**3GPP TSG RAN WG1 #106-e R1-2108399**

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

**Agenda item:** 8.1.1

**Source:** Moderator (Samsung)

**Title:** Moderator summary#4 for multi-beam enhancement: ROUND 3

**Document for:** Discussion and Decision

## Introduction

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

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| 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
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This summary includes the following:

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

**This round targets some email endorsement after the next GTW on Monday 08/23 (12:00-15:00 UTC). Please provide your inputs. As usual I will move the discussion on prospective proposals to the email reflector as it gets close to the endorsement time.**

## 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) and 2 (inter-cell beam management)

Table 1 Summary: issue 1 and 2 sticky points

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| **Proposal 1.B-3****Working Assumption (to be confirmed this week)**On Rel.17 unified TCI framework, for intra-cell beam indication, the following DL RSs can share the same indicated Rel-17 TCI state as UE-dedicated reception on PDSCH and for UE-dedicated reception on all or subset of CORESETs in a CC: * DMRS(s) associated with non-UE-dedicated reception on CORESET(s) and the associated PDSCH
	+ FFS: Any restriction on the SS type other than USS associated with the CORESET(s)

*Objected by Futurewei***Proposal 2.A.1+5**On Rel.17 beam indication enhancements for inter-cell beam management, the supported Rel-17 MAC-CE-based and/or DCI-based beam indication (at least using DCI formats 1\_1/1\_2 with and without DL assignment including the associated MAC-CE-based TCI state activation) applies to:* The same channels and signals as for intra-cell beam management (what has been agreed up to day 5 of RAN1#106-e). Select one from the following alternatives:
	+ Alt1. Additionally applicable for non-UE specific channels
		- Note: Some companies have concerns that this violates RAN conclusion from RAN#92-e
	+ Alt3. No additional channel from non-serving cell is allowed
* For the aforementioned applicable DL channels and DL signals, SSB associated with a physical cell ID different from that of the serving cell is used as an indirect QCL reference for DL TCI (in case of separate DL/UL TCI) or joint TCI
	+ Note: When RS X is an indirect QCL reference of a target channel, there exists at least one other source signal on the QCL chain between RS X and the target channel. Here, Rel-15/16 QCL rule is reused by replacing SSB with SSB associated with a physical cell ID different from that of the serving cell
* This inter-cell beam management does not mandate a UE to support more than one active TCI state / QCL per band

*3rd bullet point was proposed by Apple, but Futurewei couldn’t accept* |

Futurewei has stated that the reason for their objection over proposal 1.B-3 is because it is related to proposal 2.A-1+5. While the two are not categorically related (one for intra-cell, the other for inter-cell), the wording “the same channels and signals ...” indeed links proposal 2.A-1+5 by reference to proposal 1.B-3.

To progress together and compromise, the moderator proposes the following combo:

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| **Combo Proposal**:On Rel.17 unified TCI framework, for intra-cell beam indication, the following DL RSs can share the same indicated Rel-17 TCI state as UE-dedicated reception on PDSCH and for UE-dedicated reception on all or subset of CORESETs in a CC: * DMRS(s) associated with non-UE-dedicated reception on CORESET(s) and the associated PDSCH
	+ FFS: Any restriction on the SS type other than USS associated with the CORESET(s)

On Rel.17 beam indication enhancements for inter-cell beam management, the supported Rel-17 MAC-CE-based and/or DCI-based beam indication (at least using DCI formats 1\_1/1\_2 with and without DL assignment including the associated MAC-CE-based TCI state activation) applies to:* The channels and signals as for intra-cell beam management except for CORESET(s) along with the respective PDSCH reception(s) if the CORESET(s) is associated with any Type0/0A/1/2 CSS set
* For the aforementioned applicable DL channels and DL signals, SSB associated with a physical cell ID different from that of the serving cell is used as an indirect QCL reference for DL TCI (in case of separate DL/UL TCI) or joint TCI
	+ Note: When RS X is an indirect QCL reference of a target channel, there exists at least one other source signal on the QCL chain between RS X and the target channel. Here, Rel-15/16 QCL rule is reused by replacing SSB with SSB associated with a physical cell ID different from that of the serving cell
* This inter-cell beam management does not mandate a UE to maintain more than one active TCI state / QCL per band for a given time
	+ That is, beam switching across slots is used to receive or transmit along two different beams
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Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **1) Share your inputs on the above Combo Proposal** |
| LG | Support combo proposal, which is a good compromise. |
| MediaTek | We are fine with the combo proposal in principle. However, for the first sub-bullet of the second bullet, when precluding channels from the applicable list, we suggest to describe it more specifically. If we follow current wording, one potential issue we have mentioned several times is that PDCCH receptions on the same CORESET could belong to non-UE-dedicated and UE-dedicated channels at the same time, and we don't prefer to handle separate beam indications on the same CORESET. In summary, we suggest the following specific definition of “non-UE-specific channels”:* The channels and signals as for intra-cell beam management except for ~~non-UE-specific channels~~ CORESET(s) along with the respective PDSCH reception(s) if the CORESET(s) is associated with any Type0/0A/1/2 CSS set

[Mod: Done] |
| Mod V3 | Revised per MediaTek’s comment |
| NTT Docomo | For the last sentence (added by Apple), if we understand of Apple’s comment correctly, it is from UE capability perspective: i.e. L1/L2 inter cell mobility does not mandate UE to “support” more than one active TCI states. In Rel.15, mandatory capability was one active TCI state for PDSCH and one active TCI state for PDCCH (i.e., total two TCI states). As we already agreed, DCI based beam switching is optional for unified TCI state. But, we need to discuss whether it is allowed to activate Rel.15 TCI state to CORESET0 and Rel.17 unified TCI states to common beam, for a basic UE. If the answer is no, “one” active TCI should be fine (it means unified TCI cannot activated, if Rel.15 TCI state is activated in any channel/RS). We think this is more general discussing for both intra-cell and inter cell, so it may be good to discuss separately.Also, if UE supports one active TCI, the beam switching should be done by MAC CE (not slot by slot), hence we suggest to update as below.* This inter-cell beam management does not mandate a UE to report more than [one] active TCI state / QCL per band [per BWP in CC] in UE capability signaling.
	+ If UE reports [one], beam switching can be done by MAC CE.

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| Apple | First, we would like to say that if this feature is really going to be deployed, it should not mandate UE to support >1 active TCI states. I do not think UE would spend quite a lot of effort to increase number of beam tracking loops just for this feature.Second, if we want to split the common and dedicated signals, we think we should use PDCCH to take instead of CORESET as follows. The number of CORESETs is limited, we should avoid the way that some CORESETs are for dedicated signal while some are for common signal.* The channels and signals as for intra-cell beam management except for PDCCH along with the respective PDSCH reception(s) if the PDCCH is associated with any Type0/0A/1/2 CSS set

Third, we tried to see a potential outcome of the RACH procedure if this split is supported and enabled.* Msg1 (PRACH) – SC
* Msg2 (RAR) – SC
* Msg3 – SC or NSC?
* Msg4 (C-RNTI based PDCCH) – NSC

A RACH procedure is split on two cells. Is it really reasonable? Further, how to make sure CBRA based BFR can work in this case, now that the beam for Msg4 has already failed?Fourth, regarding PDCCH on Type3 CSS, sometimes it can be a DCI format 2-x, which is a common signal, while sometimes it can be a DCI format 0-x/1-x, which is a dedicated signal. As some companies argued, common signal should always be from the SC, then should Type3 CSS be precluded as well? But if Type3 CSS is included, sometimes it may be used to send dedicated signal, then does it mean UE needs to communicate with both cells from dedicated signal perspective, which is mTRP operation?I guess we would see more issues. But compared to inter-cell mTRP, we failed to see the benefit for this feature. Initially we thought this might be more friendly to UE implementation (it only requires 1 active TCI), but if this requires the same complexity as inter-cell mTRP, I do not really know why UE would choose to support this feature instead of inter-cell mTRP. Maybe the whole feature can be deprioritized and we can prioritize inter-cell mTRP.@Docomo, in Rel-15, 1 active beam for both UL and DL is mandatory (FG 2-62). In commercial UE, we also see it can only support 1 active beam. |
| Ericsson | Support |
| Futurewei | This is a good way to compromise. Support with the following suggested change on the last sub-bullet:* This inter-cell beam management does not mandate a UE to maintain more than one active TCI state / QCL per band for a given time
	+ That is, beam switching across slots can be used to receive or transmit along two different beams
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### Issue 3 (beam indication signaling medium)

Table 5 Summary: issue 3

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| **Proposal** | **Companies’ views** |
| 3.A BAT quantization/definition* Alt1: X ms (hence not SCS dependent)
* Alt2: Y symbols (hence SCS dependent)
 | **Alt1 (X ms)**: Apple, OPPO, CATT, ZTE**Alt2 (Y symbols**): Ericsson, Samsung, Qualcomm, Intel, MTK, NTT Docomo, Spreadtrum, Lenovo/MotM, Xiaomi, LG, Sony, Nokia/NSB, IDC |
| 3.B How to determine BAT in case of CA | **Highest BAT among CCs**: Samsung, MTK, Xiaomi, Nokia/NSB, **The BAT is determined by the scheduled carrier, and offset if added based on the relation between the SCS of PDCCH and the scheduled channel (existing)**: Ericsson**BAT for smallest SCS among CCs**: Qualcomm, Intel, Lenovo/MotM, Sony**One value for all CCs**: Apple, Spreadtrum, OPPO, CATT, ZTE**BAT for CC with largest delay**: NTT Docomo |
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**Proposal 3.A**: On Rel-17 DCI-based beam indication, regarding application time of the beam indication, the first slot that is at least Y symbols after the last symbol of the acknowledgment of the joint or separate DL/UL beam indication.

* In case of CA, the BAT is determined by the scheduled carrier, and offset is added based on the relation between the SCS of PDCCH and the scheduled channel

Table 6 Additional inputs: issue 3

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| **Company** | **Input** |
| Mod V0 | **Please share your views on the FL proposal** |
| LG | OK |
| MediaTek | Not support due to the following points:* Proposal 3.A can be used only for Xcarrier scheduling and is not general for all CA case (e.g., common TCI state ID update). The BAT for common TCI sate update across a set of CCs need to be discussed separately.
* We don't think the BAT with offset for Rel-16 Xcarrier scheduling can be directly reused for the Rel-17 TCI update. At least Rel-17 BAT happens after HARQ-ACK on the PUCCH cell rather than after scheduling DCI on the scheduling cell.
* How to determine the Y symbols and the first slot may need to be discussed separately. In our view, similar to the application time of MAC-CE command, the Y symbols can be determined based on the PUCCH cell. The fist applicable slot can be determined based on the scheduled CC, or the CC with the smallest SCS among CCs for common beam operation.

One suggestion to the proposal:On Rel-17 DCI-based beam indication, regarding application time of the beam indication, the first slot that is at least Y symbols after the last symbol of the acknowledgment of the joint or separate DL/UL beam indication.* For cross-carrier scheduling, the first slot is determined by the scheduled carrier, and the Y symbols is determined by the carrier with the acknowledgment.
* For common TCI stare ID update across a set of configured carriers, the first slot is determined by the carrier with the smallest SCS among the set of configured carriers, and the Y symbols is determined by the carrier with the acknowledgment.
 |
| NTT Docomo | Support. Is it correct understanding how to determine the offset (added based on the relation between the SCS) is FFS? |
| Apple | We think Xms is the best and simplest way. But if we want to use Y symbols, we think it should be as follows. If we cannot converge, we suggest we choose Xms.* In case of CA, the BAT is determined based on smallest SCS among the CCs at least within the band
 |
| Ericsson | I have a feeling that we confuse the application time (which is configured by the NW) and the UE capability. For what the NW configures, it does not really matter what SCS we choose: it simply has to be consistent. Here I think the MTeK proposal for common TCI state update makes a lot of sense. Or we could say that this is always given in the shortest symbol length, to avoid fractions.For the UE capability, I assume that there will be different values for different SCS, and the NW must make sure that the new beam can be applied for all CCs that are simultaneously updated. So the NW must multiply the per-SCS capability with the symbol duration, and configure an application time that is larger than the max.The next question is now if the UE needs more time if the ACK is sent on a carrier with another SCS. This is not at all clear to me. The solution adopted for x-carrier scheduling in R16 points to that it is possible to just add an offset.  |
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### Issue 4 (MP-UE)

Table 7 Summary: issue 4

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| **#** | **Issue** | **Companies’ views** |
| 4.1 | Whether to support the following measurement/reporting scheme for UE-initiated panel activation/selection:* Opt1-1: A panel entity corresponds to a reported CSI-RS and/or SSB resource index in a beam reporting instance
	+ 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)
* Opt1-2: A panel entity is referring to a new panel ID within CSI/beam reports
	+ FFS: Detailed design of the new panel ID including the information conveyed by the new panel ID
	+ Note: The association between the new panel ID and the panel entity is determined by the UE

Opt1-3: No additional specification support | **Opt1-1:** Huawei/HiSi, Sony (2nd priority), MTK, Intel, Apple (if UE-initiated beam reporting and UE cap are supported), [Nokia/NSB], IDC**Opt1-2:** Huawei/HiSi, ZTE, vivo, IDC, MotM/Lenovo, Spreadturm, Sony, Samsung, CMCC, Fraunhofer IIS/HHI, AT&T, LGE, NTT Docomo, Xiaomi* Panel ID: Huawei/HiSi, ZTE, CMCC, Fraunhofer/HHI, AT&T, LGE, NTT Docomo, Xiaomi, IDC
* Resource set: Samsung

**Opt1-3:** CATT, OPPO, FGI/APT, Ericsson, Apple (if UE-initiated beam reporting and UE cap are **not** supported) |
| 4.2 | Whether to support CB-based SRS resources with different numbers of ports | **Yes**: Huawei/HiSi, CATT, OPPO, Qualcomm, [Fraunhofer IIS/HHI], Apple (only the SRS set aligned with UE selected panel can be indicated), LGE, NTT Docomo, MTK, IDC**No**: [vivo], Ericsson |
| 4.3 | Whether to support NCB-based SRS resource sets with different numbers of resources | **Yes**: ZTE, LGE, Apple (only the SRS set aligned with UE selected panel can be indicated), IDC, CATT**No**: [vivo], Ericsson |
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It was proposed offline that a possible compromise is to agree on Opt 1-3 of 4.1 together with the proposal below

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

* No specification enhancement on UE reporting to facilitate UE-initiated panel activation/selection
* Support codebook-based SRS resources with different maximum number of UL MIMO layers per panel entity
	+ FFS (to be concluded in RAN1#106bis-e): need for dynamic reporting of SRS resource specific candidate spatial source(s)

Table 8 Additional inputs: issue 4

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| **Company** | **Input** |
| Mod V0 | **1) Share your input on the above FL proposals** |
| LG | The first bullet is too strong since it could mean that it precludes all different types of UE reporting for MPUE (captured in the agreement @104b-e below) and could contradict with the FFS point, which is a UE reporting. We could accept the proposal if the first bullet is constrained to beam report enhancement(i.e. L1-RSRP/SINR report), i.e. Opt1-3, as a compromise although we prefer Opt1-1 and Opt1-2 if this compromise solution can make a progress on MPUE issue.**Agreement @104bis-e**On Rel.17 enhancements for MPUE, investigate and, **if needed**, specify the following:* UE reporting of panel-specific information as a UE capability, for example:
	+ Information related to the total number of DL/UL panel entities
	+ Information related to the number of (max) antenna ports/layers per panel entity
	+ Information related to the maximum number of resources per panel entity for SRS BM
	+ Information related to panel selection delay
	+ Information related to panel activation delay
* UE reporting information related to minimal activation/selection delay for a panel based on L1 or L2 signaling
* UE reporting of panel activation/selection status of a panel entity, e.g. active state for both DL and UL, or active state for DL only
	+ FFS: details of this information (e.g. minimal activation/selection delay for a panel) and signaling (e.g. L1 or L2 signaling)
* UE-reported information in MPE report (if supported) is used to indicate the minimal activation/selection delay and panel activation/selection status
* Note: above ‘panel entity’ is a logical entity and how to map physical panels to the logical entities is up to UE implementation
* Note: This will depend on the final outcome of whether specification support for UE-initiated panel activation/selection is agreed
 |
| MediaTek | The 1st bullet and 2nd bullet in this proposal seem conflict with each other. Without UE reporting on UE-initiated panel activation/selection, we don't know to make UL MIMO layers adaption work. Regarding the FFS, we don't quite understand the meaning of “SRS resource specific candidate spatial source(s)”. |
| NTT Docomo | We share similar understanding with MediaTek. If there is no specification enhancement on UE reporting of panel activation/selection, we don’t think codebook-based SRS resources with different maximum number of UL MIMO layers per panel entity can be useful. Without UE reporting, NW may not know how to configure these SRS resources with different max rank. We think if the 2nd bullet is supported, UE reporting need to be supported together. And we support them both. |
| Apple | If we support the second bullet only, it is like a NW controlled UE panel selection, which we have strong concern. |
| Ericsson | We can support the FL proposal as long as the first bullet remains. |

### Issue 5 (MPE mitigation)

Table 9 Summary: issue 5

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| **Proposal** | **Companies’ views** |
| 5.A below | **Support:** Qualcomm, NTT Docomo, Spreadtrum, Lenovo/MotM, OPPO, Xiaomi, vivo, ZTE, CMCC, Sony, Nokia/NSB, Samsung**Not support:** Ericsson, Intel, Apple, MTK, CATT, LG,  |

The following observation can be made:

* 5.1: In round 0 (and since the last meeting), the proponents of 1A and 2A failed to converge. In this round we will try to start from option 1D. The proposal below is made based on the inputs from companies’ contributions and discussion. Note that this is the last attempt (i.e. we will not return to 1A and/or 2A).

**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 [together with N≥1 SSBRI(s)/CRI(s)]
* FFS: Whether N represents the number of selected beams or the number of panels
* 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 10 Additional inputs: issue 5

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| **Company** | **Input** |
| Mod V0 | **1) Check and update Table 9** **2) Share your inputs on the above FL proposals** |
| NTT Docomo | Support. |
| MediaTek | Okay for progress |
| Apple | In our view, at least SSBRI/CRI should be included, otherwise, how to interpret the >1 P-MPR? |
| Ericsson | Event-driven reporting alone will not solve the problem – it is not a useful addition to the standard.  |
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### Issue 6 (advanced beam refinement/tracking)

(Round 4)

# 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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