| **Agreement from Rel-16 eMIMO**In Rel-16, only introduce specification enhancement for MPUE-Assumption3* MPUE-Assumption3: Multiple panels are implemented on a UE and multiple panels can be activated at a time but only one panel can be used for transmission.
	+ Note that this does not require a UE to always activate multi-panels simultaneously
	+ Note: UE can control the panel activation/deactivation
 |

Third, for Issue 4.1, it is too early to decide whether panel ID is needed at this stage. Panel ID could be introduced not only for UL beam indication, but also for UE feedback/report. In our view, RAN1 could first decide what enhancements are needed in high level, then discuss what signaling should be introduced (e.g., panel ID) later. In this sense, we suggest to categorize the potential issues for MP-UE as follows:

|  |  |
| --- | --- |
| **#** | **Issue** |
| 4.1 | MP-UE assumption |
| 4.2 | The need for enhancing beam indication (e.g., introduce panel ID) to facilitate panel-specific UL beam selection |
| 4.3 | The need for enhancing/introducing UE report to facilitate panel-specific UL beam selection |
| 4.4 | The need for panel-specific timing and power control enhancements |
| 4.5 | The need for MPE mitigation |

[Moderator] As Samsung mentioned, 4.1 has been included in the WID and therefore needs no discussion. 4.5 is taken care of in issue 5. Issue 4 has been rearranged to address some of the comments and confusions.We still think it is too early to discuss whether Panel ID (or group ID, something else) is needed to enable panel specific UL transmission. We prefer to first discuss how enable UL panel selection based on BM procedure (e.g., beam measurement, report, indication, or any combinations) including Issue 4.2, considering the use case like MPE mitigation. @Samsung, thanks for pointing out that WID already captures MP-UE assumption. However, we still failed to see the need to finalize unified TCI framework before discussion on MPUE. For example, if RAN1 decides to introduce panel ID as UL common TCI extension, then it could be discussed together in Issue 2.1 in a later phase. If not, unified TCI framework has less/no impact on other enhancement to MPUE. |
| Samsung | Regarding the comment from DOCOMO and MediaTek about discussing this item in parallel with TCI framework. In our view, there is clearly overlap and dependency. The TCI framework and associated signaling framework are generic frameworks that can be used for DL and UL beam indication, one of its application is multi-panel selection. If the TCI framework/signaling and multi-panel UE are worked on in parallel, we run the risk of wasting time on multi-panel until the TCI framework/signaling is at a sufficient level of mature, just like what happened in Rel-16, when the discussion got stuck in hypothetical situations related to TCI framework and signaling.Regarding the second comment from MediaTek, the MP-UE assumption has been clearly stated in the WID: “Identify and specify features to facilitate UL beam selection for UEs equipped with multiple panels” (fast panel selection, equivalent to Assumption 3 in Rel.16) so there is no need for discussion on this point. |
| Apple | We think firstly it is better that we can have a common understanding on the panel assumption, e.g. whether different panels can have different properties, e.g. number of ports/antennas, and so on.If all panels are the same, the necessity to introduce something like a “panel ID” seems to be low. |
| Qualcomm | For 2.4, it should be discussed after MPE is agreed to proceed. The WID says UL beam selection with multiple panels should consider MPE, which is the major topic in this item. Even if MPE is agreed, we don’t believe explicit panel ID is needed at least in R17* 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
 |
| vivo | The discussion of UL multi-panel could be started earlier. We see the necessity of enabling panel specific transmission with legacy signaling and mechanisms. Agree that this issue may need to be discussed together with MPE. |
| CATT | Our understanding is that all LTE/NR MIMO features have been physical-equipment-agnostic and that all channel tracking/measurement/feedback/scheduling functionalities are based on radio signals (e.g. pilots/channels) defined in RAN specification. We are open to discussing explicit panel ID, but would appreciate clarification on its criticality, e.g. any functionality that cannot be equivalently achieved based on the current NR paradigm (e.g. implicit).  |
| ZTE | In our views, in order to avoid repeating discussion for STxMP in R-16, we need to firstly consider the relationship between UE panel and DL RS to be reported in group based reporting. After the enhancement of group based reporting (e.g., in item 2c), e.g., introducing of group ID in group based reporting, we can further review whether or how to introduce an ID for panel switching.  |
| Ericsson | So far, we have not found a use case for an explicit panel ID. On the other hand, an explicit panel ID is associated with clear disadvantages – it limits UE implementation flexibility.We tend to agree that we first have to investigate the use case and benefits of a panel ID, before we look into the details. MPE could be one such use case. |
| LG | We support updated 4.2.1, 4.2.2, and 4.3. For 4.1, we are open for explicit ID or implicit ID but it seems urgent to make a common understanding in RAN1 on the signaling granularity to which each panel can be mapped. |
| Huawei/HiSilicon | We share similar view as DOCOMO and MediaTek that MP-UE should be discussed in parallel to TCI enhancements. Of course there are a certain dependency or correlation between TCI framework and panel switching, which shall be understood better by RAN1. Otherwise, there will be potential risk of UL MP not being supported efficiently.  |
| Sony | For 4.1, we agree with moderator that unified TCI state does have some overlapped and dependent aspects with UE panel ID. If RAN1 studies and discusses unified TCI first, then there could be some unexpected constraints when we come to UE panel identification. So we would prefer to start UE panel identification as early as possible.For 4.3, due to multi-path transmission at FR2, different beams between NW and UE may experience different transmission paths, resulting different TA required to maintain good performance. In current spec, only up to 4 TAGs seems not enough to cover the multi-beam operation. Hence we are supportive to 4.3.In addition, we also believe to have a definition and some common assumptions of the “panel” can be benefit for facilitating further discussion on panel ID. |
| OPPO | First of all, we prefer to discuss in later meetings. This issue has been discussed a lot during rel16. Particularly, for 4.1, very likely, we will repeat the same discussion as in rel19. So do not see the benefit to spend much time to repeat the same discussion again. Furthermore, It might depend on the design of UL TCI state and common beam operation. For 4.3: In our view, panel specific UL timing and power control are NOT needed. As specified in rel15/16, power control is based on a path loss RS that is associated with the Tx beam. So we already support ‘beam’-specific power control, why backoff to support panel specific power control. UL timing is determined by the distance between the UE and the gNB. Changing panel for transmission is beam switching in essence. Why beam switching will change the UL timing? |
| Lenovo/Mot | This discussion is dependent on UL-TCI framework, i.e. whether UE can derive panel information from signaled UL-TCI state, or a separate (implicit or explicit) panel ID needs to be signaled to the UE. We should firstly achieve a common understand on the multiple UE panel assumptions at least including the maximum number of activated panels, antenna ports per panel, time gaps for panel switching and whether all activated panels can be used for DL reception. |
| Fraunhofer IIS/HHI | In our opinion, the indication of the panel for the UL transmission shall be kept separate from the UL TCI framework, irrespective of whether an explicit panel ID is used or not. The panel may be determined via association with an UL RS during an UL transmission, or determined by the UE when a DL RS is used as a reference for UL transmission. |
| Futurewei | Considering that multi-panel UE needs to deal with panel specific beam reporting, indication, timing and power control, we prefer having a new panel ID defined early to facilitate the discussions.  |
| Intel | For 4.1, the need for an explicit panel ID is not clear for us unless MPE mitigation techniques are agreed. In the case that MPE mitigation techniques are supported, the indication of explicit panel ID might be helpful for power conservation purposes. Otherwise, current FR2 multi-panel (e.g., 3 panel UE) implementations can still function without explicit panel indication.  |

* 1. MPE mitigation

Table 6 Summary of issues raised in RAN1#102-e for MPE mitigation

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 5.1 | Need for MPE mitigation | [Moderator] To be evaluated via EVM | Since this issue (e.g. some schemes in 5.2) may depend on the outcome of unified TCI and signaling (issue 1 and 3) as well as MP-UE (issue 4), it can be finalized in later meetings. However, the moderator agrees that some basic principles (as suggested by Apple) can be discussed and finalized early.  |
| 5.2 | Methods, if needed5.2.1: CRI report5.2.2: MPE status report, e.g. BFR report, early notification5.2.3: Panel selection report (NW configured)5.2.4: UE-initiated UL beam or panel selection | 5.2.1: Qualcomm, NTT Docomo, IDC, ZTE (through PHR reporting)5.2.2: Nokia/NSB, Qualcomm, Sony, NTT Docomo, IDC, Samsung5.2.3: APT, NTT Docomo, OPPO, vivo, ZTE (through PHR reporting)5.2.4: Samsung, Sony, vivo, ZTE (through PHR reporting), LG |

|  |  |
| --- | --- |
| **Company** | **Input** |
| NTT Docomo | The dependency with unified TCI is unclear. We think we just need to consider the dependency with progress on MP-UE. |
| MediaTek | Share similar view with DoCoMo. Unified TCI is not prerequisite to MPE mitigation. It depends on the methods to address this issue. Meanwhile, we think the methods for MPE mitigation should be discussed as a part of MP-UE enhancement.  |
| Samsung | Regarding the comments from Docomo and MediaTek, it may be possible to agree on the need without resorting to TCI framework and MP-UE, but the discussion on the exact scheme depends heavily on TCI and MP-UE. Just to give an example, consider a UE with beam correspondence without beam sweeping, the UL and DL channels can refer to the same TCI state (assuming no MPE issue). Once MPE issue occurs, the UE might have to use a different panel/TCI State for uplink, clearly here there is a dependence on TCI framework and signaling.  |
| InterDigital | As we also support 5.2.1 and 5.2.2, we added our company name in Table 1. Although we agree that details of indication methods can be decided after having the outcome of united TCI framework, but we also think that basic principle of MPE mitigation can be discussed before having the decision. [Moderator] The basic principle (e.g. problem statement) has been extensively discussed in Rel.16. It can be surely restated as a part of conclusion in RAN1#102-e hence needs no further discussion.  |
| Apple | We failed to see the connection between MPE and unified TCI. The fundamental issue for MPE is that only UE knows what happened. So it has nothing to do with the TCI indication, but the key point is how to let gNB aware such issue. So we failed to see the reason to deprioritize it.[Moderator] If explicit UL beam indication ends up being supported (assuming separate UL common and DL common TCI updates), there is at least one solution that requires UL TCI state update (which is a part of unified TCI framework). This is not de-prioritization. The pipelined work plan is due to the time limitation and logical dependence. But whenever there is no dependence, the group can progress on issues such as the issues you mentioned above. |
| Qualcomm | For 5.2.3 and 5.2.4, we don’t need any panel ID to address the MPE issue, which can be addressed by UL beam reselection with corresponding panel transparent to gNB |
| vivo | We are also supportive of 5.2.3 |
| ZTE | Regarding MPE related reporting, we share the same views with Apple, NTT DOCOMO and MediaTek that there is few relationship between unified TCI and MPE mitigation. So, we prefer to treat this issue in parallel. Regarding reporting format, we prefer to reuse PHR reporting that is also agreed in R16, and then we can downselect panel or beam specific UL reporting. |
| Ericsson | We have just finalized the EVMs for MPE, shouldn’t we use those to evaluate before jumping into solutions? The actual solution should be implemented in the UL TCI framework, not in the spatial relation framework. Not sure if there are solutions that are agnostic to the beam selection methodology. The EVMs were just designed to answer 5.1, not to distinguish between the other options.[Moderator] Correct. On the other hand, 5.2 can offer some example schemes for evaluation.  |
| LG | We support 5.2.4. This issue seems tightly correlated with 2.4. |
| Huawei/HiSilicon | We have similar suggestions as DOCOMO and MediaTek. |
| Sony | We share a similar view as Apple. The main issue here is about indicating the MPE event on UE side to the gNB, and the discussion can be carried out in parallel to the unified TCI discussion. |
| OPPO | Before discussing the methods, we shall first discuss if the UE can support panel-specific P-MPR. In rel16, RAN4 has decided to ask the UE to report a P-MPR value to the NW. However, how to determine the P-MPR value is not specified. We shall ask the RAN4 if it is feasible for the UE to support panel-specific P-MPR.  |
| Futurewei | We think the issue could be divided into MPE detection, signaling and indication and each item needs to be treated. |
| Intel  | We do not see the link between unified TCI and MPE. Rather we think MPE mitigation and panel indication for multi-panel UEs may be inter-dependent and MPE should be discussed first before beginning detailed discussion of panel indication in 4.1 |

* 1. Miscellaneous enhancements

Table 7 Summary of issues raised in RAN1#102-e for miscellaneous enhancements

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator assessment** |
| 6.1 | SSB-based BM via PRACH | AT&T, Samsung, Xiaomi | 6.2 and 6.6 are supported by 7 companies.6.2 can be assigned a new separate category. The moderator tends to agree that beam acquisition latency significantly contributes to the overall beam switching latency.6.6 will be discussed in item 2c to avoid work overlap.The other issues may not fit in the current WID but can be discussed if time permits |
| 6.2 | Beam tracking/acquisition latency reduction, e.g. enabling P2/P3 via additional QCL with A-TRS, joint P2-P3, TCI/beam group/subset, dynamic TCI for periodic RS, beam sweeping, predictive beam indication | Apple, AT&T, Nokia/NSB, Samsung, Futurewei, Ericsson, Intel |
| 6.3 | Increasing # SRS resources or MAC CE update of spatial relation for P-SRS | NTT Docomo, Qualcomm, vivo |
| 6.4 | Beam-specific UL PC | IDC, Qualcomm, ZTE (panel-specific) |
| 6.5 | Rel.15/16 default beam operation | Vivo, Qualcomm (UL default beam in mTRP) |
| 6.6 | Partial BFR  | AT&T, IDC, Qualcomm, Xiaomi, LG, vivo, MediaTek |
| 6.7 | “Dual-polarized” beam | Sony |
| 6.8 | MAC CE switches/updates TCI-state/resource of P-CSI-RS/TRS | NTT Docomo, Qualcomm, vivo, MediaTek |
| 6.9 | Simultaneous PL RS update across CCs | Qualcomm, ZTE, vivo |
| 6.10 | Simultaneous pathloss RS activation for multiple SRS resource sets | Qualcomm |

|  |  |
| --- | --- |
| **Company** | **Input** |
| NTT Docomo | We believe this Issue 6.3 fit in current WID. It is related to signaling mechanisms to improve latency and efficiency with more usage of dynamic control signaling, and can be moved to Issue #3.3. |
| Samsung | We support 6.1 |
| InterDigital | “BFR” in issue 6.6 is not clear to us. According to our review on AT&T’s contribution, “BFR” should be updated to “partial BFR”. With the update, we also support issue 6.6. |
| Apple | We think one important problem is to handle TCI action latency, which is actually the beam tracking latency reduction. We think it is clearly mentioned in WID. We suggest changing the title of 6.2 as beam tracking latency reduction or TCI action latency reduction. If this issue cannot be solved, other enhancement for 1a would be meaningless. |
| Qualcomm | A few more topics are added. We support to discuss the BM OH/latency reduction as a separate general topic, which is described in WID:1. 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 |
| ZTE | We share the same views with QC that issue 6.9 Simultaneous PL RS update across CCs can be further considering. That issue has been identified in R16, but due to lack of time, it is postponed. |
| Ericsson | We tend to agree with Apple that if we do not address TCI action latency reduction, other enhancements would be meaningless.  |
| LG | 6.4 could be merged to 4.3, and we support 6.6 but it may have an overlap with MTRP BM agenda. |
| Sony | To be more precise on 6.7. We feel that this belongs to the WID. In general, BM heavily depends on RSs in both directions. Either side needs to decide on what polarization to use for a transmission, which may be ok in most cases. However, only half the channel is sounded (one polarization). When there is no knowledge about the receivers limited capability (i.e. single polarization capability, by design or caused by sharp AoA) like in the case of SSB transmission there is an outage probability.With e.g. dual polarized SSB (e.g. based on a cyclic delay diversity approach) the probability for identifying the strongest beam could be enhanced. |
| Futurewei | We also support discussing beam tracking and latency reduction as a separate topic focusing on 6.2, |
| Intel  | Issue 6.2 is quite critical for overall beam management enhancement and we believe this issue should be discussed with high priority. The main performance bottlenecks in current multi-beam framework are in beam acquisition and beam indication/TCI state activation. We have proposed latency reduction through flexible beam mapping as well as potential indication of SSB QCL information to reduce beam acquisition delays. These options should be added to 6.2 and we are open to further discussion.  |

Appendix A: compilation of companies’ proposals from submitted contributions

Unified TCI framework

**Table 8 Views: unified TCI framework**

|  |  |
| --- | --- |
| **Company** | **Input** |
| Huawei/HiSi | Proposal 1: QCL TypeD RS resource in a TCI state of a CORESET can be the source of common beam indication, for data and control transmission/reception for DL and UL, especially for intra-band CA.Proposal 4: Further discuss and clarify benefits of using SRS resource(s) for DL beam indication in term of “unified TCI” framework.Proposal 5: In Rel-17, when PDCCH beam is used as the common beam for both DL and UL, UE should refer to the TCI state of the latest monitored CORESET.Proposal 6: To enable multi-TRP and multi-panel based DL data and control reception, support default Tx beams and PL-RS by common beams (i.e. plural beams), at least for intra-band CA. |
| Futurewei | Proposal 1: Consider introduce new framework for common beam management and indicationProposal 2: Consider dynamically associate correspondence beams for uplink with downlink common beams by the reuse of SRI bit fieldProposal 4: Consider support dynamic common beam update based on measurement report |
| vivo | * Existing solution of default beam scheme in Rel-15/Rel-16 can be extended to unify the beam indication for different DL/UL channels/RSs.
* The TCI state of a CORESET, e.g. CORESET with the lowest controlResourceSetId, can be used as the common beam for other DL/UL channels/RSs to reduce signaling overhead of beam indication.
* Support common beam operation for multi-TRP case.
* DL and UL channels can share a common TCI state pool configured by RRC.
* Support configuration of SRS as QCL-TypeD source for DL channel.
* For UL beam indication, it can be considered that the SRS for ‘beamManagement’ is directly applied in SRI field, the size of which can be extended with multiple bits.
 |
| ZTE | For unified TCI framework to achieve common beam indication for both DL and UL transmission, the following aspects can be determined according to the indicated TCI state and its association information.* QCL assumption for DL channel(s) or RS resource(s), e.g., PDCCH/PDSCH/CSI-RS.
* Spatial relation and power control parameters for UL channel or signal, e.g., PUCCH/PUSCH/SRS.
* SRS resource or port parameter for PUSCH transmission.

Proposal 2: Regarding signalling structure for achieving unified TCI framework,* The common TCI state pool for both DL and UL should be supported as a baseline
* The following two candidate functionalities can be both considered in order to balance the signalling overhead and scheduling flexibility.
	1. There is a common TCI state pool for both DL and UL, but data and control transmission/reception for DL and UL can be separately indicated with an independent TCI state from the pool by channel/RS-dedicated command(s).
	2. There is a common TCI state pool for both DL and UL, and both data and control transmission/reception for DL and UL can be indicated with one common TCI state from the pool by a single command.

Proposal 5: Study mechanism of sharing a RRC TCI state pool for a set of CCs.* FFS: how to determine QCL Type-A RS across CC in such case.
* Note that QCL Type-D RS in a TCI state can be applied for all CCs in the set of CCs.
 |
| Interdigital | DL TCI state based on UL RS and UL TCI state based on DL RS should be supported. |
| Sony | * Specify the QCL assumption among SSB/CSI-RS resource sets on different BWPs/CCs (intra band).
* For inter-band CCs, a common beam management procedure, including TCI states across bands, should be considered for data/control, DL/UL, multiple BWPs, multiple TRPs and multiple UE panels.
* Study and specify (if necessary) a unified TCI state framework which can be applied to UL beam management in addition to DL beam management.
 |
| MediaTek | Proposal 1: Introduce common/default beam for CSI-RS measurement at least for CSI acquisition, and PUSCH transmission scheduled by non-fallback DCIProposal 2: Extend Rel-15/16 TCI framework to PUCCH, PUSCH, and SRS for UL beam indication* Study how to indicate a TCI states for a PUCCH/PUSCH/SRS transmission
* Support SRS as a spatial QCL source in a TCI state at least for UL beam indication

Proposal 3: To extend Rel-15/16 TCI framework to a PUSCH/PUCCH transmission, study how to provide a power control setting to the PUCCH/PUSCH transmission. Proposal 4: To extend Rel-15/16 TCI framework to a non-codebook-based PUSCH transmission, study how to provide port-related information to the non-codebook-based PUSCH transmission. |
| CATT | Proposal-1:Common beam can be applied to data and control, and DL and UL. Proposal-3: Different combinations of channels sharing the common beam should be supported. Proposal-4: Starting and ending of CB operation could be explicitly indicated or predefined in the spec.Proposal-5: Introduce an UL-TCI state which at least includes an RS for indication of UL spatial filter,* The RS in UL-TCI for spatial filter indication should at least support UL RS (SRS for BM) and DL RS (CSI-RS/SSB)
* FFS whether pathloss RS is directly provided in UL-TCI state, or separately
 |
| Fraunhofer IIS/HHI | * The UL TCI framework shall be defined as a standalone framework such as the TCI framework in the DL to replace the existing spatial relation framework.
* Use DL channels as references in addition to DL reference signals for spatial relation in the UL TCI framework.
 |
| Lenovo/MotM | * Study how to support SDM/FDM/TDM based PDSCH scheduled by a DCI without TCI field.
* Introduce UL-TCI in DCI to signal UL TX beam independently from the SRS resource to enhance flexibility for Rel-17 codebook-based PUSCH transmission.
* Introduce UL-TCI based power control for Rel-17 codebook-based PUSCH transmission
 |
| Ericsson | Proposal 1 Focus on reducing the activation delay and speeding up the signaling.Proposal 2 After performing a measurement on an aperiodic CSI-RS, the UE would update the TCI state used as QCL source for the PDCCH/PDSCH DMRS to the QCL source corresponding to the best CSI-RS.Proposal 6 Implement complete support for common beam operation that considers restrictions in the UE hardware relevant for intra-band and inter-band carrier aggregation.Proposal 7 Introduce an UL TCI which could serve as a direct source for the spatial properties of all UL signals: SRS, PUCCH and PUSCH.Proposal 8 UL TCI is optionally configured. |
| Intel | * SRS/CRI based flexible beam mapping can be used to reduce beam indication and tracking latency.
* To reduce beam acquisition latency, beam relations between different SSB beams can be indicated to the UE such that Rx beam refinement can be achieved without exhaustive search. Similar functionality can also be used for CSI-RS based narrow beam acquisition to avoid exhaustive beam search.
 |
| AT&T | * Uplink TCI state can replace spatial relation info for all uplink transmit signals.
* From a signalling perspective, configuration of TCI states can follow that of spatial relation info for PUCCH, SRS, and PUSCH to support dynamic beam switching
* Introduce more dynamic TCI configuration for periodic reference signals such as CSI-RS.
 |
| OPPO | Proposal 1: Support a common beam operation mode in which all the DL and UL channels and reference signals follow the same Tx beam and a single signaling can switch the Tx beam for the whole system.Proposal 2: Support single common beam in multiple CCs.Proposal 3: A TCI state for PUSCH shall include or be associated with the following information:* SRS resource(s) for port indication
* Spatial relation info
* Pathloss reference signals and power control parameters.
 |
| Samsung | Proposal 1: A common beam indication (TCI state update) is used by the UE when:* receiving DL data and UE-dedicated DL control.
* transmitting UL data and UL control.

Proposal 2: When beam correspondence is assumed between DL and UL transmissions, a unified beam indication framework indicates a joint TCI state for DL and UL. When beam correspondence is not assumed between DL and UL transmissions, a unified beam indication framework indicates a DL TCI state separate from an UL TCI state.Proposal 3: For multiple CCs, investigate how to extend the common beam indication framework to include common beam indication for a subset of CCs, cross-carrier beam indication (e.g., DCI on CC1 indicating the common beam for CC2), and cross-carrier scheduling (e.g., beams for receiving PDCCH on CC1 and PDSCH on CC2).Proposal 7: Investigate combining TX and RX beam refinement in beam management procedure.Proposal 8: Investigate CSI-RS design by allowing partial repetition of the CSI-RS resources across DL spatial domain transmission filters, wherein a UE may assume that a subset of CSI-RS resources have a same spatial domain transmission filter. |
| CMCC | Proposal 2: It should be clarified which pair should have the priority or should be design as a whole, considering data and control, downlink and uplink, transmission and reception, and multiple-carrier situation.Proposal 3: Common beam mechanism can be considered to enhance the beam tuning speed of PUCCH.Proposal 4: Support UE to report CRI/SSBRI in DL beam reporting, where the CRI/SSBRI refers to a preferred spatial relation RS for UL transmission. |
| Spreadtrum | Proposal 1: Adopt at least one of the following ways to achieve common beam* Alt1: define unified default beams for different channels based on current beam indication mechanism
* Alt2: define new beam indication signaling for different channels
 |
| Apple  | Proposal 1: To speed up beam acquisition, RAN1 should introduce schemes to include more than one SSBs in a UE beam tracking loop.* As a starting point, RAN1 can study schemes for gNB to provide some QCL information for SSBs within a CC and across CCs

Proposal 2: For overhead and latency reduction, support gNB to indicate whether UE can perform intra-symbol beam sweeping for 1-port CSI-RS for BM.Proposal 3: For overhead and latency reduction, support 1 CSI-RS resource to be transmitted in multiple symbol to facilitate joint P2/P3 beam management.Proposal 4: RAN1 should study to introduce a new QCL type indication to let UE aware that two BM-RSs are based on the same Tx beam. Proposal 6: For uplink beam indication, when SSB/CSI-RS is indicated, it should be defined that the spatial domain Rx filter is a reference to determine spatial domain Tx filter, instead of mandating UE to use the same spatial domain filter. |
| Beijing Xiaomi | Proposal 2: Consider to modify the mechanism of PUSCH beam indication to support unified framework of DL and UL beam indication.Proposal 3: Wide beam for high mobility UE is much more preferred.Proposal 4: Simultaneous transmission of multiple reference signal for beam management should be considered.Proposal 5: Larger step size for beam management report can be considered to reduce signaling overhead.Proposal 7: Beam selection based on UE trajectory need to be considered.Proposal 8: Conditional beam measurement report need to be supported to tradeoff the signaling overhead and latency.Proposal 9: We prefer to reuse the TCI frame work of Multi-TRP PDSCH for UL beam indication of multi-panel and TDM based UL transmission between multi-panels is much more preferred. |
| LGE | Introduce ‘beam linkage state’ configured by RRC in which DL/UL channels/signals that share a common DL RS for QCL type-D RS and/or spatial relation RS are listed across one or multiple CCs. When a QCL type-D RS or spatial relation RS is updated for one of the channels/RSs in the list by legacy beam indication method, the same RS is applied as QCL type-D RS or spatial relation RS for other channels/RSs in the list. |
| APT | **Error! Reference source not found.** |
| NTT Docomo | Proposal 2-1:* + Enhancement to align common UL/DL beam across CCs in Rel.17 should focus on multi active beam operation (i.e. multiple beams are activated for UL/DL channels per a UE)
		- 1) To align default TCI-state and default spatial relation
		- 2) To align explicit indicated TCI-state and spatial relation

Proposal 2-2:* + Update default TCI-state/QCL of PDSCH, to align with default spatial relation rule
		- If CORESET is configured in the active DL BWP on the scheduled CC, TCI-state/QCL of the lowest CORESET ID; else, lowest TCI-state ID of PDSCH in the active DL BWP on the scheduled CC

Proposal 2-3:* + TCI state field of DCI format 1\_1/1\_2 is reused to indicate UL beam of corresponding HARQ-ACK transmission on PUCCH/PUSCH, if Rel.17 higher layer parameter is configured
		- No explicit beam indication is required for the PUCCH/PUSCH to align UL/DL beam

Proposal 3-1: * + To support more efficient spatial relation update for periodic SRS, following options can be considered.
		- Option1. Increase the number of SRS resources per resource set or the number of SRS resource sets.
		- Option2. Support MAC CE based spatial relation update for periodic SRS.

Proposal 3-2:* + To enable MAC CE to update TCI-state/resource of P-CSI-RS, MAC CE activates/deactivates P-CSI-RS resources
		- UE is not required to receive the deactive CSI-RS resources, and hence, there is no scheduling restriction of PDSCH on the same symbol of deactive CSI-RS resources.
 |
| Qualcomm | Proposal 2: Support including default PDSCH beam in the common beam.Proposal 3: Support a common beam selected for a group of UEs.Proposal 4: Support simultaneous pathloss RS activation across multiple CCs.Proposal 5: Support simultaneous pathloss RS activation for multiple SRS resource sets.Proposal 6: Support to extend default UL beam to mTRP scenario.Proposal 7: Configured UL TCI state can indicate both spatial RS and PL RS.Proposal 8: For CB/NCB based PUSCH, scheduling DCI should indicate corresponding TPMI/TRI/SRI in or together with the UL TCI state.Proposal 11: Default UL beam defined when spatial relation is not configured can be reused for the case when UL TCI is not indicated.Proposal 12: gNB should enable either UL TCI state or spatial relation for UL beam indication.Proposal 13: For L1/L2 intra-cell mobility, support multiple TAGs per serving cell.* Each TAG can correspond to one or more TRPs with similar propagation delay to the UE.
 |
| Nokia/NSB | Proposal 1: Support common beam defined by a TCI state for DL control and data and UL control and data that takes into UE’s UL transmission capability, e.g. MPE. This may include the following options:* Separate common beams for DL (control and data) and UL (control and data)
* Common beam for DL and UL (control and data)

Proposal 2: Support common beam for DL and UL (control and data) per TRP in multi-TRP scenario for the UE.Proposal 3: Support replacing spatial relation reference signal with a TCI state for PUCCH and SRS resource.Proposal 4: TCI states that could be used for fast UL beam indication need to be restricted compared to DL beam indication e.g. due to MPE issue or UE’s transmission capability in uplink compared to reception capability in downlink in panel domain (e.g. UE may be able to receive using multiple panels at a time but transmit using a single panel at a time). Proposal 5: Consider beam repetition/diversity transmission schemes for PUCCH and PUSCH based on TCI states where UE’s transmission capabilities e.g. in panel domain are taken into account. |

L1/L2-centric mobility

**Table 9 Views: L1/L2-centric inter-cell**

|  |  |
| --- | --- |
| **Company** | **Input** |
| Huawei/HiSi | Prioritize the support of intra-cell mobility using L1/L2-centric solutions to enable/improve common beam operation for DL/UL intra-band CA and unified TCI framework used for multi-panel/M-TRP implementation scenario |
| Futurewei | Consider decouple the signaling and procedure of beam management from handover procedure for inter-cell mobility |
| vivo | * Support L1 inter-cell beam report based on L1 inter-cell beam measurement.
* Support the reporting of the L1 measured inter-cell beam qualities based on legacy L3 inter-cell beam measurement behavior.
* Support L1 inter-cell beam measurement outside SMTC with low increase of complexity and power consumption.
* Clarify the scheduling restrictions for L1 inter-cell beam measurement.
* CSI reporting/resource setting configuration could be updated to include PCI information for inter-cell beam management.
* Support to report timing offset between different cells in L1/L2 report
* For inter-cell mobility in Rel-17 both QCL enhancement for DL and spatial relation enhancement for UL should be considered.
* TCI state/spatial relation/power control enhancement with additional information of the target cells (at least including PCI information) should be considered for inter-cell mobility.
 |
| ZTE | Proposal 4: Regarding L1/L2-centric intra-cell and inter-cell mobility,* Further study the mechanism of saving latency about “first SSB transmission after MAC-CE command” for known TCI state switching.
* Further study L1-RSRP reporting and dynamic indication for DL/UL beam(s) in a neighboring cell, in order to reduce the delay of applying the new TCI state including RS resource of neighbor cell, i.e., corresponding to unknown TCI state switching.
 |
| Interdigital | * SSB based beam measurement for inter-cell operation should be supported.
* An indication of a reference signal from cells other than the serving cell should be supported in TCI state for inter-cell operation.
 |
| Sony | * Specify the QCL assumption among SSB/CSI-RS resource sets on different BWPs/CCs (intra band).
* For inter-band CCs, a common beam management procedure, including TCI states across bands, should be considered for data/control, DL/UL, multiple BWPs, multiple TRPs and multiple UE panels.
* Study and specify (if necessary) a unified TCI state framework which can be applied to UL beam management in addition to DL beam management.
 |
| CATT | Including PCI in the TCI states is supported. |
| Ericsson | * Include a PCI in the TCI state to facilitate the use of reference signals from non-serving cells as QCL sources.
* Define the CSI-SSB-ResourceSet so that one report can contain measurements from different cells.
* Introduce a PCI in the configurations related to UL transmissions: spatial relations and pathloss reference RS.
 |
| OPPO | Study beam measurement/reporting and/or beam indication of SS/PBCH block of target cell for inter-cell mobility. |
| Samsung | For L1/L2-centric inter-cell mobility, support* beam measurement based on RSs associated with serving as well as neighbouring cells
* beam report which includes indicator for (RS-ID, cell-ID)
* TCI state definition which includes or is associated with cell-ID
 |
| CMCC | The motivation and benefit of DL/UL beam management enhancement to support higher L1/L2-centric inter-cell mobility needs to be clarified. |
| Spreadtrum | For Rel-17 MIMO, L1/L2-centric inter-cell mobility is de-prioritized. |
| Apple  | To facilitate L1/L2 centric inter-cell mobility, the TCI states can be divided into N groups, where each group is associated with one SSB configuration* The SSB configuration should at least include physical cell ID, SSB transmission power, and SSB periodicity
 |
| Qualcomm | Proposal 13: For L1/L2 intra-cell mobility, support multiple TAGs per serving cell.* Each TAG can correspond to one or more TRPs with similar propagation delay to the UE.

Proposal 14: For L1/L2 inter-cell mobility, support TCI state with QCL source as SSB from non-serving PCI.Proposal 15: For L1/L2 inter-cell mobility, support L1/L2 based selection of serving cell(s), including PCell.Proposal 16: For L1/L2 inter-cell mobility, a set of candidate serving cells can be pre-configured for L1 measurement, based on which a subset of pre-configured cells can be dynamically activated by L1/L2.Proposal 17: Support updating timing advance for non-serving cell or PCI. |
| Nokia/NSB | * L1/L2 centric inter-cell mobility utilizes the beam management framework (measurements and reporting) and should not duplicate the RRC level event based mobility procedures at the lower layer
* RAN1 to discuss and clarify the scope of L1/L2 centric mobility and the relationship to inter-cell multi-TRP.
	+ The simplest form of L1/L2 centric mobility could be just to enable beam reporting on non-serving cells
 |

Dynamic TCI signaling

**Table 10 Views: dynamic TCI signaling**

|  |  |
| --- | --- |
| **Company** | **Input** |
| Huawei/HiSi | Proposal 2: Support using one MAC CE to update TCI states for multiple CORESETs within a CC as well as across multiple CCs in a given CC list.Proposal 3: Introduce one unified enabler, e.g. by RRC or MAC CE, to configure/activate ‘common beam’ across selected CCs/channels. |
| Futurewei | Proposal 3: Consider support common beam update with both MAC-CE and L1 DCI signaling |
| vivo | * Support MAC CE-based scheme for common beam indication.
* Support multiple common beams in Rel-17 for different channel/RS.
	+ Support MAC CE-based multiple common beams update.
* Support simultaneous spatial relation update by a MAC CE for PUCCH resource/PUCCH resource group for all the BWPs in the indicated CCs.
* Support MAC CE-based TCI state update for SP-/AP-CSI-RS.
* Support pathloss RS update for PUCCH/PUSCH/SRS by a MAC CE for all the BWPs in the indicated CCs.
 |
| ZTE | Proposal 3: Support DCI based common beam indication for multiple channels in unified TCI framework, in order to further reduce indication latency and save signaling latency over Rel-15/16 default beam approach for both DL and UL.* Further study DCI format, applicable timing and retransmission/repetition mechanism.
 |
| MediaTek | Proposal 6: Update associated DL CSI-RS in the SRS resource set with usage=‘nonCodebook’ by MAC-CEProposal 7: Support TCI-state update for NZP CSI-RS for a set of CCs in the same or different band by single MAC-CE |
| CATT | Common beam indication may be based on L1 (DCI) or L2/L3 (RRC/MAC-CE). |
| NEC | PDCCH to indicate a common beam for PDCCH and corresponding PDSCH, and application timing for the updated beam should be defined. HARQ-ACK feedback for the updating information can be considered. |
| Fraunhofer IIS/HHI | * Support MAC-CE indication of UL TCI references for PUCCH and SRS.
* In the case of PUSCH, use the UL TCI for indicating spatial relation when scheduled with DCI format 0\_1.
 |
| Lenovo/MotM | Proposal 5: Dynamic control signaling such as MAC CE or DCI can be introduced to reduce overhead and latency for RRC configuration. |
| Samsung | Proposal 4: To support common TCI state update for DL data and the associated DL assignment (UE-dedicated control), L1-control-based beam indication is introduced in Rel-17.Proposal 5: Investigate the use of UE-group beam indication to further reduce DL signalling overhead, baseband power consumption, as well as improve reliability. Also investigate the use of two-part beam indication to further enhance the efficiency of UE-group beam indicationProposal 6: For L1/L2-centric inter-cell mobility, support* beam measurement based on RSs associated with serving as well as neighbouring cells
* beam report which includes indicator for (RS-ID, cell-ID)
* TCI state definition which includes or is associated with cell-ID
 |
| Apple | Proposal 5: The beam indication signaling should be simplified and per link per CC group based beam indication should be supported.* RAN1 should avoid DCI based beam indication in future work
 |
| Beijing Xiaomi | Common RRC signaling and common MAC-CE signaling for data/control of DL only, UL only or both DL and UL need to be supported. |
| LGE | Consider updating beam RS for PDCCH/PUCCH by the dynamically updated beam RS for PDSCH/PUSCH by DCI. |
| Qualcomm  | Proposal 1: Support DCI based beam update for PDCCH.Proposal 9: MAC-CE can select/activate UL TCI state for PUCCH and P/SP/AP SRS resource.Proposal 10: For PUSCH scheduled by DCI, MAC-CE can activate a subset of configured UL TCI states, and the scheduling DCI can indicate corresponding UL TCI codepoint. |
| Nokia/NSB | Proposal 6: Support L1 based TCI state switch for PDCCH with the following functionalities:* the target TCI state is in the active TCI state list for PDSCH
* switch is confirmed with HARQ-ACK sent by the UE
 |

MP-UE

**Table 11 Views: MP-UE**

|  |  |
| --- | --- |
| **Company** | **Input** |
| Huawei/HiSi | * For Rel-17 UL panel selection, UE implementation assumptions may be clarified firstly, including no dedicated DL/UL panels, no beam correspondence across panels and the maximum number of active panels is smaller than the number of panels equipped.
* Virtual panel indication based on ‘unified TCI framework’ should be supported in Rel-17.
* UE panel management should consider at least, e.g. panel status alignment between gNB and UE, panel-level timing adjustment, and panel-specific power control.
 |
| Futurewei | * Consider extend beam management to support simultaneous multi-panel transmission and reception for inter-cell mobility
* Consider align basic UE panel and its operation assumptions for evaluation and design
 |
| vivo | * UE panel switching scheme enhancement in Rel-17 should at least consider the following aspects:
	+ UE power saving
	+ multi-TRP operation
	+ MPE mitigation.
* Study the measurement, reporting, signaling and procedures for alignment of panel switching at gNB and UE.
* Optimize the UE operation with only one activated panel for control/data transmission/reception for both MPUE-Assumption1 and MPUE-Assumption3 in Rel-17.
* UE panel ID can be introduced to assist network and UE’s alignment of panel activation/deactivation.
 |
| ZTE | For fast panel selection, the following aspects should be considered.* Spatial relation/TCI state including DL RS can be associated with activated panel IDs in the case of beam correspondence, with the assistance of UE panel-specific reporting, e.g., group based reporting.
* Sounding procedure for antenna switching can be further studied for supporting UE fast panel switching.
 |
| Interdigital | * Beam specific power control should be supported in UL TCI state.
* Discussion on specification support of panel ID indication can consider a panel ID indication in an UL TCI state as a starting point.
* Consider a UE centric UL panel determination for some useful cases
 |
| Sony | * An ID explicitly configured in spatialRelationInfo can be used for UL panel-specific beam selection.
* Confirm the working assumption on explicit panel-specific indication on PUSCH/PUCCH/SRS and include PRACH with conditions FFS.
* We suggest that definition of a UE panel and the related properties are addressed prior to further advancing discussions related to UE panel enhancements.
* A beam can be defined as a spatial filtering associated with one or two antenna ports carrying one or two layers separated in the polarization domain.
 |
| MediaTek | Proposal 8: The followings are assumed for Rel-17 enhancements on multi-panel UE:* More than one panels can be activated at a time
* UE controls panel activation and deactivation for DL reception and/or UL transmission

Proposal 9: In Rel-17, only introduce enhancement based on DL beam management for panel-specific UL beam selection Proposal 10: Study how to provide information of panel configuration corresponding to the reported DL RSs to gNB to facilitate panel-specific UL beam selection.Proposal 11: In Rel-17, for enhancement on multi-panel UE, introduce a unified assumption and framework to facilitate both UL transmission and DL reception. |
| CATT | Proposal-7: Following alternatives on panel selection can be considered* Alt-1: Mapping between RS and panel is transparent to gNB.
* Alt-2: Mapping between RS and panel is non-transparent to gNB, panel-ID is associated with each DL/UL signal.

Proposal-8: For panel switching, the following alternatives are to be considered* Study network controlled and UE-initiated panel switching.
* Study mechanism for UL beam management realignment between network/UE, after switching of UL panels.
 |
| Fraunhofer IIS/HHI | * A panel shall be defined as a set of UE antenna ports that can independently control the direction and power of a UE beam.
* UE panel/port indication or selection may be kept separate from the UL TCI framework to avoid complicating the framework
* The UE panel/port indication or selection may be performed by other methods such as
	+ association of specific indices or indicators with UL RSs or channel(s) to indicate UE panel(s), or
	+ autonomous selection by the UE in the case a DL RS is chosen as a reference for Tx beam selection.
 |
| Lenovo/MotM | Proposal 8: The definition, configuration and signaling of UE antenna panel should be studied. Proposal 9: How to report the panel state information timely should be studied.Proposal 10: The association relation between a beam and an activated panel should be reported to gNB as part of beam reporting.Proposal 11: Both explicit way and implicit method of reporting of association relation between a beam and an activated panel should be studied. |
| AT&T | Panel identifier is not needed in conjunction with UL TCI framework.  |
| OPPO | * UL panel selection and beam selection shall support activating only one Tx panel to save UE power.
* Consider panel-specific beam measurement and reporting.
 |
| Samsung | For multi-panel UEs, fast panel selection is facilitated by including an index of RS resource or resource set associated with a panel into the UL TCI state definition. |
| CMCC | To support panel-specific UL transmission, DL beam reporting should be enhanced to report the panel-ID that UE has used to receive the CSI-RS/SSB along with CRI/SSBID. |
| Spreadtrum | Proposal 3: On panel specific UL beam selection, the agreements achieved in Rel-16 should be considered as a starting point. Proposal 4: Support to introduce a new ID for indicating panel specific UL beam selection.Proposal 5: Panel ID can be explicitly configured in spatialRelationInfo or UL TCI state together with the reference RS.Proposal 6: Support panel selective transmission for PUSCH, PUCCH and SRS, excluding PRACH.Proposal 7: Support UE to explicitly/implicitly report panel information in beam reporting. |
| Apple | * A panel can be defined as an antenna port(s) group, where the antenna port to antenna element mapping is up to UE implementation.
* The uplink panel selection should support UE with panels with different properties, e.g. different number of RF chains, different EIRP and so on.
 |
| LGE | * Rel-17 MPUE enhancement should support at least 2 active panels.
* Panel identification method should be supported, e.g. explicit panel ID can be configured to UL channels/RSs so that gNB can control UL triggering from a specific UE panel.
* Support panel-specific power and timing control.
 |
| APT | **Error! Reference source not found.*** NW signaling
	+ - * + indication to select UL transmission panel from currently active panels
				+ indication to request a number of panels to be activated/deactivated based on UE capability
* UE reporting
	+ - * + Report to indicate information of currently activated panels
 |
| NTT Docomo | * Support gNB controlled panel selection for UE UL transmission using single panel.
* Support explicit panel ID in configuration signaling or UE reporting to facilitate panel selection controlled by gNB.
* Both UE controlled panel activation/deactivation with informing to NW and NW controlled panel activation/deactivation with indication to UE can be considered.
 |
| Nokia/NSB | Study possibility to have activated TCI state(s) for the uplink fast beam and panel selection via DCI.  |

MPE mitigation

**Table 12 Views: MPE mitigation**

|  |  |
| --- | --- |
| **Company** | **Input** |
| vivo | * Support MPE enhancement based on Rel-16 MPE framework in RAN4.
* Support MPE enhancement per panel basis in Rel-17.
* For panel switch triggered by MPE event, both multiple activated panel operation and single activated panel operation should be considered for DL reception and UL transmission.
* Mechanisms for alignment of DL reception panel and UL transmission panel due to panel switch triggered by MPE should be designed to facilitate single activated panel operation.
 |
| ZTE | Beam/panel-specific P-MPR is introduced in UL power control framework, also study the additional parameter |
| Sony | * For UE supporting beam correspondence without UL beam sweeping, RAN1 should study and, if necessary, specify MPE-aware beam reporting.
* For UE supporting beam correspondence with the aid of UL beam sweeping, RAN1 specifies UE behavior on MPE-aware UL beam sweeping.
* Associate the P-MPR values with the spatial relation for UL transmission to mitigate the coverage loss due to the MPE.
* Introducing a panel-specific P-MPR associated to a panel ID.
* To avoid UL MPE issue, it would be beneficial for RAN1 to study and, if necessary, specify the mechanism of UE triggered UL beam/panel switch.
 |
| Intel | Amend RAN4 solutions for MPE to include recovery information indicating alterative UL beam with lower P-MPR or duty cycle constraints |
| OPPO | * First study the feasibility of per-beam or per-panel human detection and send LS to RAN4 to ask about the feasibility.
* Based the RAN4 reply on feasibility of per-beam or per-panel human detection, consider to use the mechanism of reporting P-MPR as starting point for further enhancements.
 |
| Samsung | For MPE mitigation, investigate a mechanism for providing an alternate UL TX beam as well as a UE-initiated UL TX beam update. |
| Apple | RAN1 could study how to maintain the same understanding between gNB and UE on the minimal delay for a beam switching with regard to panel switching delay, as well as the MPR difference for different panels |
| NTT Docomo | * A new UL beam measurement and reporting method considering MPE can be supported.
* MPE issue detection/reporting and UL beam failure recovery mechanism due to MPE issue can be considered.
 |
| Qualcomm  | * Support UE to report preferred CRI/SSBRI for DL and UL transmissions, separately.
* Support UE to report UL beam failure due to MPE issue.
	+ The Rel-15/16 BFR procedure can be a reference for the MPE reporting procedure.
* The condition for UE to trigger MPE report should be specified.
 |
| Nokia/NSB | * Inform the gNB on the upcoming presence of a blocking user well before MPE actions are triggered to evaluate alternative uplink TX beams. Initiate monitoring for alternative links before the actual MPE event is triggered. In this way, the network has time to determine setup the best link maintenance for UL and/or DL during the MPE event and avoid RLF.
* Support UE to report well before MPE events CRI/SSBRI, where the CRI/SSBRI refers to a preferred spatial relation RS for UL transmission and metric per CRI/SSBRI to reveal UL transmission capability under MPE events from achievable EIRP point of view (e.g. PHR or P-MPR reporting per candidate UL beam based on CRI/SSBRI).
 |

Miscellaneous enhancements

**Table 13 Views: miscellaneous**

|  |  |
| --- | --- |
| **Company** | **Input** |
| Interdigital | Efficient beam failure recovery operation for inter-cell operation should be supported. |
| Sony | * The reporting of UE capabilities related to the ability of the UE to simultaneously steer in the same direction beams belonging to CCs in different bands should be considered.
* For the optimization of TCI states across bands, the polarization property of beams should be considered.
* RAN1 needs to study and specify (if necessary) whether additional signaling is necessary when a beam can support up to two independent layers separated by polarization.
 |
| MediaTek | Support one or more BFD/RLM RS update by single MAC-CE |
| NEC | Study the impact to beam failure detection RS if the PDCCH beam is updated dynamically |
| Lenovo/MotM | * Default TCI states for aperiodic CSI-RS reception in multi-DCI based multi-TRP scenario should be specified in Rel-17.
* Default spatial relation and PL-RS for UL signal including PUCCH, SRS and PUSCH scheduled by DCI format 0\_0 in multi-TRP should be supported in Rel-17.
* Default TCI state(s) for PDSCH and aperiodic CSI-RS reception should be supported for cross carrier scheduling in CA considering different multi-TRP mode configuration per carrier.
 |
| AT&T | * NR supports explicit SS block index indication in msg. 3.
* Whether or not the SS block indices are reported in msg. 3 can be indicated to the UE.
* Specify partial beam failure recovery to reduce latency and overhead
* PUCCH channels corresponding to functioning CORESETs are used to carry recovery request transmission for failed CORESETs.
* Beam management procedure should support the indication of partial control channel failure.
 |
| Sharp | Rx point specific enhancement should be introduced. |
| Nokia/NSB | * Study feasibility of having P2 CSI-RS as QCL source for TRS.
* Consider supporting self-contained (no association to P-TRS) A-TRS upon P2 CSI-RS beam, i.e. P2 CSI-RS acting as a QCL source for the A-TRS.
* Consider different beam reporting enhancements for Rel-17 to enable efficient multi-beam operation in single/multi-TRP environment.
 |

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