**3GPP TSG RAN WG1 #103-e R1-2008147**

**e-Meeting, October 26th – November 13th, 2020**

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

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

**Document for:** Discussion and Decision

**Change history – Moderator versions**

|  |  |  |
| --- | --- | --- |
| **Version** | **Add companies’ inputs** | **Moderator changes** |
| 04 | Vivo, ZTE, Qualcomm, OPPO, Xiaomi, Samsung  | Additional observation, proposal 2.1 |
| 06 | NTT Docomo, MediaTek, Lenovo/MoM, APT, Intel | Additional observation, revise proposal 1.1, 3.1, 4.2, 6.1 per inputs |
| 09 | Vivo2, MediaTek2 | Additional observation, revise proposal 1.1, 2.1, 3.1 (vivo2, Intel) |
| 11 | Vivo3 (minor), Samsung2 (minor) | Additional observation, correct minor mistake and add one more bullet on proposal 2.1, rearrange issue 5 proposal, edit proposal 6.1 |
| 13 | Qualcomm2 | Additional observation, minor update proposal 3.1/3.2 |
| 15 | CATT, other offline comments | Additional observation (especially issue 1, 2), revision on proposal 2.1 (reporting and beam indication matters), rearrange editorial ‘notes’ on proposal 3.1.  |
| 16 | Only moderator | Additional observation for issue 4, a few minor editorial on FL proposals (no substantial changes) toward final version |
|  |  |  |

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:

|  |
| --- |
| * Enhancement on multi-beam operation, mainly targeting FR2 while also applicable to FR1:
	+ Identify and specify features to facilitate more efficient (lower latency and overhead) DL/UL beam management to support higher intra- and L1/L2-centric inter-cell mobility and/or a larger number of configured TCI states:
		1. Common beam for data and control transmission/reception for DL and UL, especially for intra-band CA
		2. Unified TCI framework for DL and UL beam indication
		3. Enhancement on signaling mechanisms for the above features to improve latency and efficiency with more usage of dynamic control signaling (as opposed to RRC)
	+ Identify and specify features to facilitate UL beam selection for UEs equipped with multiple panels, considering UL coverage loss mitigation due to MPE, based on UL beam indication with the unified TCI framework for UL fast panel selection
 |

This summary includes the following:

* Issue categorization
* Observation and proposal
* Summary of current companies’ positions on each of the aspects within the category
1. Issue Categorization (from RAN1#102-e)

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

|  |
| --- |
| 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. **Advanced beam refinement and tracking** targeting high-mobility and large number of configured TCI states **-** given the unified TCI framework design for intra- and L1/L2-centric inter-cell mobility, and multi-panel UE support (cf. the above aspect 1, 2, 3, and 4)
	1. Overhead and latency reduction of beam refinement
		1. Goal: evaluate and select schemes (including NW signaling and configuration as well as UE signaling) to enable faster gNB/UE beam refinement
		2. Refinement is understood as selecting narrower (more spatially precise) beam from a set of candidate beams (gNB and/or UE beams, jointly or separately) which also includes beam sweeping
	2. Overhead and latency reduction of beam tracking
		1. Goal: evaluate and select schemes (including NW signaling and configuration as well as UE signaling) to enable faster gNB and/or UE beam tracking
		2. Tracking is understood as prompt/predictive response to the change in propagation link

*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*
		- *Performance assessment based on the agreed EVM*
 |

1. Summary of companies’ inputs based on the issue category in Table 1

The summary is based on the issue categorization in Table 1. The listed issues are structured primarily to facilitate some progress on pending issues identified in the agreements made in RAN1#103-e.

* 1. Issue 1 (unified TCI framework)

Table 2 Summary: issue 1

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 1.1 | Additional applicability of the common QCL information  | CSI-RS resource for CSI:* **Yes**: vivo, OPPO, Nokia/NSB, Spreadtrum, Convida, Samsung, Qualcomm, ZTE, NTT Docomo, MediaTek, APT, Intel, CATT
* **No**: Huawei/HiSi

Some CSI-RS resource(s) for BM:* **Yes**: OPPO, Samsung, Qualcomm, ZTE, NTT Docomo, Intel, CATT
* **No**: Huawei/HiSi, vivo, APT, MediaTek, APT (other than repetition “on”), Lenovo/MoM

CSI-RS for tracking:* **Yes**: vivo, Nokia/NSB, Spreadtrum, Convida, Fraunhofer IIS/HHI, Qualcomm, ZTE(for AP-TRS only), APT, Intel, CATT
* **No**: Huawei/HiSi, MediaTek, OPPO

Periodic CSI-RS: * **Yes**: Apple, Qualcomm (separate update), NTT Docomo (prefer resource switching to enable resource sharing across UEs)
* **No**: ZTE
 | For common QCL: * Some CSI-RS resource(s) for BM can be used for RX beam refinement (P3)
* CSI\_RS for tracking: need to clarify if this is intended for all tracking CSI-RS
 |
| 1.2 | Additional applicability of the common UL spatial filter to SRS for BM | Some SRS (resource set(s)) for BM:* **Yes**: OPPO, Samsung, Apple, Qualcomm, Intel (with BC), CATT, ZTE
* **No**: Huawei/HiSi, APT, Spreadtrum, Convida, NTT Docomo, MediaTek, Intel (without BC)
 | Intended for UL RX beam refinement (U2)Note: Beam correspondence (BC) is assumed. Can Intel’s preference be understood as when separate UL is configured? |
| 1.3 | Maximum value of M (DL) and N (UL) | **Max=1 for sTRP**: CATT, OPPO, MediaTek, Spreadtrum, Convida, Nokia/NSB, Samsung, Fraunhofer IIS/HHI, Apple, ZTE, APT **Max=2 for mTRP**: Nokia/NSB, Fraunhofer IIS/HHI, Samsung, Apple (M=2), AT&T, APT**Max>1**: Sharp, NTT Docomo (to enable DCI based), Futurewei, IDC, vivo (multiple beams per TRP, Max=4), ZTE, Qualcomm, Lenovo/MoM | Some companies favoring Max>1 (including Max=2) suggest to progress on unified TCI design for Max=1 to an extent before considering Max>1: Samsung, Nokia/NSB, Fraunhofer IIS/HHI, ZTEThe discussion can progress as follows: 1) Decide first whether to support mTRP, if so, what’s the max #. 2) Decide max # TCIs per TRP (discussion includes use cases).It is assumed that M and/or N TCIs will be updated together in one beam indication (also cf. 1.4, 1.5)  |
| 1.4 | TCI state applicability to a subset of CORESETs (in addition to all CORESETs) | **Yes**: LGE, Nokia/NSB, Ericsson, Qualcomm, NTT Docomo, APT, Intel **No**: ZTE | Need discussion to clarify potential use cases other than mTRP. For mTRP, it is obvious that one of the M TCI states applies only to a subset of UE-dedicated CORESETs. |
| 1.5 | TCI state applicability to a subset of PUCCHs (in addition to all PUCCHs) | **Yes**: LGE, Nokia/NSB, Ericsson, Qualcomm, APT**No**: ZTE |
| 1.6 | Support for common TCI state for intra-band and inter-band CA | **Yes**: Futurewei, vivo, CATT, Samsung, OPPO, LGE, Qualcomm, Ericsson, Sony, NTT Docomo, MediaTek, APT (for intra-band only), Intel, ZTE **No**: -- |  |
| 1.7 | Separate UL and DL beam indication (for, e.g. MPE mitigation):Alt1. Joint TCI including non-corresponding DL QCL and UL spatial filter reference, common pool Alt2-1. Separate UL TCI, common TCI pool with DL TCIAlt2-2. Separate UL TCI, separate TCI pool from DL TCI  | **Alt1**: OPPO, ZTE, CATT, Convida, Samsung, NTT Docomo, Apple **Alt2-1**: AT&T, Xiaomi, Nokia/NSB, Intel, APT, MediaTek **Alt 2-2**: Futurewei, CMCC, Nokia/NSB, Sony, Fraunhofer IIS/HHI, Xiaomi, APT, Ericsson, AT&T, Qualcomm, MediaTek, Lenovo/MoM | Before concluding this issue, the use case for separate UL beam indication needs to be discussed and understood better. Thus far, the only use case is MPE mitigation (since BC is mandatory). |
| 1.8 | Additional source RS types for UL TX spatial filter | Non-BM CSI-RS* **Yes**: Huawei/HiSi, vivo, Nokia/NSB, Ericsson, Qualcomm, ZTE
* **No**: Convida

Non-BM SRS* **Yes**: Spreadtrum, Qualcomm, ZTE
* **No**: Convida

DL channels: Fraunhofer IIS/HHI | Note: SSB has been agreed in RAN1#102-e – no need to be discussed again |
| 1.9 | SRS for BM as source RS for DL RX spatial filter | **Yes**: IDC, vivo, Samsung, Sony, Nokia/NSB, Convida, CATT**No**: Ericsson, ZTE | Need further discussion if this entails some joint use of SRS with a DL RS to ensure it is functional when UE orientation changes (and whether it will resolve concern) |
| 1.10 | Additional parameters included in or concurrent with (but not included in) in unified TCI  | UL PC parameters (P0/alpha, CL index)* **Yes**: IDC, Lenovo/MoM, Futurewei, CMCC, Samsung, Qualcomm, ZTE, MediaTek, Intel (for PUCCH)
* **No**: Huawei/HiSi

PL RS:* **Yes**: IDC, vivo, ZTE, OPPO, Lenovo/MoM, Qualcomm, Fraunhofer IIS/HHI, Futurewei, Samsung, MediaTek, Intel
* **No**:

UL timing parameters* **Yes**: LGE (panel-specific)
* **No**: Apple, OPPO, MediaTek (should be discussed in MTRP AIs)
 | At least two factors need to be discussed: 1) common vs separate UL/DL beam indication (cf. NTT Docomo input), 2) whether the parameters are included in the unified TCI or (analogous to Rel.15/16) defined separately from unified TCI (cf. MediaTek input) |
| 1.11 | Support default QCL/spatial relation for joint/common TCI  | **Yes**: Huawei/HiSi, vivo (extend R15/R16), Fraunhofer IIS/HHI, NTT Docomo, Ericsson (CORESET with lowest ID), Sharp, Spreadtrum, Qualcomm, Xiaomi, Lenovo/MoM, Intel**No (not needed)**: Nokia/NSB, MediaTek, OPPO  | Note: If supported, for separate DL and UL beam indication (MPE), whether one default QCL/spatial relation is sufficient (for DL and UL) may need to be discussedIt has been pointed out the that the need is unclear for unified TCI framework. So further discussion seems needed before we can proceed. |
| 1.12 | How to provide QCL information for signals where the common QCL (cf. #1.1, #1.2) is not applicable | **Alt1. Reuse Rel.15/16 TCI/spatial relation:** ZTE**Alt2. NW association with common TCI states:** MediaTek, Samsung | Although this may need to wait until #1.1. and #1.2 progress, listing alternatives for further down selection can help. |

**Proposal 1.1**: On Rel.17 unified TCI framework, support common TCI state (including TCI state update and activation) across a set of configured CCs for intra-band [and inter-band] CA:

* FFS: separate TCI states in case of inter-band CA

**Proposal 1.2**: [issue 1.1, 1.2, and possibly 1.12... need more discussion]

**Proposal 1.3**: [issue 1.8, 1.9... need more discussion]

**Proposal 1.4**: [issue 1.3, affecting 1.4... need more discussion]

Table 3 Additional inputs: issue 1

|  |  |
| --- | --- |
| **Company** | **Input** |
| Qualcomm | Please find the added view per issue in the above list. Support FL’s proposal.  |
| Xiaomi | Please find the added view for some issues in the above list. Support the proposal. |
| Samsung | In general, supportive of proposal 1.1. For the case of intra-band CA, it seems reasonable to have a common TCI state across the carriers. For the case of inter-band CA, having a common TCI state across carriers is a good starting. However, we would like to add FFS for separate TCI states in case of inter-band CA. |
| NTT Docomo | For 1.10, if the unified TCI is for UL TCI state only, we think it is reasonable to include UL PC/PL-RS parameters in UL TCI state configuration. However, if the unified TCI is for both DL and UL TCI state, we think we can consider the association configuration between UL PC/PL-RS parameters and the unified TCI configuration. |
| MediaTek | **On Issues 1.1, 1.2, 1.4, 1.5:** It is also needed to clarify how to provide QCL information for the RS/channel not applying common QCL information. Whether Rel-15 TCI/spatial relation is reused (it means common TCI states, Rel-15 DL TCI states, and spatial relations are configured for a BWP/CC at the same time), or NW can associate common TCI states with them separately (it means only one common TCI pool is configured).**On Issue 1.7:** We see that MPE mitigation is at least the use case to have separate TCI for DL and UL. Since it is not possible that NW can predict the pair of non-corresponding DL QCL and UL spatial filter references for a UE, NW has to configure all possible combinations of DL QCL and UL spatial filter references, which means a lot of TCI states. Thus, Alt1 is not an efficient way to support separate TCI for DL and UL.**On Issue 1.8:** On SSB, in the last meeting, SSB is already agreed to be used as source RS to determine a UL TX spatial filter in the unified TCI framework. Not sure why it is still an issue.**On Issue 1.10**: Not sure whether “additional parameters in unified TCI” means that UL-PC parameters are put in each TCI state together with source RS. If yes, we think not all companies captured in the “yes” support it. Even we don't have to decide the detail at this stage, but it is better to reuse the description in the previous agreement.**On Issue 1.11**: At least for the case M, N = 1, before the application of time of a newly indicated common TCI, the most recent common TCI state shall be used. Thus, we don't see the need to have default QCL/spatial relation for joint/common TCI.**On Issue 1.12**, prefer Alt2 since it doesn't have to maintain multiple QCL pools (common TCI, DL TCI, and spatial relation).**On FL proposal 1.1**, we are fine with this proposal. |
| APT | For Proposal 1.1, we support intra-band CA part. We are not clear about the applicability for inter-band CCsFL comment: Inter-band CC with common activation has been supported in Rel.16 so it is natural to extend this to Rel.17 with unified TCI framework. But we can discuss more (inter-band is now bracketed) |
| Intel | Views updated in Table 2. OK with proposal 1.1For issue 1.3: For the case of M>1 TCI states for CORESETs, there might some dependence on discussion in mTRP agenda. We are ok to discuss the cases for single TRP first (M=1 and M>1) and then address any mTRP related issues later. For Issue 1.7: We prefer to remove dependence on MPE mitigation from the wording: Separate UL and DL beam indication ~~for MPE mitigation~~For Issue 1.11: We would like to clarify that the default beam assumption is for scheduling below threshold and for the case when MAC-CE activates more than 1 joint or DL TCI state.  |
| InterDigital | We are fine with proposal 1.1 |
| vivo | We would like to make the following FFS point more general:* FFS: how to update TCI states in case of inter-band CA
 |
| ZTE | **On Issues 1.1:** In general, common TCI state is preferred to update the QCL assumption of DL RS rather than periodic RS, considering that the periodic RS is cell specific from gNB perspective. If the periodic RS is updated dynamically, gNB has to transmit UE-specific periodic RS, and the overhead of RS is very huge.**On Issues 1.2:** Considering there are still many remaining issues for sTRP (i.e., M=N=1) and many on-going discussion topics for Rel-17 mTRP, we suggest to focus on unified TCI framework for sTRP firstly and postpone the mTRP-related unified TCI discussion after the solution corresponding to sTRP and Rel-17 mTRP framework for PDCCH/PUCCH/PUSCH are stable.**On Issues 1.4 and 1.5:** We do NOT see a clear motivation for further supporting a subset of CORESET or PUCCH in the sTRP case. The Rel-15/16 framework already can provide sufficient flexibility for per CORESET or PUCCH group/resource TCI update, and, if considering backward compatibility with Rel-15/16 design, we can discuss whether channels/signals to which common TCI state is applied can be pre-indicated by gNB.**On Issues 1.7:** From our perspective, a single TCI state pool in RRC level is sufficient for providing all candidates used for further down-selection by MAC (for instance, in Rel-15, gNB may configured 64 TCI state/spatial relation corresponding to each of candidate gNB beams in RRC). For progress, we may only need to further discuss whether a separate MAC-CE command for updating DL and UL TCI state pool in MAC level, e.g. for MPE.**On Issues 1.9:** According to current spec, the UL beam for SRS-BM should be exactly the same as a source DL RS in spatial relation. Further introducing SRS-BM can NOT provide any further information compared with directly using the source DL RS. **On Issues 1.10:** From our perspective, “concurrent with (but not included in) in unified TCI” is sufficient. Meanwhile, we prefer to explicitly associate PL RS with TCI state as first priority, and can live with implicit method as in default beam approach in R16. |

* 1. Issue 2 (L1/L2-centric inter-cell mobility)

Table 4 Summary: issue 2

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 2.1 | Use cases: network architecture  | **NSA with common LTE anchor**: Samsung, Ericsson, Qualcomm, ZTE**SA**: Samsung, Qualcomm, ZTE | Use cases also need to take into account the limited TU allocation for Rel.17 NR FeMIMO. This implies that enhancements on handover and RRC reconfiguration are practically infeasible unless additional TUs are allocated (RAN level decision). |
| 2.2 | Use cases: CA aspects (in addition to non-CA) | **Include only intra-band CA**: IDC, Samsung, Nokia/NSB, MediaTek**Include intra- and inter-band CA**: Qualcomm**Include NR-PSCell**: Ericsson, Qualcomm |
| 2.3 | Use cases: intra- vs inter-frequency, inter-RAT | **Exclude inter-frequency and inter-RAT**: Ericsson, Samsung, ZTE (only for inter-RAT), NTT Docomo**Include inter-frequency**: ZTE |
| 2.4 | Use cases: sTRP and mTRP | **Only sTRP**: Nokia/NSB, Samsung, OPPO, MediaTek |
| 2.5 | Use cases: DU aspect | **Only cells in the same DU**: Samsung, Qualcomm, ZTE |
| 2.6 | Scope of enhancements: EG1. Minimum RAN2 impact: TCI and measurement/reporting EG2. Timing offset issues, TAEG3. RA/RACH  | **EG1 only**: Ericsson, Nokia/NSB, Apple, OPPO, Xiaomi, MediaTek, Lenovo/MoM, ZTE**EG1+EG2**: vivo, Qualcomm, Samsung, NTT Docomo**EG1+EG2+EG3**: Intel, ASUSTeK, CATT, CMCC, Qualcomm, APT | See observation for 2.1-2.5 EG1: whether this also allows beam indication for non-serving-cell PCI(s) needs to be discussed. |
| 2.7 | Method(s) for incorporating non-serving cell info in TCI | **Indicate RS of non-serving cell as QCL source**: IDC, ZTE, Samsung, Nokia, Lenovo, ASUSTeK, Qualcomm, OPPO, Xiaomi, NTT Docomo, APT, MediaTek**Include PCI in TCI**: vivo, CATT, Sony, Xiaomi, Ericsson, NTT Docomo, APT, ZTE | Whether these two are competing alternatives or not may need some discussion.With TCI enhancement, whether beam indication for non-serving-cell PCI(s) can be done needs to be discussed. |
|  |  |  |  |

**Proposal 2.1**: On Rel.17 enhancements to enable L1/L2-centric inter-cell mobility:

* The following use cases are assumed:
	+ Network architecture:
		- NSA with common LTE anchor
		- [SA]
	+ Intra-band CA and NR-PSCell
		- FFS: If inter-band CA is also included
	+ Only cells in the same DU
	+ Intra-frequency-band and intra-RAT (excluding inter-frequency-band or inter-RAT)
	+ Only involving single-TRP cells
* The following enhancement scope is assumed:
	+ Minimum RAN2 impact
	+ Facilitating measurement and reporting of non-serving cells/PCIs via incorporating non-serving cell info in TCI and/or Reporting/Resource Settings, along with the necessary measurement and reporting scheme(s)
		- FFS: Detailed/exact method(s)
		- FFS: Whether this also implies the support of beam indication (TCI state update along with the necessary TCI state activation) for TCI(s) associated with non-serving cell(s)

**Proposal 2.2**: [issue 2.7 options/synthesis... need more discussion]

Table 5 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Qualcomm | Please find the added view per issue in the above list |
| Xiaomi | Please find the added view for some issues in the above list.  |
| MediaTek | Please find the updated views in the above table. |
| Qualcomm2 | Support FL’s proposal. For the FFS, prefer to include inter-band CA and SA. RAN4 already defines UE common analog beam per band combination, which can be for inter-band CA. Including inter-band CA allows UE to switch from PCI 1 to PCI 2 with same band combination for inter-band CA. Also, we didn’t see additional complexity for SA compared with NSA, since both do not require RRC reconfiguration if the PCI change is via beam update.  |
| InterDigital | We are fine with proposal 2.1 |
| vivo | We have the following comments* For the statement that focus on “Only involving single-TRP cells”, we would like to point out that it could be further relaxed to the case that “Only involving receiving signals from single~~-TRP~~ cell~~s~~ at a time instance”
* For the measurement and reporting part, we would like to clarify that “Facilitating measurement and reporting of non-serving cells/PCIs via incorporating non-serving cell info in TCI and/or Reporting/Resource Settings, along with the necessary measurement and reporting scheme(s) with Rel15/16 synchronization assumptions for measurement of non-serving cell RS”
 |
| ZTE | Please find the updated views in the above table. Meanwhile, based on the following definition of intra-frequency, we can NOT preclude intra-frequency which strongly restrict gNB implementation for this feature. Precluding/including inter-frequency is also relevant to the discussion in Item-2b whether other information rather than PCI, e.g., frequency information of SSB, can be configured with TCI state. For SA part, we share the same views with Qualcomm.

|  |
| --- |
| From RAN4 spec* A measurement is defined as a SSB based intra-frequency measurement provided the centre frequency of the SSB of the serving cell indicated for measurement and the centre frequency of the SSB of the neighbour cell are the same, and the subcarrier spacing of the two SSBs are also the same.
 |

Consequently, we have the following update for FL proposal as suggested:**Proposal 2.1**: On Rel.17 enhancements to enable L1/L2-centric inter-cell mobility: * The following use cases are assumed:
	+ Network architecture:
		- NSA with common LTE anchor
		- ~~[~~SA~~]~~
	+ Intra-band CA and NR-PSCell
		- FFS: If inter-band CA is also included
	+ Only cells in the same DU
	+ Intra-/Inter-frequency-band and intra-RAT (excluding ~~inter-frequency-band or~~ inter-RAT)
	+ Only involving single-TRP cells
* The following enhancement scope is assumed:
	+ Minimum RAN2 impact
	+ Facilitating measurement and reporting of non-serving cells/PCIs via incorporating non-serving cell info in TCI and/or Reporting/Resource Settings, along with the necessary measurement and reporting scheme(s)
		- FFS: Detailed/exact method(s)
		- FFS: Whether this also implies the support of beam indication (TCI state update along with the necessary TCI state activation) for TCI(s) associated with non-serving cell(s)
 |
|  |  |

* 1. Issue 3 (beam indication signaling medium)

Table 6 Summary: issue 3

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 3.1 | Beam indication medium for common TCI state update (unified TCI framework)Alt1. DCIAlt2. MAC CE | Alt1: Futurewei, IDC, ZTE, CATT, OPPO, Samsung, Sony, Apple (also with MAC CE for other uses case(s)), Nokia/NSB, NEC, MediaTek (existing DCI format(s)), Sharp, Spreadtrum, Ericsson (existing DCI format(s)), Qualcomm, AT&T, NTT Docomo, Verizon Wireless, [Intel], Lenovo/MoM, vivo (ok with the compromised FL proposal)Alt2: Huawei/HiSi, vivo Fraunhofer IIS/HHI, Xiaomi, Convida | Majority view: Alt1Some Alt1 companies propose to at least consider group-common DCI (Futurewei, Samsung, MediaTek, Intel, NTT Docomo, Qualcomm) but some raise concern (OPPO, Ericsson, Nokia/NSB, IDC, Apple). No Alt.1 companies raise concern on UE-specific DCI.A number of Alt1 companies propose using MAC CE for activating TCI states similar to Rel.15/16 (as a compromise, to reduce # TCI codepoints in DCI): Apple, Samsung, MediaTek, NTT Docomo, Qualcomm, CATTA number of Alt1 companies propose a mechanism for UE to send an ACK upon successful decoding for reliability: Futurewei, ZTE, Apple, OPPO, Samsung, Nokia/NSB, NEC, NTT Docomo, Qualcomm, CATT |
| 3.2 | Detailed design aspects of DCI-based beam indication (Alt1 in 3.1) | The following issues are identified:1. UE-specific DCI format (reuse some existing format(s), new design) and ACK mechanism (implicit from DL-related DCI, Rel.15 SPS PDSCH release): Futurewei, ZTE, CATT, NTT Docomo, Ericsson Samsung, Nokia/NSB, NEC, Qualcomm
2. TCI state activation time including UE capability issue: Apple, ZTE, Samsung, NEC, Qualcomm
3. DCI content: Futurewei, OPPO, Samsung, NTT Docomo
4. TCI state assumption/update for common beam indication DCI: vivo
5. Max # activated TCI states: Futurewei
6. Separate UL beam activation/indication (depending on issue 1 /6 decision): NTT Docomo, Apple, MediaTek
 |
|  |  |  |  |

**Proposal 3.1**: On beam indication signaling medium to support joint TCI state update in Rel.17 unified TCI framework:

* Support L1-based beam indication (TCI state update) using UE-specific (unicast) DCI format to indicate joint TCI state update from the active TCI states
	+ In addition, support a mechanism for UE to acknowledge successful decoding of TCI state update
	+ The applicable channels of the indicated beam(s) include those other than described in proposal 3.2 aspect IV (pending aspects)
* Support activation of one or more TCI states via MAC CE analogous to Rel.15/16:
	+ Note: If only one TCI state is activated, L1-based beam indication is not needed
* Note: Following the terms in RAN1#102-e agreement for issue 1:
	+ The joint TCI state update can include M DL and/or N UL common TCI state(s)
	+ “Common” refers to common beam for DL or common beam for UL; “Joint” refers to simultaneous/joint DL and UL beam using a common beam applicable for both DL and UL

**Proposal 3.2**: In RAN1#103-e, further discuss and identify alternatives for the following pending (FFS) design aspects of joint TCI state update, to be down selected *by* RAN1#104-e:

* Aspect I: Selected UE-specific DCI format(s) and its associated exact acknowledgment mechanism(s)
* Aspect II: TCI state activation time/latency (e.g. longer than *timeDurationforQCL*) including UE capability issue
* Aspect III: DCI content
* Aspect IV: TCI state assumption/update for the following cases (to be discussed along with issue 1):
	+ The beam indication UE-specific DCI (i.e. the CORESETs with the DCI received by UE) and the associated PUSCH/PUCCH for the acknowledgment of the beam indication DCI
	+ Non-UE-specific CORESETs and PUSCH/PDSCH scheduled/activated and PUCCH transmission triggered by non-UE-specific CORESETs
	+ Configured-grant based PUSCH (note: Tx beam for Type 1 CG-PUSCH is configured by RRC and Tx beams for Type 2 CG-PUSCH cannot changed during the active time).
* Aspect V: Max # TCI states activated by MAC CE (8 from Rel.15/16 vs. >8)
* Aspect VI: Separate UL beam activation/indication
* FFS: Additional enhancement such as L1-based beam indication with group-common DCI
* FFS: Whether the Rel.17 beam indication can also apply to TCI state update for single channel (e.g. PDSCH only, single CORESET) or a subset of channels

Table 7 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Qualcomm | Please find the added view per issue in the above list. Support FL’s proposal #3.1. For FL’s proposal #3.2, we prefer to prioritize issue I and II.  |
| Vivo | In general, can be supportive of FL proposal 3.1 with the following issues considered/addressed in the text of proposal 3.1: 1. The beam for the ACK of beam indication DCI may need to follow the beam of DCI itself. However, the beam of the DCI still needs further discussion (with the added FFS above). Thus the beam of the PUCCH and PUSCH for ACK also needs FFS. 2) For the dedicated PUSCH/PUCCH scheduled/triggered by non-UE specific CORESETs, the beam may not need to be updated by the DCI since this may be used for RRC reconfiguration related procedure. The beam for these UL transmission may also need to be robust.

So, we suggest the following refinement of the text:* The updated TCI state applies at least to UE-dedicated reception on UE-specific CORESETs (other than the CORESETs for the beam indication DCI) and the PDSCH scheduled by these CORESETs
	+ FFS: TCI state assumption/update of the beam indication UE-specific DCI
* When joint DL and UL beam indication is configured, the updated TCI state also applies to dynamic-grant/configured-grant based PUSCH and dedicated PUCCH resources (other than the PUSCH scheduled/activated and PUCCH transmission triggered by non-UE-specific CORESETs)
	+ FFS: TCI state assumption/update of PUSCH/PUCCH resources for the acknowledgment of beam indication DCI

FL comment: Per MediaTek’s inputs the text has been simplified to avoid repeating previous agreement (issue 1, RAN1#102-e). The FFS points have been added and clearly mentioned as pending issues in proposal 3.2.  |
| Samsung | Support FL proposal 3.1. This provides better reliability, lower latency and less overhead than MAC CE based beam indication. Our simulations indicate an average gain of up to 12% in user throughput. To improve reliability of DCI-based TCI indication, we support having HARQ-ACK feedback for DCI. |
| NTT Docomo | Support FL’s proposal #3.1. For FL’s proposal #3.2, we prefer to prioritize issue I and III.  |
| MediaTek | * 1. If DCI-based beam indication is supported, existing UE-specific DCI format with DL/UL scheduling should be considered with the first priority, and additional HARQ-ACK feedback is not needed since UE can acknowledge successful decoding of TCI state update by reporting HARQ-ACK for scheduled PDSCH or by transmitting the scheduled PUSCH. Only for UE-specific DCI format without DL/UL scheduling, additional HARQ-ACK feedback similar to HARQ-ACK feedback for SPS release is needed.
	2. Clarify about MAC-CE activation that it is possible to active one TCI state and DCI-based indication is not needed for this case
	3. Since the applicability of the indicated/updated common TCI is discussed and agreed in Issue 1, it is not necessary to repeat it in this proposal.
	4. Could you clarify more clearly what is the issue on TCI state assumption/update for common beam indication DCI?
	5. According to the comments above, we suggest the following modifications on proposal 3.1.
* Support activation of one or more TCI states via MAC CE analogous to Rel.15/16
* Support L1-based beam indication (TCI state update) ~~with~~ using UE-specific (unicast) DCI format to indicate M/N (for DL/UL) common TCI state from the active TCI states
	+ In addition, support a mechanism for UE to acknowledge successful decoding of TCI state update
		- ~~Note~~ FFS: Exact acknowledge mechanism ~~is TBD depending on~~ associated the selected DCI format(s)
	+ ~~The updated TCI state applies at least to UE-dedicated reception on UE-specific CORESETs and the PDSCH scheduled by these CORESETs~~
		- [FFS: TCI state assumption/update of the beam indication UE-specific DCI]
	+ ~~When joint DL and UL beam indication is configured, the updated TCI state also applies to dynamic-grant/configured-grant based PUSCH and dedicated PUCCH resources~~
* Note: If only one TCI state is activated, L1-based beam indication is not needed
* ~~Support activation of multiple TCI states via MAC CE analogous to Rel.15/16~~

FL comment: #1 will be decided in next meeting (aspect I in proposal 3.2). #2,3: good points and yes. #4: please see vivo’s input. #5: incorporated with minor rewordingThanks FL’s response. Please find MTK’s further comments as follows:On FL proposal 3.2 Aspect VI, we would like to modified it as follows:Aspect VI: Separate UL beam activation/indication |
| APT | For proposal 3.1 * on the last sub-bullet of the first bullet item, we think the impact of M/N value should be considered.
* on the first sub-bullet of the first bullet item, we would like to put a note about application latency should be FFS (e.g., longer than *timeDurationforQCL*)

FL comment: Agree (M/N incorporated already. On latency, it is captured in aspect II in proposal 3.2. |
| Lenovo/MoM | Regarding FL proposal 3.1, we have the following comments1. For clarification, are both DCI-based and MAC-CE based TCI updates supported in proposal 3.1? This is our interpretation and we support this proposal with this understanding.
2. In Rel-16, the Tx beam for Type 1 CG-PUSCH is configured by RRC the Tx beams for Type 2 CG-PUSCH cannot changed during the active time. So we suggest the updated TCI state does not apply to the configured-grant based PUSCH or take it as a FFS.

FL comment: #1, since DCI-based is not used when #activated states = 1 (please see latest version of 3.1), your point should be resolved. #2: included in FFS (not so much for issue 3, but for issue 1 – for now it can be captured here but in RAN1#104-e I will add this to issue 1 category).  |
| Intel | The scope of proposal 3.1 is quite broad i.e., it applies for joint as well as separate DL/UL beam indication. We have a few initial comments:* We would like to clarify that “common” refers to common beam for DL (applies to all DL channels/RSs) and common beam for UL (applies to all UL channels/RSs) and “joint” refers to simultaneous DL and UL beam update using a common beam.

FL comment: Correct, will add this as a noteAdditionally, we have the following inputs on the current proposal:* In addition to UE specific DCI, group common DCI may also be considered for updating TCI states
* Based on the DCI formats selected as well as the HARQ ACK mechanism, the time delay after which the signaled TCI state is active needs to be further discussed. For example, if we re-use current DCI formats, for a beam indication on downlink scheduling DCI, the indicated beam may not be used before ACK is transmitted i.e., the scheduled PDSCH is received and the HARQ/ACK is transmitted based on previous TCI assumption.
* When separate DL/UL common beam indication is desired/required, the signaling should be flexible to support updating UL beams only or DL beams only. We want to include this option in the current proposal and add some FFS points for further consideration – for example, if we agree to use joint TCI state (common pool) for separate DL/UL beam indication, then UE needs to be able to differentiate between DL/UL joint beam update and DL-only or UL-only beam update based on either DCI format or some other indication/configuration. Otherwise for UL-only update, TCI state needs to ensure that DL QCL source is unchanged and only UL QCL source is updated, which might bring additional restriction on which TCI states from the common pool can be activated by MAC-CE.
* Finally, we would also like to clarify if more than 8 TCI states can be activated by MAC-CE.

Based on this, we have provided some updates to the original wording for further consideration:  On beam indication signaling medium to support common TCI state update in Rel.17 unified TCI framework:* Support L1-based common beam indication (TCI state update) with at least UE-specific (unicast) DCI
	+ FFS: L1-based beam indication with group-common DCI
	+ FFS: DCI formats that can be used to support L1-based common beam indication
	+ In addition, support a mechanism for UE to acknowledge successful decoding of TCI state update
		- FFS: activation delay for the indicated TCI state after acknowledgement
		- Note: Exact acknowledgment mechanism and TCI activation delay is TBD depending on the selected DCI format
	+ The updated TCI state applies at least to UE-dedicated reception on UE-specific CORESETs and the PDSCH scheduled by these CORESETs
		- FFS: TCI state assumption/update of the CORESET on which the UE receives the beam indication UE-specific DCI
	+ When joint DL and UL common beam indication is configured, the updated TCI state also applies to dynamic-grant/configured-grant based PUSCH and dedicated PUCCH resources
	+ When separate DL and UL common beam indication is configured
		- FFS: If a DL DCI format can be used to update UL beams
		- FFS: applicability of the updated joint TCI state for the case when DL only or UL only beam update is desired
* Support activation of multiple TCI states via MAC CE analogous to Rel.15/16
	+ FFS: Whether the number of TCI states activated by MAC-CE can be greater than 8

FL comment: Most of the above points have been addressed in the latest version of Proposal 3.2 (pending aspects). I will reflect your comments there.  |
| Vivo2 | Prefer the following version of Proposal 3.1 with clarification that the channels described in proposal 3.2 still needs further study. * Add a sub-bullet in bullet 1: The applicable channel of the indicated beams includes those other than described in proposal 3.2

Also adding some channels that needs further study in Proposal 3.2:* The beam indication UE-specific DCI (i.e. the CORESETs with the DCI) and the associated PUSCH/PUCCH for the acknowledgment of the beam indication DCI
* Non-UE-specific CORESETs
* PUSCH/PDSCH scheduled/activated and PUCCH transmission triggered by non-UE-specific CORESETs
 |
| FL comments | At least some pending issues identified in Aspect IV of proposal 3.2 will need to be discussed along with issue 1 since they involve the definition of unified TCI (e.g. channels/signals the joint/common TCI is applicable to).Also to better align with the terminology used in the previous agreement on issue 1, “joint” is used for the heading of proposal 3.1 instead of “common” (cf. issue 1a agreement in RAN1#102-e)  |
| Qualcomm2 | For latest proposal 3.1, we prefer to also include DL only (regular non-common), UL only (regular non-common), and joint DL/UL TCI state to achieve unified DCI based TCI update frame work. Note that in #102-e agreement, the issue 3 is for general DCI based TCI update as highlighted below, not restricted to a few types of TCI states. **Proposal 3.1**: On beam indication signaling medium to support joint TCI state update in Rel.17 unified TCI framework:* Support L1-based beam indication (TCI state update) using UE-specific (unicast) DCI format to indicate ~~M DL and/or N UL common TCI state(s)~~ M DL common TCI state(s), N UL common TCI states, X DL non-common TCI state(s), Y UL non-common TCI state(s) (if agreed), and/or Z joint DL/UL common TCI states from the active TCI states

FL comment: 1) Since the purpose of this enhancement is for the joint TCI state (for common beam operation), whether this can be applied to non-common (single channel) is FFS (included in Proposal 3.2). 2) Joint DL/UL is included (thanks for pointing out!) using the terms agreed in RAN1#102-e • [Issue 3] For Rel.17 NR FeMIMO, on dynamic TCI state update signaling medium: 1. In RAN1#103-e, investigate, for the purpose of down selection, the following alternatives:

Alt1. DCIAlt2. MAC CE |
| CATT | For the last bullet in issue 3.2, suggest to revise “update for single channel (e.g. PDSCH only, single CORESET)” to “update for single channel (e.g. PDSCH only, single CORESET) or a subset of channels”. |
| InterDigital | We are fine with proposal 3.1. For proposal 3.2, we also prefer to use existing DCI format if possible. In that regard, we would like to propose one FFS bullet as “FFS whether to reuse existing DCI format or introduce new DCI format” |
| Vivo3 | With the latest input that the DCI could be scheduling DCI, we would like to further refine the following statement in proposal 3.2 aspect IV:* The beam indication UE-specific DCI (i.e. the CORESETs with the DCI received by UE), the PDSCH scheduled by the beam indication DCI (or the CORESETs with the beam indication DCI DCI) and the associated PUSCH/PUCCH for the acknowledgment of the beam indication DCI
 |
| ZTE | Firstly we support FL proposal 3.1.Regarding Aspect IV in FL proposal 3.2, we are wonder: does it means that configured-grant based PUSCH may not be updated by common TCI state. Last meaning we already have the following agreement of supporting configured-grant based PUSCH as follows, and maybe we just move “Configured-grant based PUSCH” from Aspect IV as an independent aspect, e.g., Aspect VII: Details for updating TCI state for configured-grant based PUSCH (note: Tx beam for Type 1 CG-PUSCH is configured by RRC and Tx beams for Type 2 CG-PUSCH cannot changed during the active time in R15/16).**Agreement*** 1. Support joint TCI for DL and UL based on and analogous to Rel.15/16 DL TCI framework
		+ The term “TCI” at least comprises a TCI state that includes at least one source RS to provide a reference (UE assumption) for determining QCL and/or spatial filter
		+ The source reference signal(s) in M TCIs provide common QCL information at least for UE-dedicated reception on PDSCH and all or subset of CORESETs in a CC
			- FFS: Optionally this common QCL information can also apply to CSI-RS resource for CSI, CSI-RS resource for BM, and CSI-RS for tracking
			- FFS: Applicability on PDSCH includes PDSCH default beam
			- Working Assumption: Select between M=1 and M>=1
		+ The source reference signal(s) in N TCIs provide a reference for determining common UL TX spatial filter(s) at least for dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC,
 |

* 1. Issue 4 (MP-UE)

Table 8 Summary: issue 4

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 4.1 | Use cases for fast UL panel selection:Opt1. MPE mitigationOpt2. UE power saving (note: different panels can have different # ports)Opt3. UL mTRPOpt4. UL interference managementOpt5. Support different configurations across panels | **Opt1**: vivo, Samsung, Fraunhofer IIS/HHI, Intel, Nokia/NSB, MediaTek, Qualcomm, Xiaomi, NTT Docomo, APT, IDC, ZTE**Opt2**: Apple, OPPO, Samsung, Qualcomm, ZTE**Opt3**: vivo, APT, Intel**Opt4**: Qualcomm, NTT Docomo**Opt5**: Qualcomm, NTT Docomo | Whether **Opt3** should be addressed in MB (item 1) or mTRP (item 2a/c) will need to be discussed.Use cases would guide the decision on at least #4.6, 4.7, 4.8. For instance, at least Opt1, 2, 4 may suggest that (4.8) there should be an option where the UE decides panel selection/activation. |
| 4.2 | Whether to include enhancements for slow UL panel de/activation (for UE power saving) | **Yes**: vivo, OPPO, Sony, NTT Docomo, ZTE**No**: Qualcomm, MediaTek**Discuss with mTRP**: MediaTek | Note: As commented in RAN1#102-e by some companies, since Rel.17 WID only mentions fast panel selection, whether to include this enhancement needs to be agreed first.  |
| 4.3 | Whether to support per-panel UL PC | **Yes**: Sony, Fraunhofer IIS/HHI, Huawei/HiSi, LGE, Nokia/NSB, APT, Lenovo/MoM, ZTE**No**: OPPO (explicit per-panel UL PC is not needed since PC parameters is associated with uplink spatial setting)**Discuss in mTRP**: MediaTek |  |
| 4.4 | Whether to support per-panel UL TA | **Yes**: Sony, Fraunhofer IIS/HHI, Huawei/HiSi, LGE, Nokia/NSB, APT, ZTE**No**: OPPO**Discuss in mTRP**: MediaTek |  |
| 4.5 | Whether DL RX panel(s) can be different from UL TX panel(s)  | **Yes**: LGE, Nokia/NSB (but with overlap), MediaTek, Intel, NTT Docomo (with overlap), Qualcomm, Xiaomi, ZTE, APT (with overlap), Lenovo/MoM**No**: Huawei/HiSi | Early observation suggests that “Yes, with overlap” could be a good compromise. |
| 4.6 | NW to MP-UE signaling | **Panel selection/indication**: NTT Docomo, Spreadtrum, Lenovo/MoM, Xiaomi, APT, CATT, IDC, Nokia/NSB, Samsung (MPE), Qualcomm, ZTE | Note: What constitutes a panel (functionally) has been defined/agreed in RAN1#102-e. Note: First establish signaling requirements, then detailed mechanisms (including the need for a new/explicit panel ID vs. source RS/set indication, relation between panel indication with TCI framework) can be decided later based on the agreed panel definition. If panel selection report is (always) a part of beam report, CRI/SSBRI may not be needed |
| 4.7 | MP-UE to NW signaling | **Panel selection/indication**: Apple (antenna port group), CMCC, IDC, OPPO, MediaTek, Lenovo/MoM, Nokia/NSB, Samsung (MPE), ZTE, NTT Docomo, vivo, Spreadtrum, Qualcomm, Xiaomi**Along with CRI/SSBRI**: Qualcomm, vivo, CMCC, NTT Docomo, Intel, MediaTek**Along with panel CQI**: IDC**UE reporting on currently activated panel(s)**: APT, NTT Docomo, Qualcomm |
| 4.8 | Which side decides panel selection/activation [Qualcomm, APT, MediaTek] | **Alt1 NW:** ZTE**Alt2 UE:** Qualcomm, ZTE | Note: If NW decides panel activation, UE-to-NW signaling may comprise recommendation whereas NW-to-UE signaling includes assignment |
| 4.9 | Miscellaneous | Study necessity of additional signaling for two-layer dual-polarized beam: Sony |
|  |  |  |  |

**Proposal 4.2**: To facilitate fast UL panel selection for MP-UEs, *at least* the following features are supported in Rel.17:

* NW to MP-UE DL signaling on panel selection/indication
	+ FFS: Detailed mechanism for panel indication including the need for a new/explicit panel ID and the relation between panel indication with the unified TCI framework
	+ Note: Depending on the outcome of the unified TCI framework, additional NW to MP-UE DL signaling beyond beam indication may not be needed
* MP-UE to NW UL signaling (reporting) on panel-related indication
	+ FFS: Detailed mechanism for panel indication including the need for a new/explicit panel ID and the relation between panel indication with the unified TCI framework

**Proposal 4.1**: [Use case(s) for fast UL panel selection, and whether to include slow panel de/activation… need more discussion]

**Proposal 4.3**: [Which side decides panel activation … need more discussion, high priority]

**Proposal 4.4**: [DL RX and UL TX panels … need more discussion]

Table 9 Additional inputs: issue 4

|  |  |
| --- | --- |
| **Company** | **Input** |
| Qualcomm | Please find the added view per issue in the above list. Support FL’s proposal. Also added Opt. 4 and Opt. 5 for 4.1Added one issue under Miscellaneous* Which side decides panel activation (strongly prefer for high priority)
 |
| Xiaomi | Please find the added view for some issues in the above list. Support the proposal. |
| Samsung | In general supportive of FL proposal 4.2, but add the following to the 1st bullet: “Note: Depending on the outcome of unified TCI framework, additional NW to MP-UE DL signaling beyond beam indication may not be needed”  |
| Samsung | In general supportive of FL proposal 4.2, but add the following to the 1st bullet: “Note: Depending on the outcome of unified TCI framework, additional NW to MP-UE DL signaling beyond beam indication may not be needed”  |
| NTT Docomo | Please find our views in the above list. We support FL proposal 4.2. |
| APT | We are supportive of FL’s proposal. We would like to echo QC’s suggestion on deciding which side determine panel activation.  |
| Intel | Views updated in Table 8. Ok with proposal 4.2 |
| MediaTek | **On QC’s suggestion,** we share the same that the issue on which side decides UE panel activation/deactivation has to be discussed with highest priority (at least Issues 4.6 and 4.7 are better to be discussed after this issue is concluded). FL comment: added as issue 4.8 **On Issue 4.5**, we would like to clarify the meaning of “with overlap” more clearly. According to Nokia’s proposal, different sets of UE panels used for DL reception and UL transmission can be assumed but there should be a downlink reception of the QCL/spatial source on the same panel as UL transmission. Thus, to our understanding, UL panels should be a subset of DL panels. Not sure whether companies share the same understanding on “with overlap”.  |
| Qualcomm2 | We prefer to also discuss issue 4.8 with high priority, which may affect our view on the whole feature.  |
| InterDigital | Our views are updated in Table 8 and we are fine with proposal 4.2. |
| vivo | We would like to clarify that the panel info signaling may not be needed for both uplink signaling and downlink signaling. Thus for the DL part, we would like to clarify this may be implicit signaling based on UL signaling.* NW to MP-UE DL (explicit/implicit) signaling on panel selection/indication
 |
| ZTE | The definition of “UE panel ID” should be clarified firstly, and we think that it can be considered together with group based reporting in Item-2c. Also, we need to consider the AP-SRS triggering with a large triggering offset for panel activation, which is similar to AP-CSI-RS beam switching in Rel-15, e.g., 224 or 336 OFDM symbols. In such case, the sounding procedure of antenna switching may be equivalent to that of fast panel switching. For instance, one example for inter-panel antenna switching as follows. In such case, there may be different spatial relations applied to the respective UE panels, and the restriction about “same spatial relation for AP-SRS resources in a set for antenna switching” in the current spec may become invalid herein.  |

* 1. Issue 5 (MPE mitigation)

Table 10 Summary: issue 5

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Issue** | **Companies’ views** | **Moderator notes/observation** |
| 5.1 | When MPE event occurs, is UL spatial filter switching performed at beam-level or panel-level? | **Beam-level (including other UL TX beam candidates on the problematic panel)**: Xiaomi, Ericsson, Qualcomm, NTT Docomo, Intel, IDC, ZTE**Panel-level (excluding all UL TX beam candidates on the problematic panel)**: OPPO, Sony, Samsung, Xiaomi, NTT Docomo, Lenovo/MoM, Intel | This issue determines: 1) report content (CAT1), 2) candidates for alternative UL TX beam |
| 5.2 | CAT0 (MPE detection) | **No need for spec support**: MediaTek, Huawei/HiSi, Samsung, OPPO, Spreadtrum, APT**Wait until Rel.16 functionality is clear**: Ericsson**Spec support (?)**: | A number of CAT0 proposals are re-categorized into CAT1 aspects since they either represent reporting content or triggering condition.For condition-based triggering, the metric and threshold mechanisms can be decided later (e.g. BFR/partial BFR-like threshold, L1-RSRP/SINR threshold, Rel.16 PHR).Early observation suggests that CAT0 is not needed and can be a part of CAT1 if UE-initiated condition-based approach is agreed.Issue #5.3 on content (especially reporting alternate UL beam/panel) will have to be considered jointly with issue #4.7. This also depends on the conclusion on issue #4.1 and #5.1.CAT1: Can UE-initiated co-exist with NW-triggered (input from NTT Docomo)? |
| 5.3 | CAT1 (UE reporting): triggering | **No need for spec support:** Spreadtrum, OPPO**Wait until Rel.16 functionality is clear**: Ericsson,**UE-initiated condition-based**: Huawei/HiSi, Samsung, CATT, Nokia/NSB, Sony, LGE, Qualcomm, NTT Docomo, ZTE, [Intel], Xiaomi, MediaTek**UE-initiated without condition**: **NW-triggered**: NTT Docomo |
| CAT1 (UE reporting): content  | **No need for spec support:** Spreadtrum**Wait until Rel.16 functionality is clear**: Ericsson **Beam group indication**: IDC**MPE event indication**: Nokia/NSB, Samsung**CRI/SSBRI associated alternate UL panel and/or TX beam**: CATT, CMCC, Samsung, MediaTek, Intel, NTT Docomo, Qualcomm, Fraunhofer IIS/HHI, ZTE, Nokia/NSB, Apple, Sony, Ericsson, APT, Xiaomi**L1-RSRP (companion of CRI/SSBRI)**: Apple, Samsung, [Ericsson]**P-MPR**: Apple, Huawei/HiSi, IDC, vivo, Sony, Xiaomi, NTT Docomo (beam/panel specific), Nokia/NSB, CMCC, ZTE (beam/panel specific), Qualcomm, OPPO, Lenovo/MoM**Pcmax**: Apple**Virtual PHR**: Apple, ZTE |
| 5.4 | CAT2 (NW signaling in response to UE reporting) | **No need for spec support (beyond separate UL beam indication):** Spreadtrum, OPPO, MediaTek, APT, [Nokia/NSB]**gNB confirmation (ACK)**: IDC, NTT Docomo, Samsung | Note: The support of separate UL beam indication from DL has been agreed in RAN1#102-e (issue 1b). The scheme is to be decided (Alt1 vs 2-1 vs 2-2) |
|  |  |  |  |

**Proposal 5.1**: On UE reporting for MPE mitigation, support UE-initiated condition-based reporting in Rel.17

* In RAN1#103-e, further discuss and identify alternatives for the condition(s) for down-selection by RAN1#104-e

**Proposal 5.2**: [Switching, issue 5.1 ... need more discussion]

**Proposal 5.3:** On UE reporting for MPE mitigation

* [CAT1 content ... need more discussion - # companies proposing alternate panel/beam reporting is large, but more discussion is needed in relation to #4.1, 4.7, and 5.1]

**Proposal 5.4**: [CAT0 ... need more discussion]

**Proposal 5.5**: [CAT2 ... need more discussion]

Table 11 Additional inputs: issue 5

|  |  |
| --- | --- |
| **Company** | **Input** |
| Qualcomm | Please find the added view per issue in the above list. Support FL’s proposal. |
| Xiaomi | Please find the added view for some issues in the above list. Support the proposal. |
| NTT Docomo | Please find our views in the above list. And we would like to also consider periodic/aperiodic UL panel/beam reporting configured by NW, to schedule/indicate a better UL panel/beam and to avoid MPE happening. |
| APT | We are supportive of FL’s proposal.  |
| Intel | Views updated in Table 10. Note that RAN4 has already agreed to report P-MPR via MAC-CE and as such CAT1 solution is already supported. We need to further discuss augmentation of RAN4 solution to facilitate better MPE mitigation.  |
| MediaTek | On CAT1, even R16 already supports P-MPR reporting via MAC-CE, the UE still cannot provide other candidate NW beams for UL corresponding to different UL beams/panels without MPE issue to avoid the power back-off. Thus, the gain from Rel-16 P-MPR reporting is limited, which is also shown in our simulation results. Consequently, we see CAT1 solution is needed at least to support UE to report alternate UL panel(s) and/or TX beam(s). |
| InterDigital | Please check the updated view in Table 10 and we are fine with proposal 5.1. |
| vivo | Support the FL proposal with the following update:**Proposal 5.1**: On UE reporting for MPE mitigation, support UE-initiated condition-based reporting in Rel.17 with Rel-16 PMPR report as starting point.* In RAN1#103-e, further discuss and identify alternatives for the condition(s) for down-selection by RAN1#104-e
 |
| ZTE | We have one following alternative for this condition based reporting* The UL spatial resource, i.e., CRI/SSBRI, can be reported along with PHR/P-MPR MAC-CE reporting.
	+ MPE event detection as for R16 PHR/P-MPR MAC-CE can be reused as a baseline.
 |

* 1. Issue 6 (beam refinement/tracking)

Table 12 Summary: issue 6

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies** |
| 6.1 | Beam measurement and reporting enhancement via RACH for initial access (e.g. RO for measurement and MSG3 for reporting)  | AT&T, Qualcomm, Samsung, CMCC, Xiaomi  |
| 6.2 | Improving efficiency (latency, overhead) of beam refinement: * Enabling joint DL TX and RX beam refinement/tracking (P2+P3)
* Additional UE report to aid P1/P2/P3 related measurement/report configuration (triggering frequency or periodicity)
 | Apple (CSI-RS based), Samsung (CSI-RS based), Intel (using SRS/CRI), Qualcomm (e.g. reporting rate of beam direction change) |
| 6.3 | Beam management with reduced DL signaling: * Dynamic beam update based on beam report (without beam indication)
* Dynamic beam measurement and report triggered by beam indication (without CSI-RS/CSI triggering)
* Configuring/indicating to UE multiple SSBs for beam tracking
* Semi-static/pre-planned (RRC based) beam transition (for, e.g. isolated HST deployment)
* Reducing activation delay of TCI states (via storing QCL properties of a subset of source RSs for a time period)
 | Futurewei, Nokia/NSB, Samsung, Apple, Intel , NTT Docomo , Qualcomm, Xiaomi, Ericsson |
|  |  |  |

**Proposal 6.1**: Investigate and, if needed, specify *at least* the following enhancements for beam refinement/tracking in Rel.17:

* Beam measurement and reporting enhancement via RACH during initial access (e.g. RO for measurement and MSG3 for reporting)
* Improving efficiency (latency and/or overhead) of beam refinement:
	+ Enabling joint DL TX and RX beam refinement/tracking (P2+P3)
	+ Additional UE report to aid P1/P2/P3 related measurement/report configuration (triggering frequency or periodicity)
* Beam management with reduced DL signaling:
	+ Dynamic beam update based on beam report (without beam indication)
	+ Dynamic beam measurement and report triggered by beam indication (without CSI-RS/CSI triggering)
	+ Configuring/indicating to UE multiple SSBs for beam tracking
	+ Semi-static/pre-planned (RRC based) beam transition (for, e.g. isolated HST deployment)
	+ Reducing activation delay of TCI states (via storing QCL properties of a subset of source RSs for a time period)

Table 13 Additional inputs: issue 6

|  |  |
| --- | --- |
| **Company** | **Input** |
| Qualcomm | Our preferred discussion priority is issue #5, #1, #3, #2, #4 |
| Xiaomi | Please find the added view for some issues in the above list. |
| Samsung | We are supportive of investigating all the above issues. Issue #6.2 and #6.5 can perhaps be combined  |
| Intel | We think 6.4 is related to 6.3 and can be combined. We are supportive of discussing Issues #3 (and 4), #2 and #1 in order of priority.  |
| vivo | These issues should be deprioritized compared with previous 5 issues. |
| ZTE | We share the same views with vivo that issue-6 should be postponed after above five issues are stable considering the limited GTW and non-F2F meeting. Also, in our views, the key issues for latency of beam indication is: additional timing for waiting for the first SSB transmission and TL1-RSRP due to the misalignment of RAN1 and RAN4 timeline, and if discussed, we prefer to treat “Reducing activation delay of TCI states (via storing QCL properties of a subset of source RSs for a time period)” firstly among above candidates. |
|  |  |
|  |  |
|  |  |

* 1. Miscellaneous

Table 14 Summary: miscellaneous

|  |  |
| --- | --- |
| **Company** | **Input** |
| Apple | Joint SSB/CSI-RS: a new QCL-Type for 2 RSs with the same Tx beam |
| Nokia/NSB | P2 CSI-RS as QCL source for TRS |
| Lenovo/MoM | DCI or MAC CE for latency reductionMAC CE to indicate assoc. NZP CSI-RS and SRS resource set for non-CB-based UL |
| MediaTek | MAC CE to indicate assoc. NZP CSI-RS and SRS resource set for non-CB-based ULMAC CE based BFD/RLM RS update |
| Intel | QCL info between SSB and CSI-RS resource sets is indicated via MAC CE |
| NTT Docomo | P-SRS: increase #SRS resources or #SRS resource sets; MAC CE based spatial relation update  |

Appendix A: Agreements in RAN1#102-e

Issue 1

* [Issue 1] For Rel.17 NR FeMIMO, on the unified TCI framework
	1. Support joint TCI for DL and UL based on and analogous to Rel.15/16 DL TCI framework
		+ The term “TCI” at least comprises a TCI state that includes at least one source RS to provide a reference (UE assumption) for determining QCL and/or spatial filter
		+ The source reference signal(s) in M TCIs provide common QCL information at least for UE-dedicated reception on PDSCH and all or subset of CORESETs in a CC
			- FFS: Optionally this common QCL information can also apply to CSI-RS resource for CSI, CSI-RS resource for BM, and CSI-RS for tracking
			- FFS: Applicability on PDSCH includes PDSCH default beam
			- Working Assumption: Select between M=1 and M>=1
		+ The source reference signal(s) in N TCIs provide a reference for determining common UL TX spatial filter(s) at least for dynamic-grant/configured-grant based PUSCH, all or subset of dedicated PUCCH resources in a CC,
			- Optionally, this UL TX spatial filter can also apply to all SRS resources in resource set(s) configured for antenna switching/codebook-based/non-codebook-based UL transmissions
			- FFS: applicability of this UL TX spatial filter to SRS configured for beam management (BM)
			- FFS: PUSCH port determination based on the TCI, e.g., to be mapped with SRS ports analogous to Rel.15/16
			- Working Assumption: Select between N=1 and N>=1
		+ FFS: extension to common QCL information applied to only some of the CORESETs or PUCCH resources in a CC, e.g. for mTRP
		+ FFS: When used for the purpose of joint beam indication for UL and DL, whether a joint TCI pool for DL and UL dedicated for the purpose is used, or the same TCI pool as that used for the purpose of separate DL/UL beam indication is used
		+ Note: The resulting beam indication directly refers to the associated source RS(s)
		+ FFS (RAN1#103-e): Details on extension to intra- and inter-band CA
		+ FFS (RAN1#103-e): The supported number of active TCI states considering factors such as multi-TRP and issue 6
		+ FFS (RAN1#103-e): Applicable QCL types, and co-existence with DL TCI and spatial relation indication in Rel.15/16
	2. In RAN1#103-e, investigate, for the purpose of down selection, the following alternatives for accommodating the case of separate beam indication for UL and DL
		+ Alt1. Utilize the joint TCI to include references for both DL and UL beams
		+ Alt2. Utilize two separate TCI states, one for DL and one for UL. The TCI state for the DL is the same as agreed in 1a. The TCI state for the UL can be newly introduced.
			- Alt 2-1: The UL TCI state is taken from the same pool of TCI states as the DL TCI state
			- Alt 2-2: The UL TCI state is taken from another pool of TCI states than the DL TCI state
		+ Note: The resulting beam indication directly refers to the associated source RS(s)
		+ FFS (RAN1#103-e): Details on extension to intra- and inter-band CA
		+ Note: This may be related to issue 5 as well as other reasons for different TCIs such as network flexibility/scheduling
	3. Support the use of SSB/CSI-RS for BM and/or SRS for BM as source RS to determine 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
		+ FFS: Support the use of non-BM CSI-RS and/or non-BM SRS in addition
	4. In RAN1#103-e, decide if SRS for BM can be configured as a source RS to represent a DL RX spatial filter in the unified TCI framework
	5. In RAN1#103-e, decide/finalize all other parameters included in or concurrent with (but not included in) the TCI, e.g. UL-PC-related parameters (involving P0/alpha, PL RS, and/or closed loop index), UL-timing-related parameters
	6. In RAN1#103-e, identify issues pertaining to alignment between DL and UL default beam assumptions using the unified TCI framework

Issue 2

* [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 non-CA and CA setups such as intra-band and inter-band CA
		+ Use cases in comparison to Rel.15 L3-based handover (HO) taking into account potential extension of DAPS-based Rel.16 mobility enhancement to FR2-FR2 HO
		+ The extent of RAN2 impact (MAC CE, RRC, user plane protocols)
		+ 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 associated with TCI
		+ Method(s) for DL measurements and UE reporting (e.g. L1-RSRP) associated with non-serving cell(s)
		+ UE behavior for reception of signals and non-UE-specific control and data channels associated with non-serving cell(s)
		+ UL-related enhancements, e.g. related to RA procedure including TA
		+ Beam-level event-driven mechanism for L1/L2-centric inter-cell mobility

Issue 3

* [Issue 3] For Rel.17 NR FeMIMO, on dynamic TCI state update signaling medium:
	1. In RAN1#103-e, investigate, for the purpose of down selection, the following alternatives:
		+ 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
		+ Note: The study should consider factors such as feasibility for pertinent use cases, performance (based on at least the agreed EVM), overhead (including PDCCH capacity), latency, flexibility, reliability including the support of retransmission
		+ Note: This may be related to outcome of issue 1a), 1b), and 6a)
	2. In RAN1#103-e, depending on the outcome of 3a), identify candidates for more detailed design issues for the dynamic TCI state update such as
		+ Exact content
		+ Signaling format
		+ Reliability aspects including the support of retransmission
		+ Extensions, including the support of UE-group (in contrast to UE-dedicated) signaling

Issue 4

* [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 (one beam may correspond to two antenna ports if dual-polarized array is used)
		+ UE panels can constitute the same as well as different number of antenna ports, number of beams, and EIRP
		+ No beam correspondence across different UE panels
		+ FFS: For each UE panel, it can comprise an independent unit of PC, FFT timing window, and/or TA.
		+ FFS: Same or different sets of UE panels can be used for DL reception and UL transmission, respectively
	2. In RAN1#103-e, identify candidate use cases including MPE, and consider remaining aspects if use cases are identified
	3. In RAN1#103-e, identify candidate signaling schemes for the following:
		+ NW to MP-UE (taking into account potential extension of the unified TCI framework in issue 1)
		+ MP-UE to NW

Issue 5

* [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. 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. The need for UE reporting associated with an MPE and/or a potential/anticipated MPE event if the UE selects a certain UL spatial resource, e.g., corresponding to DL or UL RS
		+ CAT2. The need for NW signaling in response to the reported MPE event (taking into account issue 1) and UE behavior after receiving the NW signaling
		+ Note: RAN4 has agreed to specify P-MPR reporting (cf. CRs for TS 38.101/102/133) which can be used as a baseline scheme for further enhancement
		+ Note: This may be related to outcome of issue 4b)
	2. Companies are encouraged to submit evaluation results based on the agreed EVM to justify the benefits of the candidate solutions

# References

1. R1-2007546 Enhancement on multi-beam operation Futurewei
2. R1-2007586 Enhancements on multi-beam operation in Rel-17 Huawei, HiSilicon
3. R1-2007626 Discussions on multi-beam Enhancement Interdigital Inc.
4. R1-2007644 Further discussion on multi beam enhancement vivo
5. R1-2007763 Enhancements on multi-beam operation ZTE
6. R1-2007770 Further details on multi-beam and multi-TRP operation ZTE
7. R1-2007824 Discussion on enhancement on multi-beam operation CATT
8. R1-2008000 Enhancements on multi-beam operation CMCC
9. R1-2008148 Multi-beam enhancements Samsung
10. R1-2009367 Simulation results for multi-beam enhancements Samsung
11. R1-2008217 Enhancements on multi-beam operation OPPO
12. R1-2008755 Analysis of control signalling for multi-beam operation Dongquan OPPO Precision Elec.
13. R1-2008308 Enhancements on NR multi-beam operation AT&T
14. R1-2008346 Considerations on the enhancement of multi-beam operation Sony
15. R1-2008348 On beam management enhancement Apple
16. R1-2008573 Enhancements on multi-beam operation LG Electronics
17. R1-2008899 Enhancements on multi-beam operation Fraunhofer IIS, Fraunhofer HHI
18. R1-2008903 Enhancements on multi-beam operation Nokia, Nokia Shanghai Bell
19. R1-2008910 Enhancements on multi-beam operation Lenovo, Motorola Mobility
20. R1-2008943 Discussion on multi-beam operation NEC
21. R1-2008956 Enhancements on multi-beam operation Mediatek Inc.
22. R1-2008977 Enhancements on multi-beam operation Intel Corporation
23. R1-2009027 Enhancements on multi-beam operation Xiaomi
24. R1-2009060 Discussion on enhancements for multi-beam operation Asia Pacific Telecom co. Ltd
25. R1-2009141 Enhancements on multi-beam operation Spreadtrum Communications
26. R1-2009155 Discussion on multi-beam operation ASUSTeK
27. R1-2009158 Multi-beam enhancements Convida Wireless
28. R1-2009129 Enhancement on multi-beam operation Sharp
29. R1-2009132 Other enhancements for beam management Sharp
30. R1-2009174 Discussion on multi-beam operation NTT DOCOMO Inc.
31. R1-2009250 Enhancements on multi-beam operation Qualcomm Incorporated
32. R1-2009288 Enhancements on multi-beam operation Ericsson
33. R1-2009290 Additional simulation results on multi-beam operation Ericsson