**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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| * 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

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 PDCCH along with the respective PDSCH reception(s) if the PDCCH is associated with any 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
* For inter-cell beam management, applying more than one active TCI state / QCL per band per BWP in a CC for a given [symbol][slot] is a UE capability
	+ If UE is capable of applying only one active TCI state/QCL per band for a given time, MAC-CE based beam switching can be used to transmit or receive along two different beams
	+ Note: This does not preclude the possibility for TA update on non-serving cell in absence of common channel on non-serving cell
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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.

[Mod: From the comments, the concern is not about reporting and measurement, but applying a beam. Please check revised version]  |
| 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

[Mod: changed CORESET to PDCCH]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

[Mod: changed ‘is’ to ‘can be’ in the revised version. Please check]  |
| Qualcomm | We share similar view as Apple. Our 1st preference is to allow UE supporting 1 active TCI for this feature. If the majority believe >2 TCI is a must, we suggest to add the following changes * For intra-cell beam indication
	+ Non-UE-specific channels should be allowed to share the unified TCI. This is already supported in R15, and is critical for UE supporting 1 active TCI
* For inter-cell beam management
	+ Per Apple’s suggestion: replace CORESET to PDCCH, and include any CSS type
	+ Agree on M=N=2 at least for inter-cell beam management.
	+ Add a note to say this does not preclude TA update on non-serving cell
		- Without different timing, there seems no any benefit of this feature compared with inter-cell mTRP, which can even do simultaneous Rx

**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)~~

[Mod: OK, done] 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)~~PDCCH along with the respective ~~CORESET(s)~~PDSCH reception(s) if the PDCCH 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
* On Rel-17 unified TCI, the following combinations are supported: (M,N)=(2,1) and (2,2) at least for the inter-cell beam management
* Note: This does not preclude the possibility for TA update on non-serving cell in absence of common channel on non-serving cell

[Mod: Incorporated your inputs except for the M/N. This is a separate issue. It will also exacerbate Apple’s concern. So I will not add that bullet in this combo proposal.] |
| Samsung | Supportive of the proposal, but we would like to clarify the last bullet:* In any [symbol] [slot] the UE can apply only one active TCI state. This is to allow switching between channels associated with CSS and channels associated with USS in different symbols/slots
* This applies per CC per BWP as DOCOMO commented
* ~~This~~ Inter-cell beam management does not mandate a UE to ~~maintain~~ apply more than one active TCI state / QCL per band per BWP in CC for a given ~~time~~ [symbol] [slot]
	+ That is, beam switching across slots is used to receive or transmit along two different beams

[Mod: Done] |
| InterDigital | Support the combo proposal in principle, as it seems a good compromise. |
| Intel | We are ok with the general direction of the proposal. However, it appears that different companies have different understanding of what is supported under inter-cell beam management based on RAN conclusions and WID update. From our perspective, we understand inter-cell beam management to mean that a UE transmits/receives UE dedicated signals/channels using a TCI state associated with a PCID different from that of the serving cell PCID. Note that RAN2 identifies TRPs associated with such TCI (or more generally such TCI) as “non-serving cell”. It is also RAN2 understanding that paging cannot be received by UE from PCID different from that of the serving cell. Therefore, the UE must receive common control, paging etc. from the serving cell PCID while the inter-cell beam management can enable UE to receive UE-dedicated channels from non-serving cell PCID. This is a DPS-like operation and we believe inter-cell beam management to be a special case of inter-cell mTRP. With this understanding, we think it’s possible for a UE to receive on different active TCI states i.e., one for non-UE dedicated signaling from serving cell and one for UE-dedicated signaling from PCID other than that of serving cell. It should be a UE capability whether the UE supports more than one active TCI state to facilitate such reception. Additionally, for non-UE dedicated signaling from the serving cell, the occasions can be pre-determined and network can switch TCI (dynamically or MAC-CE based depending on UE capability). We also believe that mandating the UE to receive paging/common-control from PCID other than serving cell is against the WID. So, for the last bullet from Apple, we think it should be a UE capability and if the UE reports support of only one active TCI state, network can use MAC-CE based TCI switching to enable reception from serving cell and non-serving cell, otherwise dynamic switching can be used. So we propose the following: * ~~This inter-cell beam management does not mandate~~ It is a UE capability if it can maintain more than one active TCI state / QCL per band for a given time
	+ If UE is capable of maintaining only one active TCI state/QCL per band for a given time, MAC-CE based beam switching is used to transmit or receive along two different beams
	+ ~~That is, beam switching across slots is used to receive or transmit along two different beams~~

[Mod: Good suggestion. Done ]As for supporting M, N>1 we do think it is necessary. Different TCI codepoints can be easily used in case the UE supports more than single active TCI. [Mod: Separate issue. One step at a time please] |
| Lenovo/MotM | We like the changes suggested by MediaTek (and adopted by the moderator) to the second half of the proposal. “CORESET(s) associated with Type0/0A/1/2 CSS set” is more clear than “non-UE-specific channel”. Since two proposals are combined into this version, we suggest to make the corresponding change to the first half of the proposal as well. This turns the first half of the proposal into:**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) associated with Type 0/0A/1/2 CSS set and the associated PDSCH
	+ FFS: Any restriction on the SS type other than USS associated with the CORESET(s)

[Mod: please check latest version. “Type 0/0A/1/2” is removed per Qualcomm’s comment – which seems fine] |
| Xiaomi | Firstly we support the revised part from MediaTek.Secondly, as for the question noted from NTT Docomo, “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, we think it means inter-cell beam management can’t be supported. Thus does it mean that this inter-cell beam management does not mandate a UE to support inter-cell beam management?Thirdly, as for the last bullet copied below, it seems there is some contradiction between the main bullet and the sub-bullet. The main bullet said not mandate a UE to maintain more than one active TCI state / QCL per band for a given time, but the sub-bullet said the beam switching can be done per slot. We are wondering that how can UE switch beam per slot by maintaining only one active TCI state? We think the version from Samsung is clearer by changing “maintain” to “apply”. * *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*

[Mod: Done] |
| Mod V15 | Revised |
| ZTE | We can NOT support the FL proposal.Firstly, we support no restriction for non-dedicated channel transmission. Then, with the following restriction, the NW flexibility of allocating CORESET will be severely weaken. In current NW, up to 3 CORESETs can be configured per cell, and one of them shall be dedicated to PCell-BFR. If going with the following restriction, gNB has to make another dedicated CORESET for CSS. * 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 CSS set

For progress, we may compromise to have them with the increase of number of CORESETs from 3 to 5 (to align with mDCI-mTRP case).* For a UE supporting Rel.17 beam indication feature for inter-cell beam management, up to 5 CORESETs should be configured per BWP.

Then, for the following bullet, it is a little bit confusing from gNB vender perspective. If my understanding is correct, the intention of this proposal is to switch the CORESET dynamically for CSS and USS reception in the case of only one activated TCI state to be supported. If so, we need to evaluate this case firstly, which is different from LTE and NR design. For instance, for Paging/random access, how and how often to switch TCI state should be fully justified (in idle/in-active), maybe RAN2/4 should be involved. For now, we can NOT live with this part. * For inter-cell beam management, applying more than one active TCI state / QCL per band per BWP in a CC for a given [symbol][slot] is a UE capability
	+ If UE is capable of applying only one active TCI state/QCL per band for a given time, MAC-CE based beam switching can be used to transmit or receive along two different beams
	+ Note: This does not preclude the possibility for TA update on non-serving cell in absence of common channel on non-serving cell

Finally, personally speaking, updating all channel seems to be only right way to go, but I understand that some companies do not think so. For gNB perspective, UE does not need to decode SIB message once TCI/PCI is switched to the non-serving cell, and the corresponding configuration for RACH/Paging can be preconfigured or assumed by default(e.g., this part can be left to RAN2)  |
| Huawei, HiSilicon | As stated in the updated WID, the UE receives from and transmits towards only one cell – the unchanged serving cell. So we failed to understand why Apple kept mentioning transmission towards the so-called “non-serving cell”. We are not sure what is the intention of changing from “CORESET” to “PDCCH”. Is it to imply all configured PDCCH? We would appreciate some further clarification on this. We are not sure if the last bullet is talking about simultaneous multi-UE-beam reception. As mentioned in email discussion, when TypeD-QCL collision happens, the prioritization rule in R15 can potentially be reused. So we are not sure why it is necessary to condition on UE capability of multi-beam reception. We are also not sure what is the proposed MAC-CE supposed to do, e.g., asking UE to stop monitoring system information and receive UE-specific information only? |
| vivo | We have the following two comments:* Our understanding is that the UL part should also be included;
* We are fine with changing “maintaining” to “applying”. But “applying one active TCI state for a given symbol/slot” means UE can still dynamically switch between symbols/slots. Thus the interpretation in the sub-bullet may not be correct.
* We don’t understand the intention of the note. Hope for more clarification or FFS the note at current stage.

**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

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 PDCCH along with the respective PDSCH reception(s) and/or the respective PUSCH/PUCCH transmission if the PDCCH is associated with any 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
* For inter-cell beam management, applying more than one active TCI state / QCL per band per BWP in a CC for a given [symbol][slot] is a UE capability
	+ ~~If UE is capable of applying only one active TCI state/QCL per band for a given time, MAC-CE based beam switching can be used to transmit or receive along two different beams~~
	+ FFS: Note: This does not preclude the possibility for TA update on non-serving cell in absence of common channel on non-serving cel
 |
| MediaTek | Again, we have strong concern on separate beam indications for USS set and CSS set according to current wording. We will additional spec effort to support such new behavior. For example, we need to define the priority rule for a same CORESET if MOs of CCS set and USS set overlapped in time domain but indicated with different QCL assumptions. Also, we will need a new UE capability for this new behavior as follows:         It is a UE capability if it can supports a CORESET associated with both USS set and CSS set for inter-cell beam indication based on Rel.17 unified TCI frameworkRe the comment from Apple, even both inter-cell BM and inter-cell MTRP may require UE to support more than one active TCI states, I would say inter-cell BM based on Rel-17 unified TCI is still less complicated than MTRP operation based on Rel-15/16 QCL framework. Furthermore, I don't see why support more than one active TCI states would be non-UE-friendly feature if a DPS-like operation is the main goal of inter-cell BM. |

### 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 |
|  |  |

**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.

* 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 state 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.
* If the scheduling SCS is less than the applied SCS, the gap between the last symbol of the beam indication DCI and the application time shall satisfy the UE capability for the applied SCS plus an extra beam switch delay determined by the scheduling SCS
	+ The values defined in Table 5.2.1.5.1a-1 in 38.214 can serve as the start point for candidate values of the extra beam switch delay

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.

[Mod: Done, this seems to reflect views of most companies] |
| NTT Docomo | Support. Is it correct understanding how to determine the offset (added based on the relation between the SCS) is FFS?[Mod: Please check latest version. Yes, offset can be discussed later] |
| 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

[Mod: Latest version captures this. Please check.] |
| 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. [Mod: Please check latest version] |
| Qualcomm | We suggest to specify the BAT and the gap between DCI and application time into the following two sub bullets* 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~~ based on smallest SCS among the applied CCs

[Mod: Latest version captures this. Please check.]* If the scheduling SCS is less than the applied SCS, the gap between the last symbol of the beam indication DCI and the application time shall satisfy the UE capability for the applied SCS plus an extra beam switch delay determined by the scheduling SCS
	+ The values defined in Table 5.2.1.5.1a-1 in 38.214 can serve as the start point for candidate values of the extra beam switch delay

[Mod: Added] |
| Samsung | Ok with Main BulletFor sub-bullet:Clarify that the BAT is determined based smallest SCS out of the scheduled carriers, the SCS of the PDCCH carrying beam indication and the SCS of the corresponding HARQ-ACK feedback.**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~~ based on the smallest of the SCS of the scheduled carriers, and ~~offset is added based on the relation between~~ the SCS of PDCCH carring beam indication and SCS of corresponding HARQ-ACK physical channel~~. the scheduled channel~~

[Mod: Latest version captures this. Please check.] |
| Lenovo/MotM | We support the main bullet, but have a concern regarding the sub-bullet. When the PDCCH schedules PDSCHs in more than one carriers, how is the BAT determined? Do different carriers have different BATs if they have different SCS? A common BAT for all scheduled carrier is required by the RX beamforming hardware. That is why we propose a BAT for smallest SCS among the CCs applies to all the PDSCHs. Therefore we support Samsung’s change.[Mod: Please check latest version] |
| Xiaomi | We are fine with the main bullet. For the sub-bullet, we have some concerns.First we think the beam application time for all CCs should be same. If the BAT is determined by the scheduled carrier, does it mean that the value of Y need to be configured per carrier? In fact, only one value of Y need to be configured for each UE since common beam application time will be used for all CCs.In addition, as for the offset, it noted the scheduled channel, but if DCI format without DL assignment is used to indicate the unified TCI, there is no scheduled channel. Is my understanding right?As for the version from Samsung, is the determined BAT time also applied to the carrier with the smallest SCS among all carriers if the carrier with the smallest SCS is different from the noted three carriers? And should the value of Y be configured per CC? [Mod: Please check latest version. **@Samsung: please respond to Xiaomi**] |
| ZTE | In general, we prefer to have a simple timeline considering that ‘Y’ is preconfigured by gNB. X ms is simple, but if going with Y symbol, we think that being based on the carrier with the acknowledgment is right. We do not think we need to determine the first slot. Like Rel-16 simultaneous MAC-CE activation for PDCCH/PDSCH/SRS, the next slot is also based on the same carrier of ACK, and I do not see the necessity of slot-level alignment for different SCSs. **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.* For both cross-carrier scheduling and common TCI state ID update across a set of configured carriers, the first slot and Y symbols are both determined by the carrier of acknowledgment.

Regarding UE capability part, we need to check internal views, and provide our input later. |
| Huawei, HiSilicon | We slightly prefer Samsung’s version – a simple handling for all cases.  |
| vivo | The BAT is a configurable value, we are not sure whether we are discussing how to use the configured value or how gNB and UE are aligned on the meaning of reported UE capability If discussing how gNB and UE are aligned with UE reported capability, we prefer the following revised version from Samsung’s version. **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 minimum BAT is at least determined ~~by~~ based on the smallest of the SCS of the scheduled carriers, and ~~offset is added based on the relation between the SCS of PDCCH carring beam indication~~ SCS of corresponding HARQ-ACK physical channel
 |
| MediaTek | Support the proposal but we are also okay to the simpler version from Samsung. However, we prefer to use “the first slot and Y symbols” instead of “BAT”. Regarding the “scheduled carriers”, since the beam indication DCI in Rel-17 U-TCI may not schedule data, we prefer to change the wording. After checking the feedback from companies, it seems there are three different proposals:* (Current proposal) The first slot is determined by the carrier with the smallest SCS among the carrier(s) applying the beam indication, and the Y symbols is determined by the carrier carrying the acknowledgment.
* (Samsung) The first slot and the Y symbols are both determined by the carrier with smallest SCS among the carrier(s) applying the beam indication and the carrier carrying the acknowledgment/
* (ZTE) The first slot and the Y symbols are both determined by the carrier carrying the acknowledgment.

We open to discuss them, and suggest the following:**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, down-select one from the following alternatives for the case of CA:* Alt1: The first slot is determined by the carrier with the smallest SCS among the carrier(s) applying the beam indication, and the Y symbols is determined by the carrier carrying the acknowledgment
* Alt2: The first slot and the Y symbols are both determined by the carrier with smallest SCS among the carrier(s) applying the beam indication and the carrier with the acknowledgment
* Alt3: The first slot and the Y symbols are both determined by the carrier carrying the acknowledgment.
 |

### Issue 4 (MP-UE)

Table 7 Summary: issue 4

|  |  |  |
| --- | --- | --- |
| **#** | **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 |
|  |  |  |

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 additional specification enhancement on UE reporting to facilitate UE-initiated panel activation/selection (i.e. Opt1-3 per RAN1#104-bis-e agreement)
* 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

|  |  |
| --- | --- |
| **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

[Mod: Thanks for your understanding and willingness to compromise. The intention was indeed Opt1-3 (UE reporting of panel info is possible, but performed without any additional enhancement such as panel ID or association). I revised the text and clarified it. Plese feel free to suggest revision to capture the intention of Opt1-3 better]  |
| 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)”.[Mod: Please check my comment to LG and Ericsson’s comment] |
| 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.[Mod: Please check my comment to LG and Ericsson’s comment] |
| 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.[Mod: Thanks for your understanding and willingness to compromise]  |
| Qualcomm | Suggest to replace the 1st bullet with the panel specific UE capability, which is needed for the panel specific CB based SRS configuration.**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 UE reporting of panel-specific information as UE capability
	+ FFS: Detailed information
* 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)

[Mod: Please check my comment to LG and Ericsson’s comment] |
| Samsung | We have the same view that if there is no specification enhancement on UE reporting of panel activation/selection, then the UE panel selection/activation is controlled by NW, which means the UE may have to keep multiple panel active (if NW configures it to do so), even though the UE would have preferred to turn one panel OFF. In our view, this is too restrictive.[Mod: Please check my comment to LG and Ericsson’s comment] |
| InterDigital | We share the above views from LG, MediaTek, Docomo, Apple, Qualcomm, and Samsung. Although we also prefer to have reasonable enhancements based on Opt1-1 or Opt1-2, Qualcomm’s suggestion sounded good as an acceptable compromise at this stage, if agreeable. ‘UE capability’ reporting on panel-specific information as minimum spec supports should be okay and is at least essential for the second bullet, to move forward on this topic. [Mod: Please check my comment to LG and Ericsson’s comment] |
| Intel | With the current formulation, we are not sure how network can utilize the SRS resources with different maximum number of UL MIMO layers per panel entity i.e., how to map to panels. Also as commented before the use case of panels with different number of ports is not clear to us. Therefore we tend towards not supporting this proposal. [Mod: Please check my comment to LG and Ericsson’s comment] |
| Lenovo/MotM | To enable UE to initiate panel selection, UE needs to send relevant information to the gNB. It is premature to exclude any enhancement to UE reporting. We need to decide whether there will be change to UE reporting after the scheme takes shape. We also think panel specific information, such as # of SRS ports or maximal # of UL layers, shall be part of UE capabilities. Therefore we support Qualcomm’s change. [Mod: Please check my comment to LG and Ericsson’s comment] |
| Xiaomi | We share the above views from other companies. If no specification enhancement, how to support codebook-based SRS resources with different maximum number of UL MIMO layers per panel entity.As for measurement/reporting scheme for UE-initiated panel activation/selection, we prefer Option 1-2, which provides benefit for MPE issue by providing information which beams from the non-MPE panel can be used for UL transmission.As for the second bullet, we are fine. [Mod: Please check my comment to LG and Ericsson’s comment] |
| Mod V15 | Revised per comment from LG |
| ZTE | If enhancing this feature, we definitely need to support Option-1 firstly, and based on that, we can support the remaining FL proposal.  |
| Huawei, HiSilicon | Similar view as LG, MediaTek, DOCOMO, Qualcomm, Samsung, InterDigital, Intel, Lenovo, Xiaomi, and ZTE.  |

### 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 M≥1 SSBRI(s)/CRI(s) where M≥N
* 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

|  |  |
| --- | --- |
| **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?[Mod: Added – I agree] |
| Ericsson | Event-driven reporting alone will not solve the problem – it is not a useful addition to the standard.  |
| Qualcomm | Support. We are also fine to support NW triggered report, i.e. the last FFS, if that can address E///’s concern[Mod: Please provide a concrete wording/proposal for me to add. It is not clear to me how this is done. Does it mean we introduce a new CSI reporting format with P-MPR + SSBRI/CRI? Via UCI? If so, this is clearly not agreeable to the proponents of 1A and 1D. Note that this proposal assumes reporting via MAC CE per Rel-16 PHR reporting.]  |
| Samsung | OK in general, but have the same view as Apple, SSBRI/CRI should be included.[Mod: Done] |
| InterDigital | OK for progress and agree with Apple and Samsung to include SSBRI/CRI without bracket. We are also okay to take Qualcomm’s suggestion for the last FFS point to address Ericsson’s concern.[Mod: Please see my comment to Qualcomm] |
| Intel  | SSBRI/CRI should be included[Mod: Done] |
| Lenovo/MotM | The sentence inside the bracket “[together with N≥1 SSBRI(s)/CRI(s)]” of the first sub-bullet shall be removed, since reporting of SSBRI(s)/CRI(s) is part of the 3rd FFS below. [Mod: Done[ |
| Xiaomi | Support the proposal. And suggest to update the first bullet as below since M maybe larger than N:* N≥1 P-MPR values can be reported [together with M≥1 SSBRI(s)/CRI(s)]

[Mod: Done] |
| ZTE | Event-driven mechanism is very necessary for MPE reporting, and then, if my understanding is correct, the correspondence between panel and CRI/SSBRI should be supported? |
| Huawei, HiSilicon | As we haven’t agreed on what will be used to represent an UE panel, we prefer to keep SSBRI/CRI as part of the FFS point, i.e., not to include them in the 1st sub-bullet. Also, we are not sure where did M >= N come from.  |
| vivo | We also prefer to keep the SSBRI/CRI report in the FFS part since beam-specific and/or panel-specific report would still need to be further discussed.**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
* FFS: whether reported together with M≥1 SSBRI(s)/CRI(s) where M≥N
* 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
 |

### Issue 6 (advanced beam refinement/tracking)

(Round 4)

# References

|  |  |  |  |
| --- | --- | --- | --- |
| 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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