**3GPP TSG RAN WG1 #106-e R1-210xxxx**

**e-Meeting, August 16th – 27th, 2021**

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

**Title:** Moderator summary#5 for multi-beam enhancement: ROUND 4

**Document for:** Discussion and Decision

## Introduction

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

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| 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 for intra-cell and inter-cell scenarios to support higher UE speed 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)
		4. For inter-cell beam management, a UE can transmit to or receive from only a single cell (i.e. serving cell does not change when beam selection is done). This includes L1-only measurement/reporting (i.e. no L3 impact) and beam indication associated with cell(s) with any Physical Cell ID(s)
			1. The beam indication is based on Rel-17 unified TCI framework
			2. The same beam measurement/reporting mechanism will be reused for inter-cell mTRP
			3. This work shall only consider intra-DU and intra-frequency cases
	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
 |

This summary includes the following:

* Observation and proposal
* Summary of current companies’ positions on each of the aspects within the category

## Summary of companies’ inputs

The listed issues are structured primarily to facilitate some progress on pending issues identified in the agreements (see Appendix A).

### Issue 1 (Rel.17 unified TCI framework – note: for intra-cell beam management)

Table 1 Summary: issue 1

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| FL proposal 1.E (UL PC for SRS)Note: Already discussed since round 0 | **Support**: Apple, MTK, Qualcomm, Lenovo/MotM, NTT Docomo, FGI/APT, Ericsson, Samsung, Intel, ZTE, Convida, CATT, vivo, Futurewei, Spreadtrum, AT&T, NTT Docomo,**Not support**: OPPO |
| FL proposal 1.F (M,N>1)Note: Already discussed since round 0 | **Support**: Qualcomm, Lenovo/MotM, FGI/APT, Samsung, ZTE, IDC, CATT, vivo, Futurewei, Lenovo/MotM, AT&T, **Not support**: NTT Docomo, Ericsson, Fraunhofer IIS/HHI, Intel, Convida, MTK, Apple (ok mTRP, not ok sTRP), Spreadtrum (use cases shouldn’t be FFS), OPPO (finalize use case first), Xiaomi, CMCC, Sony |
| Finalizing UL PC parameters other than PL-RS:Whether to configure the same setting of (P0, alpha, closed loop index) per TCI state across channels and apply a channel dependent component, or not (i.e. configure a channel dependent setting of (P0, alpha, closed loop index) per TCI state)Note: It was agreed (RAN1#105-e) to finalize this in RAN1#106-e | **Yes**: Samsung, LGE, NTT Docomo**No:** ZTE, vivo, OPPO, MTK, Intel, Ericsson, IDC,CATT |

**Proposal 1.E**: On the setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index) for Rel.17 unified TCI framework, the setting of (P0, alpha, closed loop index) for SRS can also be associated with UL or (if applicable) joint TCI state.

* If not associated, the setting(s) of (P0, alpha, closed loop index) for SRS per BWP is independent of the UL or (if applicable) joint TCI states
* This is only applicable for SRS sets using Rel-17 TCI state to determine their spatial relation.

FFS: Whether more than one parameter sets can be configured, e.g. for different traffics

**Proposal 1.F**: On Rel-17 unified TCI, in addition to (M,N)=(1,1), the following combinations are supported: (M,N)=(2,1), (1,2), and (2,2) for mTRP and some sTRP use cases

* Note: At least in Rel-17, the support of N=2 does not imply the support of STxMP
* FFS: Which sTRP use case(s) and other use case(s), e.g. CORESET beam diversity, inter-cell beam management, MP-UE, inter-band CA
	+ Strive unified signaling to support sTRP use case(s)
* FFS: How to support M>1 and/or N>1

**Proposal 1.G**: On the setting of UL PC parameters except for PL-RS (P0, alpha, closed loop index) for Rel.17 unified TCI framework, a channel/signal dependent setting of (P0, alpha, closed loop index) per TCI state is configured for each of the applicable UL channels and signals.

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 1****2) Share your inputs on the above FL proposals** |
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### Issue 2 (inter-cell beam management)

Table 3 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.3 | Maximum value of K (beams associated at least with non-serving cell(s) reported in a single CSI reporting instance), i.e. KMAX beyond 4 (already agreed)Note: UE capability of supporting < KMAX is neither ruled out nor within the scope  | **8**: Ericsson, Nokia/NSB, AT&T, CATT**16**: Samsung, Huawei/HiSi, CATT, ZTE |
| 2.4 | How to set the value of K≤ KMAXAlt1: RRC configured (based on UE capability)Alt2: Dynamically selected by UE (indicated in CSI reporting, two-part UCI) | **Alt1**: Lenovo/MotM, Ericsson, ZTE,CATT**Alt2**: Samsung  |
| 2.5 | The maximum value of NMAX (number of RRC configured non-serving cell(s) for measurement/reporting) Note: UE capability of supporting <Nmax is neither ruled out nor within the scope of 2.4 | **1**: OPPO**2**: Lenovo/MotM **4**: Samsung**KMAX**: AT&T, CATT, Ericsson, ZTE, Samsung  |
| 2.7 | Whether to support event-driven reporting behaviorNote: For beam reporting, revised WID has ruled out L3 involvement | **Yes, with L1 event**: Xiaomi, Nokia/NSB, Samsung, Sony, Qualcomm, Apple, LG, [Intel], [CATT]**Yes, with L3 event**: Xiaomi, ZTE, [Intel], [CATT] **No**: Ericsson, MTK |
| 2.8 | Synchronization and timing advance assumptions between cellsNote: This issue was identified in RAN#92 and needs to be concluded in RAN1#106-e | **Single TA value across cells (TRPs with different PCIs)**: OPPO, MTK **Multiple TA values across cells (TRPs with different PCIs)**: vivo, Futurewei, Qualcomm, Intel, Ericsson, Apple, NTT Docomo, Samsung, Sony, ZTE |
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**Proposal 2.C**: On Rel.17 L1-RSRP multi-beam measurement/reporting enhancements for inter-cell beam management and inter-cell mTRP, also support KMAX = 8.

* Note: KMAX is defined as the maximum number of beams associated at least with TRP(s) with different PCIs from the serving cell that are reported in a single CSI reporting instance

**Proposal 2.D**: On Rel.17 L1-RSRP multi-beam measurement/reporting enhancements for inter-cell beam management and inter-cell mTRP, for a given UE capability of KMAX, the value of K≤ KMAX is RRC configured

* Note: K is defined as the number of beams associated at least with TRP(s) with different PCIs from the serving cell that are reported in a single CSI reporting instance
* Note: KMAX is defined as the maximum number of beams associated at least with TRP(s) with different PCIs from the serving cell that are reported in a single CSI reporting instance

**Proposal 2.E**: On Rel.17 L1-RSRP multi-beam measurement/reporting enhancements for inter-cell beam management and inter-cell mTRP, NMAX (the maximum number of RRC configured TRP(s) with different PCIs from the serving cell for measurement/reporting) is equal to KMAX.

**Proposal 2.F**: On Rel.17 L1-RSRP multi-beam measurement/reporting enhancements for inter-cell beam management and inter-cell mTRP, in RAN1#106bis-e, select one of the following alternatives:

* Alt1. Support L1-based event-driven beam reporting for inter-cell beam management and inter-cell mTRP
* Alt2. Support L3-based event-driven beam reporting for inter-cell beam management and inter-cell mTRP
* Alt3. In Rel-17, event-driven beam reporting is not supported for inter-cell beam management and inter-cell mTRP

**Proposal 2.G**: On Rel.17 L1-RSRP multi-beam measurement/reporting enhancements for inter-cell beam management and inter-cell mTRP, multiple TA values across TRPs with different PCIs from that of the serving cell are supported.

Table 4 Additional inputs: issue 2

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 3 if needed****2) Share your inputs on the above FL proposals** |
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### Issue 3 (beam indication signaling medium)

(no more for this meeting)

### Issue 4 (MP-UE)

Table 5 Summary: issue 4

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| FL proposal 4.A V1  | **Support/ok**: LG, Ericsson, OPPO, CATT, IDC, **Not support/concern**: MTK, Apple, NTT Docomo, Qualcomm, Samsung, Intel, Lenovo/MotM, Xiaomi, ZTE, Huawei/HiSi, CMCC,  |
| FL proposal 4.A V2 | **Support/ok**: LG, Sony, **Not support/concern**: Ericsson,  |

**Proposal 4.A V1**: On Rel.17 enhancements to facilitate UE-initiated panel activation and selection:

* No additional specification enhancement on CSI/beam reporting to facilitate UE-initiated panel activation/selection (i.e. Opt1-3 per RAN1#104-bis-e agreement)
* Support multiple codebook-based SRS resource sets with different maximum number of UL MIMO layers
	+ FFS: Whether/how the selection of SRS resource for codebook-based PUSCH transmission is controlled by UE.

OR

**Proposal 4.A V2**: On Rel.17 enhancements to facilitate UE-initiated panel activation and selection:

* A panel entity corresponds to a reported CSI-RS and/or SSB resource index in a beam reporting instance (i.e. Opt1-1 per RAN1#104-bis-e agreement)
	+ The correspondence between a panel entity and a reported CSI-RS and/or SSB resource index is informed to NW
	+ Note: the correspondence between a CSI-RS and/or SSB resource index and a panel entity is determined by the UE (analogous to Rel-15/16)
* Support multiple codebook-based SRS resource sets with different maximum number of UL MIMO layers
	+ FFS: Whether/how the selection of SRS resource for codebook-based PUSCH transmission is controlled by UE.

Table 6 Additional inputs: issue 4

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| **Company** | **Input** |
| Mod V0 | **Check and update Table 5 if needed based on the two alternative proposals (4.A V1 vs 4.A V2).**  |
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### Issue 5 (MPE mitigation)

Table 7 Summary: issue 5

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| **Proposal** | **Companies’ views** |
| 5.A below | **Support:** Qualcomm, NTT Docomo, Spreadtrum, Lenovo/MotM, Xiaomi, vivo, ZTE, CMCC, Sony, Nokia/NSB, Samsung, MTK, Apple, Intel (Alt1), Huawei/HiSi, LG, IDC**Not support:** Ericsson, CATT (add L1-SINR), OPPO (add vPHR, remove Alt2), [Intel], Convida,  |

**Proposal 5.A**: On Rel.17 enhancements to facilitate MPE mitigation, support the following enhancement on the Rel-16 event-triggered P-MPR-based reporting (included in the PHR report when a threshold is reached, reported via MAC-CE):

* N≥1 P-MPR values can be reported
	+ The N P-MPR values are reported together with one of the followings (to be finalized in RAN1#106bis-e):
		- Alt1: For each P-MPR value, up to M SSBRI(s)/CRI(s), where the SSBRI(s)/CRI(s) is selected by the UE from a candidate SSB/CSI-RS resource pool (FFS: how to perform the selection)
		- Alt2: For each P-MPR value, at least one panel entity indicator
* FFS: Whether N represents the number of selected beams or the number of panels
* FFS: Supported values of N
* FFS: Whether beam-specific and/or panel-specific PHR is also reported
* FFS: Additional reporting quantities, e.g. SSBRI/CRI, MPR+DL RSRP, UL RSRP, or modified virtual PHR
* FFS: additional signaling (e.g. CSI triggering) from the NW

Table 8 Additional inputs: issue 5

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 7 if needed** **2) Share your inputs on the above FL proposal (new argument, please don’t repeat the old arguments)** |
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### Issue 6 (advanced beam refinement/tracking)

Table 9 Summary: issue 6

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| **#** | **Issue** | **Companies’ views on specific candidate schemes** |
| 6.1 | Group 1: Beam management with reduced DL signaling to reduce latency* Opt 1-A. UE-initiated beam selection/activation based on beam measurement and/or reporting (without beam indication or activation from NW)
* Opt 1-B. Beam measurement/reporting/refinement/selection triggered by beam indication (without CSI request)
* Opt 1-C. Aperiodic beam measurement/reporting based on multiple resource sets for reducing beam measurement latency
 | **Opt 1-A**: ZTE, vivo, Futurewei, OPPO, Qualcomm, MTK, Ericsson, Apple, LGE, NTT Docomo, Nokia/NSB, IDC (only within an indicated TCI state group, e.g., by a group-ID)**Opt 1-B**: ZTE, IDC, Samsung, Qualcomm, OPPO**Opt 1-C**: ZTE, CATT, Qualcomm, Samsung |
| 6.2 | Group 2: Reducing activation delay of TCI states and PL-RSs (including other WGs, e.g. RAN4)* Opt 2-A: Latency reduction for MAC CE based TCI state activation, or frequency/time/beam tracking
* Opt 2-B: Latency reduction for MAC CE based PL-RS activation
* Opt 2-C: One-shot timing update for TCI state update

Note: A number of companies argued that most of the schemes in this category can be handled exclusively in RAN4 | **Opt 2-A**: ZTE (independent pools for a time period), vivo, OPPO, Qualcomm, Ericsson, Apple, NTT Docomo, Nokia**Opt 2-B**: ZTE (independent pools for a time period), vivo, Qualcomm**Opt 2-C**: Ericsson**Discuss first in RAN4:** IDC, Samsung**Send LS to RAN4**: MTK, Ericsson |

Overall the following summary on each of the options supported by >1 companies can be inferred (courtesy of Bo/ZTE):

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| Option 1-A:1. UE-initiated beam selection based on, e.g. CFRA, CBRA, UL CG, MAC-CE or UCI
	* Cat-1: The selected beam (DL-only or DL/UL) is reported by an event-triggered UE beam report.
		1. Example-1: UE sends a CBRA to gNB and after CBRA, all the channels that a unified TCI is applied for should be based on the SSB/CSI-RS associated with the PRACH.
		2. Example-2: UE initiated beam reporting based on PRACH or UL CG, and DL beam selection
		3. Example-3: MAC CE on PUSCH is sent by UE to inform the appropriate DL/UL beam to gNB, where the MAC-CE may be analogous to BFR MAC-CE.
	* Cat-2: The selected beam is reported by a legacy UE beam report (NW-initialized)
2. UE-initiated beam activation based on beam reporting
	* The reported beam is applied directly if the number of supported activated beam by the UE is one and/or after receiving gNB response signaling.
	* Cat-2: The activated beam is reported by a legacy UE beam report (NW-initialized)
		1. Event-driven mechanism (Cat-1) can be further considered.
3. UE initiated UL-only beam selection
	* If the channel conditions are bad for current beam, the UE can automatically select an alternative beam from the other beams in the gNB-configured set containing more than one UL beam.

Option 1-B: 1. AP TRS measurement can be triggered after beam activation MAC-CE to avoid SSB measurement
	* Note: CSI reporting is not needed.
2. Beam measurement and reporting is directly triggered by beam indication
	* TCI state indicated to the UE is linked (by configuration) to a CSI-RS (or SRS) resources (e.g., a CSI-RS set with repetition = ‘ON’) for measurement and measurement report
	* Note: Above applies to P2/P3/TRS/CSI

Option 1-C:1. On CMR resource configuration for aperiodic beam measurement and reporting, multiple CMR resource sets can be configured
	* Additional UE report to aid at least P3 related measurement/report configuration, such as triggering request, the number of candidate RS(s) or periodicity) should be considered.
2. UL beam sweeping with each set (joint U2+U3, e.g., by SRS) and joint DL and UL beam sweeping (e.g., P2+U3)
3. An indication on whether intra-symbol beam sweeping is possible or not can be provided by gNB

Opt 2-A:1. UE is to store the QCL properties of the root SSB (from MTK, QC, DOCOMO, Samsung and ZTE).
	* Example-1: UE shall store the QCL propertied once its measurement report is sent, e.g., for UE-initiated beam activation/selection as in Opt 1-A.
	* Example-2: UE can maintain an independent pool of QCL properties of the root SSBs by MAC-CE
2. Beam indication signaling can trigger aperiodic CSI-RS for BM and aperiodic TRS to speed up beam refinement and time/frequency offset tracking (from Apple).
3. Beam activation MAC CE can trigger aperiodic TRS to speed up time/frequency offset tracking (from vivo).

Opt 2-B:1. UE is to store the PL estimate from an independent PL-RS pool activated by MAC-CE (from ZTE).
2. UE shall use L1-RSRP as metric for pathloss estimation during the transition period (from Apple).
3. The required sample # should be up to UE capability (from QC).
4. Simultaneous PL-RS update across BWPs/CCs (from DOCOMO and vivo).
 |

The following **observation** can be made:

* Given the amount of time left for Rel-17 and the slow progress rate of 8.1.1 (some caused by the inter-WG ping-pong effect):
	+ Choosing more than one options is clearly unrealistic for Rel-17 time-frame
	+ Group 2 is more prone to the ping-ping effect
* Among all the options, Opt 1-A draws more interest than the other options

Based on the above observation, the following proposal can be made:

**Proposal 6.A**: On Rel-17 enhancements to facilitate advanced beam refinement/tracking, in Rel-17, further focus study (including down-selection) and, if needed, specification effort on Opt 1-A as agreed in RAN1#105-e (UE-initiated beam selection/activation based on beam measurement and/or reporting, without beam indication or activation from NW) comprising:

* UE-initiated (DL-only or DL/UL) beam selection, including the following options
	+ The selected beam is reported by an event-triggered UE beam reporting via, e.g. UCI, MAC CE, PRACH, UL CG, or CBRA/CFRA
	+ The selected beam is reported by a legacy UE beam report (NW-initialized)
* UE-initiated beam activation based on beam reporting
	+ The reported beam is applied directly if the number of supported activated beam by the UE is one and/or after receiving gNB response signaling
* UE-initiated UL-only beam selection
	+ The UE can select an alternative beam from the other beams in the gNB-configured set containing more than one UL beam

Table 10 Additional inputs: issue 6

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| **Company** | **Input** |
| **From Round 0** |
| Ericsson | Opt 1-C is supported from Rel-15. One DCI can point at one aperiodic trigger state, which points at two report settings. These two report settings point at two different aperiodic CSI-RS resource sets ,and where the slot offset is defined differently for the two aperiodic CSI-RS resource sets. |
| ZTE | Generally, we think that the down-selection should be based on the popularity of each candidates, and whether the companies’ proposal can be converged. If whether to send an LS to RAN4 is controversial, we may focus on group-1 firstly. From ZTE perspective, our first preference is Opt 1-C. For Opt 1-A, we think that gNB response, e.g., UE initialized beam activation by legacy UE reporting and then DCI indication for confirmation, is necessary. For Opt 1-B, we slightly prefer to focus on TRS firstly for narrowing the scope. |
| InterDigital | We share similar views with ZTE, in terms of topic prioritization, that we can focus on Group 1 first.For Opt 1-A, we believe the UE-initiated beam selection/activation (if adopted) should be at least restricted within a certain set of TCI states (not freely chosen by the UE), meaning at least a certain degree of controlling a candidate beam set (e.g., TCI state group) indicated to the UE should be given to the gNB side, for reliability of overall beam management procedures.  |
| Mod  | For the next round we will focus on Group 1 and see if we can progress.  |
| **ROUND 4** |
| Mod V0 | **Please share your inputs on proposal 6.A** |
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# References

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| --- | --- | --- | --- |
| 1 | R1-2106864 | Summary of offline discussion on unified TCI and inter-cell beam management | Moderator (Samsung) |
| 2 | R1-2106463 | Enhancements on multi-beam operation in Rel-17 | Huawei, HiSilicon |
| 3 | R1-2106541 | Enhancements on Multi-beam Operation | ZTE |
| 4 | R1-2106571 | Further discussion on multi beam enhancement | vivo |
| 5 | R1-2106640 | Remaining Details on Enhancements for Multi-beam Operation | IDC, Inc. |
| 6 | R1-2106666 | Enhancements on Multi-beam Operation | Lenovo, Motorola Mobility |
| 7 | R1-2106685 | Enhancements on Multi-beam Operation | Spreadtrum Communications |
| 8 | R1-2106789 | Further enhancement on multi-beam operation | Sony |
| 9 | R1-2106864 | Moderator summary for multi-beam enhancement | Moderator (Samsung) |
| 10 | R1-2106865 | Multi-Beam Enhancements | Samsung |
| 11 | R1-2106935 | Discussions on enhancements on multi-beam operation | CATT |
| 12 | R1-2107029 | Enhancements on Multi-beam Operation | Fujitsu |
| 13 | R1-2107085 | Enhancement on multi-beam operation | FUTUREWEI |
| 14 | R1-2107143 | Discussion on multi-beam operation | NEC |
| 15 | R1-2107203 | Enhancements on Multi-beam Operation | OPPO |
| 16 | R1-2107297 | Discussion of enhancements on multi-beam operation | FGI, Asia Pacific Telecom |
| 17 | R1-2107323 | Enhancements on Multi-beam Operation | Qualcomm Incorporated |
| 18 | R1-2107390 | Enhancements on multi-beam operation | CMCC |
| 19 | R1-2107464 | Enhancements on multi-beam operation | Fraunhofer IIS, Fraunhofer HHI |
| 20 | R1-2107485 | Enhancement on multi-beam operation | MTK Inc. |
| 21 | R1-2107570 | Enhancements to Multi-Beam Operations | Intel Corporation |
| 22 | R1-2107628 | Enhancements on Multi-beam Operation | Ericsson |
| 23 | R1-2107689 | Enhancements on Multi-beam operations | AT&T |
| 24 | R1-2107718 | Views on Rel-17 Beam Management enhancement | Apple |
| 25 | R1-2107814 | Enhancements on Multi-beam Operation | LG Electronics |
| 26 | R1-2107838 | Discussion on multi-beam operation | NTT DOCOMO, INC. |
| 27 | R1-2107893 | Enhancements on multi-beam operation | Xiaomi |
| 28 | R1-2108019 | Enhancements on Multi-beam Operation | Convida Wireless |
| 29 | R1-2108052 | Enhancements on Multi-beam Operation | Nokia, Nokia Shanghai Bell |
| 30 | R1-2106548 | Further details on Multi-beam and Multi-TRP operation | ZTE |
| 31 | R1-2106671 | HARQ feedback of SPS PDSCH reception in multi-DCI based multiple TRPs | Lenovo, Motorola Mobility |
| 32 | R1-2106872 | Additional enhancements for multi-beam | Samsung |
| 33 | R1-2107210 | Discussion on further enhancements for multi-beam operation | OPPO |
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