**3GPP TSG RAN WG1 #105-e R1-2105955**

**e-Meeting, May 10th – 27th, 2021**

**Agenda item:** 8.16

**Source:** Moderator (NTT DOCOMO, INC.)

**Title:** Summary on Rel-17 NR TEI related discussion

**Document for:** Discussion and Decision

1. Introduction

This contribution summarizes the discussions and proposals in AI 8.16 for Rel-17 NR TEI related discussion and following email discussion.

[105-e-NR-R17-TEI-01] Email discussion/approval Rel-17 TEIs  – Hiroki (NTT DOCOMO)

* 1st check point: May 24
* 2nd check point: May 27

Based on the discussions summarized in Section 2, six TEI proposals are identified in AI 8.16. According to the guidance from RAN1 chair (i.e., same guidance as in Rel-16 TEI [11] should still hold), it should be checked first whether each TEI proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor so that the discussion on the TEI proposal can be prioritized over other TEI proposals. **Companies are encouraged to clarify which TEI proposal can be supported in the list below, i.e., please add your company name if you support the TEI proposal.**

* **TEI proposal #1: Enhancement of NR codeword mapping**
  + Supported by ZTE, CMCC, China Telecom, China Unicom, SoftBank, NTT DOCOMO, Sanechips, vivo, CATT
* **TEI proposal #2: Improved Frequency-Domain Interleaving**
  + Supported by Qualcomm, Ericssson, [Intel]
* **TEI proposal #3: Enhancements to PUCCH format 2**
  + Supported by Qualcomm, NTT DOCOMO
* **TEI proposal #4: Enhancements to CSI-RS design to solve false PMI reporting issue**
  + Supported by Ericsson, NTT DOCOMO, Softbank, Verizon, T-Mobile USA, Intel
* **TEI proposal #5: NR positioning support for TA-based positioning in E-CID**
  + Supported by NTT DOCOMO INC., Ericsson, Polaris Wireless, Verizon, China Telecom, FirstNet, Deutsche Telekom, Intel Corporation, CATT
* **TEI proposal #6: Enhancements on the scheduling of PUSCH over multiple slots**
  + Supported by Huawei, HiSilicon, China Unicom
* **TEI proposal #7: Enhancements on SSB resources for RLM**
  + Supported by CATT, Ericsson
* **TEI proposal #8: Periodic SRS transmission outside DRX active time**
  + Supported by Qualcomm. [MediaTek], [ZTE, Sanechips]
* **TEI proposal #9: Joint configuration of DRX groups and Rel-16 Power saving features**
  + Supported by Qualcomm
* **TEI proposal #10: Removal of DM-RS restriction for DL MU-MIMO**
  + Supported by Intel
* **TEI proposal #11: UL MU-MIMO enhancements for DSS**
  + Supported by Intel
* **TEI proposal #12: Mitigating half-duplex issue in NR V2X groupcast NACK-only case regime**
  + Supported by Intel, Qualcomm, NTT DOCOMO, CATT, Bosch
* **TEI proposal #13: Support of 2 Tx codebook configuration to 4Tx capable UE in UL**
  + Supported by vivo, ZTE, CMCC, Samsung, NTT DOCOMO

Detailed feedback/question on each TEI proposal can alo be provided in Section 2.

Please also note that as announced at the last RAN1 meeting, making any agreement on a particular TEI proposal in this quarter requires to complete all work including CRs for the TEI proposal within this quarter according to the TEI guidance B as shown in Appendix [12].

1. Discussion on Rel-17 NR TEI proposals
   1. Enhancement of NR codeword mapping

Following proposal is made in the contribution.

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| [2] | One difference between NR and LTE is layer-to-codeword mapping, where NR only supports 1 codeword (CW) but LTE can support 2 codewords in the case when the number of transmission layers is not larger than 4.  Taking 2 layers as an example as shown in Figure 1, two layers can map to 2 CWs respectively in LTE, and independent MCS can be indicated to the two layers to match the potentially different channel conditions. In NR, in order to simplify implementation complexity, only 1 MCS can be indicated for the two layers no matter channel conditions are closed or different. However, some issues are identified in the real test of NR deployment. The NR performance is impacted by NR CW mapping in some cases when the SINR difference for the two layers are large.    Figure 1 Comparison of CW mapping between LTE and NR  ~  ***Observation 1:*** *In the real test position 1, the receiving power gap between the two layers is about 10 dB. The constellation demapping of the first layer is much better than that of the second layer in the case of rank 2 transmission.*  ***Observation 2:*** *In the real test position 2, the receiving power gap between the two layers is about 10 dB. The constellation demapping of the second layer is much better than that of the second layer in the case of rank 2 transmission.*  ***Observation 3:***  *The SINR gap between two UL MIMO layers is often large in our test results e.g. larger than 10dB. It is larger than what we observed in simulations possibly due to some practical differences e.g. inaccurate modeling of antenna placements in simulations, different blockage for different antennas, etc.*  ***Observation 4:*** *The current NR codeword mapping has limitations in some scenarios including the scenarios with large receiving SINR gap for transmission layers, and TDD scenarios with heavy DL traffic.*  ***Observation 5:*** *Based on the simulation results from both SLS and LLS, two TB/MCS can bring obvious performance gain than single TB/MCS for the case when receiving power gap is large between two layers.*  ~  Based on the real test results from section 2.1 and 2.2, the analyses and simulation results in section 3, the performance and latency may be impacted due to the limitation of the current codeword mapping mechanism.  To address the issues mentioned in above sections, we propose to support 2 codewords with 2 MCS for rank 2-4 uplink transmission, i.e. LTE-like CW mapping. Since the aforementioned issues reflect the urgent requirement of NR products, and the relevant solution does not need much spec effort, we suggest to discuss them in Rel-17 TEI agenda.  ***Proposal:*** *Support 2 codewords with 2 MCS for rank 2-4 uplink transmission (i.e. LTE-like CW mapping)* |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #1**

* **Support 2 codewords with 2 MCS for rank 2-4 uplink transmission (i.e. LTE-like CW mapping)**

This proposal is already supported by ZTE, CMCC, China Telecom, China Unicom, SoftBank, NTT DOCOMO, Sanechips, vivo.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| Company | Comment |
| NTT DOCOMO | Support. We believe 2 codewords for UL MIMO is benefitial to improve UL performance. |
| CATT | Support the proposal. |
| SoftBank | Support the proposal |
| Intel | This TEI requires a lot of specification change. Suggest considering the required functionality by using multi-DCI mTRP framework. New UE capability can be defined targeting UL only. |
| MediaTek | This proposal has HW and specification impact. Comprehensive evaluation and discussion are needed to justify the benefit versus the efforts. |
| Huawei, HiSilicon | We agree with the motivation for this TEI proposal. It was discussed heavily in both Rel-15 and Rel-16. We are open to simple solution to address the issue by following LTE codeword-layer-mapping mechanism so that gNB/UE may reuse LTE algorithm as much as possible. However it is less preferred that it is for UL only since DL and UL design shall be symmetric for this particular matter, from both gNB and NB perspective. If we will only do part of the scenarios, better to study which case is more beficial first with sufficient evaluation. |
| ZTE, Sanechips | * In response to Intel and MTK’s comments, we don’t think this TEI proposal requires a lot of specification changes. We have uploaded the corresponding TPs R1-2106101-03 in the Inbox. It can be observed from this set of TPs that the spec impact is not high. * In response to Intel’s comment on multi-DCI mTRP, mTRP can only support TDM on uplink i.e. UL-MIMO with 2CW for rank2-4 cannot be supported. Also, it will unnecessarily introduce extra complexity for UEs to support multi-DCI mTRP for the purpose of uplink enhancement in single TRP only even if a UE capability is defined targeting UL only. * In response to HW’s comment, we are open to also support this feature for DL. However, there is concern on spec impact. That’s why we choose to support this feature UL first. We suggest to do it step by step to agree this TEI proposal on UL first and then further discuss DL. * Regarding evaluation, we have done extensive evaluation in our tdoc [2], where clear gain has been observed. In addition, this issue is observed from the field. That’s why strong support from operators are observed from the current list of supporting companies. |
| Ericsson | In general, this is interesting but the scope may be too large for a TEI-17. This can be considered for Rel-18 MIMO WI instead. |
| AT&T | We are supportive of this proposal. As debated extensively in Rel. 15/Rel. 16, 2 CWs provides performance gains |
| Qualcomm | Not supportive of the proposal and we consider it a lower priority. In the initial version, it included other options, specifically the layer-dependent modulation order, which has smaller specification impact. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  Although the proposal is supported by 9 companies including operator, infra vendor and UE vendor and the proponent tried to address concerns from some companies, it seems we should continue discussion on this proposal, including whether/how the specification impact can fit into TEI with considering possibility of other options and symmetric design between DL and UL.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | We have a question for clarification: why this enhancement is only applied to UL? It is from consideration of performance (e.g. the SINR gap between layers is smaller for DL) or standardization (e.g. need additional enhancement for CSI feedback)? |
| Nokia | We share the same view as Ericsson, Qualcomm and MediaTek, this leads to reworking the data processing path and it is a proposal that has been rejected in the past. Could be considered for Rel-18 MIMO but a proper gain analysis would need to be made before agreeing to specify. |

* 1. Improved Frequency-Domain Interleaving

Following proposal is made in the contribution.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| [3] | Starting from NR Rel-15, it was identified that at large BWs and high data rates and high rank, several codeblocks (~12) can be mapped onto any single OFDM symbol. When this happens, even though interleaving exists within any given code block, the frequency diversity of each codeblock can be relatively small since each CB occupies only a small set of PRBs. VRB-to-PRB interleaved mapping was introduced to distribute codeblocks across frequency.    Unfortunately, several limitations of the NR Rel-15 VRB-to-PRB solution were identified in practice:   * Small performance gains are observed since CBs are only distributed along two sub-bands that are diverse in frequency. Much larger gains can be achieved with higher-depth interleavers having more diversity. * VRB-to-PRB interleaved mapping is happening within the BWP and not within the UE’s scheduled allocation which limits the ability to multiplex UE’s with different BWP configurations. VRB-to-PRB mapping may preclude coexistence of different UE’s with BWP switching for power savings. * There is no mode of CSI reporting which assumes VRB-To-PRB interleaved mapping, while dynamic switching between the interleaved and non-interleaved mapping is specified. The scheduler does not have an indication from the UE whether, in any given conditions, it will be beneficial to dynamically switch ON/OFF the interleaved mapping.   As a simple simulation example, we consider the case of high throughput / high spectral efficiency (where the interleaving was supposed to provide most of the gains): Rank 4, 100MHz BW, 30kHz SCS, TDL-A 30 nsec with MCS 13, 19 which correspond to the following cases:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **MCS** | **Rate** | **Modulation Order** | **# of CBs** | **# of CBs / Symbol** | | **19** | 0.85 | 6 | 79 | 7.9 | | **13** | 0.55 | 6 | 51 | 5.1 |   The gains in SINR over NR Rel-15 options to reach 90% throughput is shown below:   |  |  |  | | --- | --- | --- | | **Interleaver** | **Delta in dB, MCS = 19, MMSE** | **Delta in dB, MCS = 13, MMSE** | | **Rel-15 (No-ILV)** | 0 | 0 | | **Rel-15 (VRB2PRB ILV)** | 1.0 | 0.6 | | **8-Row** | **6.5** | **2.8** |   Based on the above observations, we make the following proposals:  Proposal 1: For the VRB-To-PRB interleaved mapping:   * **Increase the depth of the interleaver (e.g. 4 or 8 rows instead of 2 rows in NR Rel-15)** * **Perform the interleaved mapping within the scheduled allocations and not within the active BWP** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #2**

* **Support following improvements for the VRB-To-PRB interleaved mapping**
  + **Increase the depth of the interleaver (e.g. 4 or 8 rows instead of 2 rows in NR Rel-15)**
  + **Perform the interleaved mapping within the scheduled allocations and not within the active BWP**

This proposal is already supported by Qualcomm.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| --- | --- |
| Company | Comment |
| vivo | Increasing the depth of the interleaver will improve performance in given assumption, but not sure of its urgency. Interleaved mapping within the scheduled allocations and not within the active BWP may cause the multiplexing issue (PRB domain collision) with legacy UEs sharing the same active BWP, further study may be needed. |
| NTT DOCOMO | We are supportive to introduce the new interleaver in addition to the existing one to improve the performance. However, we don’t see the necessity of the 2nd sub-bullet. If there is a legacy UE to be scheduled simultaneously, there is no choice but to follow current interleaved mapping rule for coexistence. Also, as mentioned by the proponent, dynamic switching between the interleaved and non-interleaved mapping is supported. Coexistence of UEs with different BWPs can be achieved if non-interleaved mapping is used for the UE with narrower BWP for power saving. |
| CATT | Comprehensive evaluation is needed to justify the enhancement. The change of interleaver depth may cause co-existence issue with legacy UEs which should be carefully studied. In addition, the second bullet may lead to large amout of work in RAN1, and is not suitable for TEI. |
| Intel | We can support this proposal if it also include MIMO layer dependernt interleaving mapping. |
| MediaTek | We are ok to discuss the first sub-bullet. But we are not sure about the benefit of the second sub-bullet. |
| Huawei, HiSilicon | We do not favor this proposal.  The actual gain that can be expected from implementing the proposals is questionable. On one hand, the motivation to have deeper interleaver is to obtain more diversity gain from larger frequency areas, while on the other hand with second sub-bullet, the scheduled locations have smaller frequency range than its BWP size, thus, although it may enable more R17 UE multiplexing (if those UEs all support this new feature), it turns out to restrict the potential gain that can be expected. However, unfortunetly, the multiplexing capacity will not be increased either, since there are legacy UEs only supporting BWP-level interleaving such that multiplexing of different UEs for co-existence could be different and complicated. |
| ZTE, Sanechips | In our view, the use case, i.e., if a CB is mapped onto one OFDM symbol and occupies only a small set of PRBs in the symbol, may not be very typical. As for the proposed enhancements, the motivation/benefit does not seem to be clear to us.   * For the 1st sub-bullet, whether there is performance gain in such corner case needs to be carefully verified first. * For the 2nd sub-bullet, current mapping within the active BWP makes the PRB more distributed and therefore better performance, which is more important from our perspective. |
| Ericsson | We support TEI proposal#2. This is important to achieve the peak thoughput for NR. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  Although there are multiple companies supporting (or being supportive) this proposal, it seems we should continue discussion on this proposal, including necessity of 2nd bullet proposal and whether/how to address the coexistence issue with legacy UEs. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | Maybe the scenario with gain is too cornor for us. We are fine for further study and evaluation on the first bullet. For the second bullet, the application could be very litmied considering there are so many legacy UEs in the same BWP. |
| Nokia | This leads to reworking the data processing path. Could be considered as a Rel-18 enhancement but a proper gain analysis would need to be made before agreeing to specify. |

* 1. Enhancements to PUCCH format 2

Following proposal is made in the contribution.

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| [3] | Short PUCCH format, specifically, PUCCH Format 2 spans one to two OFDM symbols and is restricted to use CP-OFDM waveform. The table below summarizes the configurations available for various PUCCH formats. The lack of DFT-S-OFDM support for short PUCCH Format is a significant shortcoming that we wish to address.    Table 1 Configurations for different PUCCH Formats  Short PUCCH formats have found significant use in FR2 deployments where a large number of analog antenna beams are used to serve users in uplink/downlink. Due to large number of antenna beams, long PUCCH formats are not favored since it’s easier to support beam sweeping operations using short PUCCH formats. Further since certain beams are intended to provide cell-edge coverage while certain beams are intended for cell-center UEs, beam-specific PUCCH configurations are ideally desired. However, defining beam-specific PUCCH formats is a tedious effort and adds to overall network configuration complexity. Therefore, short PUCCH formats are typically configured across all beams. Additional details on these aspects are presented in [1].  Further, with uplink being a typical bottleneck in NR deployments, it is worth considering enhancements that help improve uplink control coverage. It is well known that DFT-S-OFDM waveforms have a smaller PAPR compared to CP-OFDM, and this enables them to be transmitted at a higher power.  Using power class 3 UE as a motivating example, Table 6.2.2-1 of 38.101-1 as provided in Table 2 specifies a set of power reduction values dependent on RB allocation and modulation order for power class 3 UEs. The power back off values are then used by the UE to calculate the lower bound on its value.  Table 2 MPR Table from 38.101-1    Note that DFT-S-OFDM with pi/2 BPSK has two sets of values defined, one for the case where the 0 dB MPR is in reference to 23 dBm and another where the 0 dB MPR is in reference to 26 dBm. This change in reference power to 26 dBm is permitted when UE is operating in TDD mode with less than 40% of the slots in a radio frame being used for uplink transmission.  It is thus seen that for a wide range of RB allocations, DFT-S-OFDM waveforms can be transmitted at a transmit power that is 2 dB higher than that possible for CP-OFDM waveforms. This motivates us to make the following proposal:  ***Proposal 2:* Support transmitting PUCCH Format 2 using DFT-S-OFDM waveform.**  Introducing DFT-S-OFDM for short PUCCH format requires a careful consideration of how the resources are split between DMRS and data. To support single symbol PUCCH transmission, it is required that DMRS and data be multiplexed on the same symbol. One option is to multiplex DMRS and data in time domain before the DFT operation [2], [3].  **Transmit-side operations**  The proposed scheme multiplexes data and reference signal within one symbol duration by virtual TDM. The time domain signal before DFT-spread and the transmitter block diagram is shown in Figure 1.    **Figure 1. Transmitter for Virtual TDM of Reference Signal and Data**  The first part of the pre DFT-spread time-domain signal is the reference signal. It is preferable for the reference signal to have low PAPR property on both time and frequency domain to keep the PAPR of the final DFT-s-OFDM waveform low and at the same time make the frequency domain channel estimation efficient.  To reduce inter-symbol interference, an additional virtual CP for reference signal can be optionally added at the beginning of the pre DFT-spread time-domain signal by copying the last symbols of the reference signal.  The reference signal symbols are followed by data symbols to form the pre DFT-spread time domain sequence. The pre DFT-s sequence goes through the conventional DFT-s-OFDM waveform synthesis to generate the final time domain waveform.  Denote the signals in Figure 1 as follows:  : pre DFT-s Reference signal with length  : pre DFT-s Data signal with length  : pre DFT-s Virtual Cyclic Prefix for Reference Signal with length  : pre DFT-s Time-domain signal with length  From the above discussion, we can see that should be , and should be  .  **Receive-side operations**  Figure 2 shows the receiver block diagram for the virtual TDM shown in Figure 1. Except the channel estimation block, the receiver is essentially equivalent to the conventional DFT-s-OFDM receiver. After FFT and tone demapper, the extracted tones are equalized and go through IDFT to obtain M time domain symbols. Then, data symbols are extracted for the decoding.    Figure 2. Receiver for Virtual TDM of Reference Signal and Data  There can be multiple options for the channel estimator. Figure 3 shows a channel estimator for the virtual TDM of reference signal and data. After FFT and tone demapper, the extracted tones go through IDFT to obtain M time domain symbols. Denote the discrete-time equivalent channel between the Tx antenna and Rx antenna for the M time domain symbols as . When the CP length for Reference signal is chosen longer than the propagation delay of , the reference signal is protected from inter-symbol interference and circular convolution is preserved. Therefore, the extracted RS symbols in Figure 3 can be represented as where denotes the -point circular convolution. The channel can be obtained by converting the extracted reference signal symbols to frequency domain by -point DFT. Finally, the estimated channel for tones can be upsampled by a factor of to obtain the channel estimation for tones, which can be used for the channel equalization in the receiver of Figure 2.    Figure 3. Channel Estimator for Virtual TDM of Reference Signal and Data – Option A.  Alternatively, the upsampling block can be further removed by using -point DFT. Figure 4 shows an alternative option for the channel estimator. The extracted tones go through -point IDFT to obtain time domain symbols. Then, the data symbols are replaced by zeros, and the modified time domain symbols converted to the frequency domain by -point DFT. Finally, the channel tones can be estimated in the frequency domain.    Figure 4. Channel Estimator for Virtual TDM of Reference Signal and Data – Option B.  Clearly, this proposed transmission scheme can provide the multiplexing of reference signal and data with arbitrary pilot ratio while keeping the low PAPR property of DFT-s-OFDM waveform.  **Simulation Results**  In this section, we simulate and compare the link performances of the proposed virtual TDM scheme and compare with that of OFDM where the reference signal and data is FDMed.  Figure 5 presents two plots that illustrate the characteristics and the performance of the DFT-S-OFDM waveform. First, Figure 5 shows that DFT-s-OFDM waveform has at least 2 to 2.5 dB PAPR gain over CP-OFDM --- this is a reasonably well known result. Second, Figure 5 also shows that when comparing the link level performance between CP-OFDM (with data-RS FDM) and DFT-S-OFDM, it is observed that there is little to no difference at least for small payloads. For the link level performance, a three-bit payload is considered, and transmitted over 2 RB. The additional virtual CP length for RS is set to be zero, and the pilot ratio is chosen as 50% for both cases. Thus, taking both these observations into account, we see that the proposed scheme can provide up to 2 dB better performance than a CP-OFDM-based approach.   |  |  | | --- | --- | |  |  |   Figure 5 PAPR for CP-OFDM and DFT-s-OFDM waveforms (on the left) and link level performance comparison between DFT-S-OFDM and CP-OFDM (on the right).  Based on the discussion above and the simulation results, we make the following proposal:  ***Proposal 3:* Consider pre-DFT data-DMRS multiplexing to enable DFT-S-OFDM waveform for PUCCH Format 2.** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #3**

* **Support transmitting PUCCH Format 2 using DFT-S-OFDM waveform**
  + **Consider pre-DFT data-DMRS multiplexing to enable DFT-S-OFDM waveform for PUCCH Format 2.**

This proposal is already supported by Qualcomm.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| --- | --- |
| Company | Comment |
| vivo | It could be beneficial, but it could involve large work in RAN4. |
| NTT DOCOMO | We support to introduce PF2 using DFT-s-OFDM.  Short PUCCH format is an important feature for FR2 deployment with beam-based operation. However, current PF2 is CP-OFDM based format and the performance is not good compared to PF3/4, which are DFT-s-OFDM based format. Details of the enhanced format can be discussed further. |
| CATT | The motivation is not clear. If UL coverage is an issue,  PF#3/PF#4 with less OFDM symbols, e.g., 4 symbols, can used instead of PF#2. Beam sweeping within one slot is still possible. If UL coverage is not an issue, e.g., for cell-center UEs, PF#2 without enhancement can be used.  Even RAN1 agrees to introduce DFT-s-OFDM waveform for PF#2, the simplest way would be using two symbols PF#2 with TDM multiplexing between DM-RS and UCI where UCI is transmitted with DFT-s-OFDM waveform. |
| SoftBank | We support the proposal. |
| Intel | Using DFT-s-OFDM waveform for PF2 can improve the PAPR. However, this TEI has substantial impact on receiver implementation, especially channel estimation. Given the large workload for this topic, it is not clear to us whether it can fit into the TEI. |
| MediaTek | We are not supportive for this TEI. The overall system performance gain is not clear while the improvement is at expense of design changes. If coverage is a problem, gNB can configure PUCCH formats 3 and 4. |
| Huawei, HiSilicon | We doubt this can be a TEI proposal. There was a considerable number of suggested PUCCH formats in Rel-15 and a careful downseletction had to be done. The merits of this proposal appear to not have been justified, e.g., with system simulation results. We also note that PUCCH format 3 with 4 OFDM symbols is a viable configuration. In the WI on >52.6 GHz, it is also observed that the UE transmit power is not necessarily limited by the CM, as there are other regulatory constraints. |
| ZTE, Sanechips | It is understandable that PAPR could be reduced if DFT-S-OFDM is introduced for PUCCH format 2. However, it would require new signal generation procedure for PUCCH format 2 and corresponding new channel estimation methods, which may degrade the performance compared to the traditional frequency domain channel estimation method. In addition, it seems the provided evaluation results haven’t taken DTX-to-ACK threshold into account. Thus, it needs to first carefully evaluate the potential SNR performance loss, with or without considering DTX-to-ACK threshold. |
| Ericsson | We think the problem Qualcomm identifies is an important one. However, the work load does seem large for a TEI, and so should be considered e.g. in the context of Rel-18. Moreover, whether this solution or another has better gain vs. receiver complexity should be considered before proceeding further. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  Although there are multiple companies supporting (or being supportive) this proposal, it seems we should continue discussion on this proposal, including whether/how the specification impact can fit into TEI and achievable gain based on evaluation. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| Nokia | Agree with many, we “downselected” to 5 PUCCH formats, and we should be very careful before defining a 6th PUCCH format. A new channel is not TEI item. |

* 1. Enhancements to CSI-RS design to solve false PMI reporting issue

Following proposals are made in the contributions.

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| [9] | As been previously informed [R1-2001918], from OTA testing of commercial NR UEs, a critical issue has been found related to MIMO performance near cell edge. The issue has been detected for both 32 and 8 port CSI-RS and for two UEs with chipsets from different vendors.  This is a real-life network issue related to MIMO which severely impacts NR performance and can be summarized as:   * **Near cell edge**, while still connected to a serving cell, **the NR UE selects PMI as if it was served by an interfering cell**, hence false PMI selection and reporting   + This leads to a sharp drop in PDSCH throughput at cell edge   + PMI selection logged at UE, hence this issue is not due to poor UCI feedback channel quality * The problem occurs **whenever a CSI-RS resource from the serving cell collides with a CSI-RS resource from a neighboring cell**    + The problem occurs even though different seed is used for CSI-RS sequence generation in serving and interfering cell respectively * As the analysis in this contribution shows, a cause of the problem is **due the Rel.15 design that the same CSI-RS sequence** is used for all CSI-RS ports in the CSI-RS resource   + To mitigate this, the UE must perform more advanced channel estimation, which is unnecessary complex and can be avoided if the problem with the CSI-RS design is mitigated * It is argued that the false-PMI selection problem can be solved with **cell planning of non-colliding CSI-RS** in adjacent cells, however,   + Non-overlapping CSI-RS in different cells (reuse larger than one) introduces the need for cell planning which is cumbersome and against the reuse one principle of modern RAN   + Even if non-colliding CSI-RS is configured by the use of CSI-RS cell planning, colliding CSI-RS between different cells is very hard to avoid in practical networks even if such frequency reuse is adopted because the topology is much different from hexagonal and far away gNB with colliding CSI-RS still hits the UE   + Simulations (see section 3.1) shows that the peak PDSCH throughput performance when using colliding CSI-RS (with a new Rel.17 CSI-RS sequence) is better than when non-overlapping CSI-RS. Hence, it seems it is better to have another, well designed CSI-RS as interference than PDSCH.   + Deliberately configuration of colliding CSI-RS has huge benefits for operators as it relives the need for network planning of CSI-RS, ease of migration and densification, lower interference and minimal overhead. This is elaborated in Section 4.     Figure 1 Illustration of the observed problem from field testing with commercial UEs. The UEs served by gNB 1 are reporting PMII instead of PMID where PMII is the PMI the UE would report if served by gNB 2.  To solve this problem, we suggest the following   1. Correct the CSI-RS design as a TEI-17 to remove the false PMI reporting problem.   Note that the repetition of same sequence of multiple CSI-RS ports also lead to high PAPR of the CSI-RS transmission and was discussed to be corrected in Rel.16 eMIMO WI. However, RAN1 was divided on the severity of the issue for CSI-RS and it was concluded to be non-consensus to correct this problem. Only DM-RS PAPR was corrected in Rel.16.  It now turns out that the same problematic CSI-RS design with repetitive behaviour also creates the false PMI problem and if a resolution is introduced by this TEI, it can be designed to resolve both PAPR issue and false PMI selection issue.  ~   1. Using measurements using commercial NR UEs from two different vendors, the PMI reporting fails at low SINR. It seems the PMI reporting when nearing the cell edge behave as the PMI reporting the UE would have been reporting if instead served by the interfering cell. This leads to a signifcant drop of throughput of NR at cell edge.   ~  The following sections provides an in-depth analysis of the cause of the problem and why configuration of non-colliding CSI-RS is not a solution that is attractive or even work in all deployments. In this section, we give the standardization based solution together with simulation results that shows that the issue completely disappears.  To summarize, the solution makes the interference from an adjacent base station that transmit CSI-RS appear as spatially white noise at the receiver. This is accomplished by introducing a port specific scrambling of CSI-RS ports while preserving orthogonality between the ports of a CDM group.  The solution is illustrated by Table 1 for the 4 port CSI-RS resource from row 4 of 38.214, where a new Rel.17 sequence per port (is introduced and which is multiplied with the original sequence. The index runs over the resource blocks, so in each RB, a new value of is used for each port. If the CDM group spans multiple OFDM symbols, the same value is used in all these OFDM symbols.  Table 1 TEI-17 proposal to the CSI-RS sequence, to solve the false PMI reporting issue observed in the field    The sequences can be based on the existing Gold-31 pseudo random sequence already used throughout the 38.211 specifications.   1. As a TEI-17, support a port specific multiplier sequence to the CSI-RS resource sequence to remove the false PMI reporting issue.   ~   1. Using raw CSI-RS channel estimates (K=1) that doesn’t utilize the processing gain of the use of pseudo-orthogonal sequences in different cells exaggerate the problem of false PMI selection   ~   1. Due to the use of same sequence sample for all CSI-RS ports, the spatial covariance matrix is dominated by the spatial covariance of the CSI-RS transmitted from the interfering cell if raw channel estimation samples are used   ~   1. If per port sequence is introduced, the spatial interference covariance matrix is randomized and appear “close to spatially white”, which reduce the problem as the spatial colored property in the covariance matrix from the interfering cell is removed   ~   1. So far only Type I CSI feedback has been analysed, the false PMI selection issue may be even more pronounced for Type II CSI feedback. In addition, the impact of this on any new CSI feedback schemes introduced in future releases is at risk. Hence, leaving this issue unsolved may yet again hit us back in a future release.   ~   1. Network deployments where cell planning is used for CSI-RS can only partially mitigate the problem in the general case, due to strongly interfering stray signals transmitted from cells further away which are commonly observed in e.g. metropolitan deployments.   ~   1. Network deployment with colliding CSI-RS between all cells have significant benefits to the operator in terms of no need for such network planning, ease of network densification and evolution when adding new sites, lower reference signal overhead and low interference at low load in network. Deploying with non-colliding RS should be avoided due to these reasons.   ~   1. It must be ensured that UE implementation is prepared well for colliding CSI-RS (including TRS and all other uses of CSI-RS), and RAN4 test cases should include colliding CSI-RS deployments. Further note that such a test case with two TRS is currently being considered in RAN4 for multi-TRP operation in Rel.16 |
| [6] | We do not support this TEI proposal with the following reasons.   1. There has been inter-cell interference mitigation mechanism in place since Rel-15. There is no missing critical technical component in the spec. 2. There are UEs already implemented descrambling over neighbor cell interference. Procedurally the proposal does not qualify as Rel-17 TEI but a new spec’s mechanism designed for enabling certain UEs to upgrade to new RRC without changing low-level CSI-RS channel estimation implementation. 3. The new sequence is not backward-compatible.   For Rel-15/Rel-16 UEs already implemented descrambling over neighbor cell interference, they will not be able to support this Rel-17 TEI without low-level CSI-RS channel estimation change. Therefore, gNB still needs to separate CSI-RS configuration into two groups: one with newly adding per-port scrambling and the other with regular pre-Rel-17 setup. This introduces extra CSI-RS overheads per cell and defeats the purpose of simplifying network planning from avoiding CSI-RS reuse.  We note that CSI-RS sequences are typically used for multiple functionalities but not just for PMI reporting. A new CSI-RS sequence design should take all related functionalities into consideration instead of limiting to solving a particular issue. RAN1 had not studied potential impacts of the new proposed sequences; we think it is not proper to handle sequence design in Rel-17 TEI.  **Proposal:** Study on CSI-RS enhancement is not needed in Rel-17 TEI. |

Based on the above contributions, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #4**

* **Correct the CSI-RS design as below to remove the false PMI reporting problem**
  + **Support a port specific multiplier sequence y^(p^' ) (n) to the CSI-RS resource sequence**

This proposal is already supported by Ericsson, NTT DOCOMO, Softbank, Verizon and T-Mobile USA.

This proposal is already concerned by MediaTek.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

|  |  |
| --- | --- |
| Company | Comment |
| vivo | We are open for discussion, however smart UE implementation can avoid the problem. |
| NTT DOCOMO | We support the proposal. We believe this issue could happen in any of operation with more than 4 CSI-RS ports operation, and once it happens, large performance degradation is observed. Thus, we support the proposal to solve the issue |
| SoftBank | We support the proposal. |
| Intel | Support the TEI proposal. We have preference to address this problem in RAN4 by special performance requirement in the collided CSI-RS that would avoid problematic UE implementations |
| MediaTek | We do not support this proposal. Our view is well captured by moderator. |
| Huawei, HiSIlicon | We have not observed similar issues, from both practical network and UE sides. Depending on the implementation, there are some proprietary optimizations to mitigate the risk of false PMI report, by both gNB implementation and UE CSI processing. Therefore, the motivation for this TEI proposal is not yet seen. |
| ZTE, Sanechips | We are open for the discussion. However, as mentioned by multiple companies, advanced UE implementation is more preferred compared with the new CSI-RS sequence design which may cause more CSI-RS overhead. It can be further discussed compared to solutions with RAN4 impact only. |
| AT&T | We are supportive of the proposal to solve the false PMI reporting issue in TEI17. As mentioned by other companies, the solution presented can be used as a starting point and other solutions can be evaluated to solve the issue. |
| Qualcomm | We are open to consider this proposal further. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  Although there are multiple companies supporting (or being supportive) this proposal, it seems we should continue discussion on this proposal, including other option such as advanced UE implementation with RAN4 impact only. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | Firstly, according to the commens from some companies, similar issue was not observed by other network vendors. We need to frist confirm that whether this is due to cell planning or other reasons. Secondly, for a cell edge UE, with similar SINR for CSI-RS reception from serving cell and neighboring cell, it is not expected to measure CSI based on neighboring cell CSI-RS, assuming that different scrambling IDs are applied. If the SINR of neighboring cell CSI-RS is significantly higher than serving cell, the UE should hand over to neighboring cell. |
| Nokia | A more effective solution would be to introduce a release independent RAN4 requirement and test case for UEs. |
| Ericsson | **To MediaTek:**   * You mention “descrambling over neighbour cell interference,” is what you mean that UE shall average over sufficiently large bandwidth that the per RB sequence values have an effect? It may be so that some UEs doesn’t show the false PMI reporting behaviour but some other does, depending on the implementation. So I think you should be positive to resolve the issue in RAN4 with a test? This to ensure that all UEs can handle configurations with overlapping CSI-RS from all cells in a good manner (since this is the preferred deployment configuration). * If this new sequence is used for TRS (as you hint towards), what potential issues do you foresee that needs to be studied? * It is true that two separate periodic CSI-RS resources needs to be configured, but our analysis gives that this is still worth the extra overhead since the network performance benefit of having correct PMI from cell edge users is likely much larger than the extra overhead of a second periodic CSI-RS resource. It is well known that improving cell edge user performance has a large impact on network performance since these users occupy a lot of resources in time.   **To OPPO:**   * You seem to propose that operator should apply a handover threshold that is zero, i.e. handover to the neighbour cell exactly when the serving cell SINR drops is the same as the neighbour cell. That would lower the risk of false PMI reporting, but I believe this is too restrictive for operators to use such threshold and there is a large risk of handover ping pong effect. Also, there are other factors that determine the handover threshold. I think it it better to resolve the root cause of the false PMi instead. * Yow wrote *“it is not expected to measure CSI based on neighboring cell CSI-RS, assuming that different scrambling IDs are applied.”* I think you have misunderstood the cause of the problem. The UE is still measuring on the serving cell. Different scrambling sequences in the different cell doesn’t help to resolve this problem. Please check our tdoc with the analysis. * You mentioned other network vendors and that they didn’t observe the issue of false PMI reporting. Did these vendors use overlapping CSI-RS in neighbouring cells?   **To Huawei, HiSilicion:**   * You mentioned that you didn’t observe the issue of false PMI reporting. Did you use overlapping CSI-RS in neighbouring cells when performing this tests? * The proprietery solution on gNB side you mention is to use non-colliding CSI-RS resources in different cells, but this requires CSI-RS resource cell planning, which is not desirable by several operators. * For propretiary solution on UE side, wouldn’t a RAN4 test be needed to ensure that all UEs implement so that they handle colliding CSI-RS in different cells well? |
| Qualcomm | A few additional remarks:  In order to alleviate possible concerns, it would be interesting to know in what scenarios the problems were observed, if such information is shareable. It appears likely that when large delay spread is assumed in CSI-RS processing, there may be more false PMI reporting issue. Therefore, it would be also interesting to know in what network topology the issues occurred.  In any case, having port-dependent scrambling is a safer solution from multiple viewpoints, so we are supportive of considering it further. |

* 1. NR Positioning support for TA-based positioning in E-CID

Following proposal is made in the contribution.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| [8] | TA-based methods were already available in LTE for E-CID positioning, which were mainly used for meeting important regulatory requirements (e.g., localization during emergency calls). It is essential that when operators deploy NR Network and migrate from the LTE-based TA solutions, NR positioning should also be capable of providing this same important functionality, instead of a downgrading, which we have today.  Specifically, not every network element (gNBs, LMFs) or UEs may support Rel-16 UL SRS or DL-PRS based positioning – this is especially true in multi-vendor scenario environments, where network elements are coming from different vendors, and hence the possibility of interoperability issues which may lead to longer deployment period. Therefore, solutions similar to LTE which are based upon simple basic communication procedure such as TA should be made available to address such migration issue in a timely manner, and meet the same requirement for 5GS on providing UE location information during emergency calls.   1. Measurements and reporting similar to LTE TA Type2 are also needed in NR to provide positioning solutions to meet regulatory requirements and to ensure seamless positioning solutions when migrating from LTE to NR.   Besides helping to comply with regulatory requirements, TA measurements could also improve latency. Release 17 NR positioning use cases have considerably lower latency requirements compared to Release 16 and in [1] it was indeed observed that the latency could be greatly reduced if the network can report existing measurements based on timing advance, instead of using the PRS-based gNB Rx-Tx time difference measurement. Moreover, re-using already available measurement such as TA could help complementing the other measurement reports (such as PRS/SRS based reports) without introducing more RS overhead.   1. The network can report TA-based gNB RxTx time difference measurement without additional RS overhead cost or additional LPP signaling.   When looking at the LPPa/NRPPa specifications, in E-UTRA RAT the eNBs/ng-eNBs are able to report E-UTRA Angle of Arrival and Timing Advance Type 1/Type 2 in E-CID to the location server. Timing Advance Type 2, which is eNB Rx-Tx time difference measurement, is based upon PRACH (as seen in TS 36.214 extract below), which is considered a usual and required measurement to be signalled by UE to gNB in order to perform communication. Thus, it should already be supported by all networks.   |  |  |  | | --- | --- | --- | | 5.2.4 Timing advance (TADV)  |  |  | | --- | --- | | **Definition** | Type1:  Timing advance (TADV) type 1 is defined as the time difference  TADV = (eNB Rx – Tx time difference) + (UE Rx – Tx time difference),  where the eNB Rx – Tx time difference corresponds to the same UE that reports the UE Rx – Tx time difference.  Type2:  Timing advance (TADV) type 2 is defined as the time difference  TADV = (eNB Rx – Tx time difference),  where the eNB Rx – Tx time difference corresponds to a received uplink radio frame containing PRACH from the respective UE or similarly NPRACH from the respective NB-IoT UE.. | |   In this respect, Type 2 TA is only dependent on the gNB reporting and does not introduce any new measurement or reporting from the UE side, or any big system level impact. Therefore, the specification impact to support TA type 2 would be very limited, and it would not impact the UE.   1. TA type 2 does not impact the UE   Considering the important issues of interoperability and RAT migration, as well as the difficult contexts of 2020 and 2021 years - making positioning a crucial technology - we propose to focus this TEI on addressing the gap between LTE and NR by introducing the NR type-2 TA, similar to LTE definition. The specifications changes will be the timing advance definition in TS 38.215, and support of NRPPa reporting of NR TA as part of NR E-CID. For the NRPPa change, the reader can find an example in the Annex section of this paper. For the 38.215 changes, a draft CR can be found in [2].   1. Define the timing advance measurement for NR as follow:   Type2:  Timing advance (TADV) type 2 is defined as the time difference  TADV = (gNB Rx – Tx time difference),  where the gNB Rx – Tx time difference corresponds to a received uplink radio frame containing PRACH from the respective UE..   1. Extend the gnodeB Rx-Tx definition to include the PRACH based measurement:  * TgNB-RX is the Transmission and Reception Point (TRP) [18] received timing of uplink subframe #*i* containing SRS or PRACH associated with UE, defined by the first detected path in time. * TgNB-TX is the TRP transmit timing of downlink subframe #*j* that is closest in time to the subframe #*i* received from the UE. * Multiple SRS resources for positioning can be used to determine the start of one subframe containing SRS. * PRACH is used to determine the start of one subframe containing PRACH.  1. Send an LS to RAN2 and RAN3 with the agreement to add Type 2 TA reporting for NR so that their corresponding specification changes can be updated. |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #5**

* **Define the timing advance measurement for NR as below**
  + **Timing advance (TADV) type 2 is defined as the time difference TADV = (gNB Rx – Tx time difference), where the gNB Rx – Tx time difference corresponds to a received uplink radio frame containing PRACH from the respective UE**
* **Extend the gnodeB Rx-Tx definition to include the PRACH based measurement**
* **Discuss whether to include type 1 TA measurement and reporting as well, or leaving it for further study for RAN1 during rel17 positioning enhancements**
* **Send an LS to RAN2 and RAN3 with the agreement to add Type 2 TA reporting for NR so that their corresponding specification changes can be updated**

This proposal is already supported by NTT DOCOMO INC., Ericsson, Polaris Wireless, Verizon, China Telecom, FirstNet, Deutsche Telekom, Intel Corporation and CATT.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

|  |  |
| --- | --- |
| Company | Comment |
| vivo | We are fine with the proposal assuming it has no impact to UE. |
| Intel | We support proposal. |
| MediaTek | We are ok to discuss the proposal if it has little impact on UE implementation. |
| Huawei, HiSilicon | We support the motivation of the technical parts of this TEI proposal. However, it is not appropriate for a TEI to discuss changes to the WI scope, thus the 3rd main bullet should be revised or removed.  Technically, if PRACH is used, it should be based on PDCCH order, so that stage-2 specifications TS 38.300 and TS 38.305 in RAN2 should also be included. Then it appears clarification would be needed on if this can be properly handled in at least RAN2, and possibly also RAN3 depending on how their specs would be impacted, given the strong discouragement of cross-WG TEIs by RAN.  In addition, we believe NTA-offset should also be included in the respective message along with Type-2 TA or added to the gNB Rx – Tx time difference in the Type-2 TA definition, see the figure below. |
| ZTE, Sanechips | We are positive for this enhancement because   * Rel-16 Multi-RTT only supports gNB Rx-Tx time difference based on SRS, so it precludes the case that PRACH can also acquire similar information. In Rel-16, UE Rx-Tx time difference can only be reported by UE through LPP, if we support this enhancement, network can still do positioning even UE can’t support LPP. * It’s natural to extend to support what we have defined in LTE. Such enhancement is beneficial for positioning latency reduction and efficiency improvement.   There is an on-going positioning WI in Rel-17. We are also fine to update the scope of Rel-17 positioning WI for this enhancement as it involves multiple WGs, the workload should be clearer for the corresponding WGs if it is done in a proper WI. |
| Qualcomm | We can be open to consider the type 2 TADV under a clear common understanding that it will not have any UE impact, and it is for serving gNB only (similar to LTE).  We are not supportive of disussing Type 1 TA, nor leaving it up for further study during the rel-17 positioning enhancements. The Rel-17 Positioning work is heavy loaded, and the WID was converged after long discussions. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  Although there are many companies supporting (or being supportive) this proposal, it seems we should continue discussion on this proposal, including whether/how the WID scope of the Rel-17 positioning enhancement should be updated and whether this proposal fits into TEI as RAN2/3 impacts are expected.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| Ericsson | Thanks a lot to all companies providing feedback for this TEI. We would like to clarify that the revision presented for this meeting focused on type-2 TA and removed type-1 TA from the proposed scope. Thus the third bullet can be removed. We hope this would address the concern from Huawei and Qualcomm above. |
| Nokia | We are supportive of the proposal |
| NTT DOCOMO | Thank you for a lot feedback. Considering companies’ feedback, we believe many companies could be supportive of Type2 TA parts in the TEI proposal #5. In order to move the discussion forward, we are OK to take the only parts related to Type2 TA in this meeting and left the part related to Type1 TA to the next meeting. Therefore, we can update as follows:   * **Define the timing advance measurement for NR as below**   + **Timing advance (TADV) type 2 is defined as the time difference TADV = (gNB Rx – Tx time difference), where the gNB Rx – Tx time difference corresponds to a received uplink radio frame containing PRACH from the respective UE** * **Extend the gnodeB Rx-Tx definition to include the PRACH based measurement** * **Send an LS to RAN2 and RAN3 with the agreement to add Type 2 TA reporting for NR so that their corresponding specification changes can be updated** |
| Huawei, HiSilicon  (updated) | For Type2, we will support the proposal if the issue related to NTA,offsetreporting is addressed. As illustrated before, we prefer the following change on the fourth bullet, assuming the third bullet is removed already.   * **Send an LS to RAN2 and RAN3 with the agreement to add Type 2 TA and NTA,offset reporting for NR UL E-CID so that their corresponding specification changes can be updated** |

* 1. Enhancements on the scheduling of PUSCH over multiple slots

Following proposal is made in the contribution.

|  |  |
| --- | --- |
| [5] | Following the timing order of DL/UL DCI formats, as shown in Figure 1, UL DCI format transmitted in slot n+1 schedules a PUSCH transmission in slot n+k, so the second DCI format in slot n+2 is not allowed to indicate a PUCCH carrying the HARQ feedback corresponding to the PDSCH and the PUCCH is overlap with the PUSCH in slot n+k.    Figure 1. Timing restriction on UL/DL scheduling for HARQ information multiplexed on PUSCH  The same scheduling restriction, although not described explicitly in the spec, is also applied to the PUSCH with repetitions. However, due to the length of PUSCH transmissions in time, the restriction introduces more strict constrains on gNB scheduling for the case of PUSCH repetition.  To achieve higher throughput and/or achieve better coverage, gNB has to allocate more symbols for UL transmission, e.g. 14 symbols in each slot are assigned for PUSCH transmission, and therefore, it is difficult to avoid overlapping of PUCCH and PUSCH in the slots of PUSCH repetitions. For the case aiming to have less latency, PUSCH repetition type B is configured with less than 14 symbols, however, type-B PUSCH repetition will span contiguous UL symbols which leaves no spare time resources for PUCCH between repetitions and it is also difficult to avoid overlapping between PUSCH and PUCCH. Hence, it seems hard to always allocate PUSCH and PUCCH TDMed in each PUSCH repetition slots and to comply with the scheduling restriction, gNB might have to indicate the HARQ feedback after all PUSCH repetitions.  Take an example for FDD system as shown in Figure 2, UL DCI in slot n schedules a PUSCH transmission over slots from n+2 to n+5 and the number of symbols for each PUSCH repetition is 14. PUCCH conveying the HARQ feedback corresponding to PDSCH in slot n+1 is not allowed to transmit in the slots of PUSCH repetition, i.e. slot n+2 ~ n+5. So the earliest opportunity for HARQ reporting is in slot n+6, which results in a large k1 value and delay for HARQ feedback. The delay would become larger if more repetition times are assigned for PUSCH, and the k1 value could be as high as (K2 + number of PUSCH repetition) slots.    Figure 2. Scheduling of HARQ feedback with timing restriction in FDD system  ***Observation 1: If PUSCH repetition is configured, the timing restriction on scheduling HARQ after UL grant introduces large delay for HARQ feedback, which could be as high as (k2 + number of PUSCH repetition) slots.***  In Rel-16, the number of PUSCH repetitions are counted by configured transmissions, the canceled repetitions caused by DL/UL collision will not be deferred. However, in Rel-17, the repetitions of PUSCH would be enhanced to transmit in available UL slots only, PUSCH repetitions may keep occupying a series of contiguous UL slots and leave no opportunity to transmit PUCCH for a long period, especially for TDD system. Illustrated in Figure 3, a DL domain frame is configured as DDDSU. In the slot 0 of frame N, UL DCI triggers PUSCH to repeat 4 times and each repetition occupies 14 symbols like the example in FDD system. Consequently, for the consecutive UL slots for frame N and N+1, gNB cannot schedule PUCCH to transmit the HARQ information associate with the PDSCHs scheduled in the DL slots of both frames. In other word, due to the PUCCH scheduling restriction, the DL data transportation are blocked for dedicated k1 values. For example, if the value of k1 is set as 7>k1>1, PDSCHs cannot be scheduled within any slots of frame N and frame N+1.    Figure 3. Scheduling of HARQ feedback with timing restriction in FDD system  ***Observation 2: If PUSCH repetition is configured, the timing restriction on scheduling HARQ after UL grant causes PDSCH blockage for dedicated small k1 values.***  As the analysis above, if repetition is enabled for PUSCH, the scheduling restriction for HARQ feedback after UL grant will introduce a large delay for HARQ reporting. The PDSCH scheduling is also blocked due to lack of PUCCH resource and the DL data rate is also slowed down in the meanwhile. Therefore, optimizations for PUSCH repetitions on the scheduling restriction should be studied to overcome the performance loss caused by the restriction.  ***Proposal 1:*** ***Optimization of timing restriction on scheduling HARQ after UL grant should be supported for the case of PUSCH repetition.***  Two alternatives can be considered for the optimization of the scheduling restriction. One alternative is to only apply the timing restriction to initial PUSCH repetition. That is, it is allowed to schedule PDSCH after UL grant with the corresponding HARQ-ACK multiplexed on non-initial PUSCH repetition(s) to avoid additional latency for HARQ feedback and blockage of DL data, as shown in Figure 4. For this alternative, the scheduling of first transmission is similar as that of the single PUSCH transmission, thus a uniform design could be applied for both cases which has less standards impact.  Another alternative is to release the restrictions for all the PUSCH repetitions. No matter initial or non-initial PUSCH repetitions, all of them can convey the HARQ bits for PDSCHs indicated after the UL DCI. This will bring a higher level of flexibility for gNB scheduling, but gNB has to treat single slot and multiple slots PUSCH separately. On the other hand, the removal of scheduling restriction will cause invalidation of total DAI in the UL DCI. More investigation on DAI mechanism and impact analysis on DCI design are needed, which means lots of standard efforts are required as well. So considering the limited time for TEI discussion, the first alternative is more preferable due to less standards impact.  ***Proposal 2: The time restriction on scheduling HARQ after UL grant is only applied to initial PUSCH repetition, and HARQ information bits corresponding to the PDSCH(s) scheduled after UL grant which triggers the PUSCH transmission are allowed to be multiplexed on the non-initial repetitions.***    Figure 4. Apply the timing restriction to the initial PUSCH repetition only  The optimization of timing restriction in section 2.1 relaxes the scheduling of PUCCH and makes it possible to piggyback the HARQ information corresponding to PDSCHs scheduled later than the instance of UL DCI received. However, in this case the total DAI in UL grant cannot reflect the number of scheduled PDSCH(s) after the UL grant, which would have impact on the HARQ-ACK codebook size determination. Therefore, some enhancements are needed here.  As shown in Figure 5, if the scheduling restriction is maintained for initial repetition but relaxed for non-initial ones, i.e. the first alternative in Section 2.1, the total DAI in the UL DCI format can be still applied to the first PUSCH repetition. For the non-initial PUSCH repetitions, one simple way is to use the DAI in the last DL DCI instead to count the quantity of PDCCH monitoring occasion and calculate the number of HARQ bits, which is same as the HARQ feedback on PUCCH. One potential problem raised by some companies in RAN1#104b-e meeting is the impact due to last DCI missing. Considering the reliability requirement of PDCCH decoding, the probability of DCI missing is relative low and thus the impact might not be a very serious issue.    Figure 5. Update total DAI in UL DCI by the DAI in DL DCI  One alternative to address the impact from DCI missing is to still use the total DAI in the UL DCI format scheduling PUSCH repetition to calculate the HARQ information bits on each PUSCH repetition, assuming that the total DAI covers both the number of PDCCHs sent before the UL DCI and the ones delivered after the UL grant. Although, in the PHY layer, gNB cannot anticipate how many PDSCHs will be scheduled in the next slots, , gNB may set an upper bound of HARQ bits as the total DAI in UL grant to cover all the possible PDSCH(s) receptions, as shown in Figure 6. The challenge of this solution is the uncertainty for the future scheduling from gNB side. If the total DAI is set too large, additional resources are wasted. If the DAI is set too small, it will also limit the potential PDSCH receptions so that to degrade the downlink data rate.    Figure 6. Total DAI in UL DCI cover all past and future DL grants  Another method is to update the total DAI by other signaling. For example, a new DCI can be sent to UE to update the DAI value just before the PUSCH transmission subject to the timeline conditions, similar operation as DCI format 2\_4 which used to cancel the PUSCH transmission scheduled previously. As shown in Figure 7, UL DCI\_2 is transmitted to UE to update the total DAI value which is notified by UL DCI\_1 in slot n+1, to incorporate the HARQ information corresponding to the PDSCH\_2 scheduled in slot n+2. The shortage of this method is also obvious, additional DAI update signaling will bring more scheduling complexity and resources waste.  Considering above three methods to determine the HARQ information bits on PUSCH comprehensively, it seems the first option (i.e. rely on the DAI in last DL DCI) is more appropriate for TEI from the specification impact perspective. Note similar operation is also applied for multiplexing HARQ on CG PUSCH (without UL DCI scheduling or UL DAI). Therefore, following proposal is made.    Figure 7. New UL DCI delivered to update DAI value  ***Proposal 3: When the timing restriction on scheduling HARQ after UL grant is released for the non-initial PUSCH repetitions, DAI in the last DCI is applied to determine the number of HARQ information bits multiplexed on the non-initial PUSCH repetitions.*** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #6**

* **Support the optimization of timing restriction on scheduling HARQ after UL grant for the case of PUSCH repetition**
  + **The time restriction on scheduling HARQ after UL grant is only applied to initial PUSCH repetition, and HARQ information bits corresponding to the PDSCH(s) scheduled after UL grant which triggers the PUSCH transmission are allowed to be multiplexed on the non-initial repetitions**
  + **When the timing restriction on scheduling HARQ after UL grant is released for the non-initial PUSCH repetitions, DAI in the last DCI is applied to determine the number of HARQ information bits multiplexed on the non-initial PUSCH repetitions**

This proposal is already supported by Huawei, HiSilicon and China Unicom.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

|  |  |
| --- | --- |
| Company | Comment |
| vivo | It is one of the open issues being discussed in coverage enhancement AI 8.8.1.1, better discuss in currently open WI |
| NTT DOCOMO | We understand the motivation. On the other hand, using DAI in the last DL assignment instead of UL DAI seems not good way since if the DL assignment is not decoded successfully, PUSCH performance becomes degraded or gNB needs to do blind decoding. Careful discussions are necessary for this issue, so we are slightly negative on this proposal as TEI. It seems that Coverage enh. WI is discussing this issue. |
| CATT | We are ok to discuss this proposal. |
| Sharp | We support the motivation of the proposal on time restriction relaxation. The proposal looks good. |
| MediaTek | We share a similar view with vivo. We think it is better to discuss this in R17 coverage enhancement WI. |
| Huawei, HiSilicon | We support this proposal. Current spec has a tight restriction on DL scheduling after UL grant and the restriction will bring a large HARQ feedback delay and DL repcetion blockage when PUSCH repetition is enbled.  The proposal is going to relax the scheduling restriction for non-initial PUSCH repetition. For the initial PUSCH repetition, the restriction is still applied similar as signle PUSCH transmission. For the HARQ bits generation, the UL DAI in the UL grant is applied for the initial repetition, and DL DAI in DL grant is used instead for non-initial PUSCH repetition(s).  As the comment from others in last meeting, companies think last DCI missing causes the misalignment of HARQ information bits between gNB and UE. We think the probility of DCI missing is not too high and issue is not very severe. We should also note that for CG PUSCH multiplexing HARQ bits, DL DAI is used already.  We think the proposal has limited spec changes and reuses the existed method as much as possible, while we are also open to discuss any solutions to fix the issue. |
| Panasonic | We are supportive to discuss this proposal. When the number of repetitions is larger, the repetition transmission would occupy a lot of UL slots. If there is a HARQ-ACK feedback, HARQ-ACK would have to wait until PUSCH repetition have been finished and with the restriction on PDSCH scheduling, DL spectral sfficiency and/or latency will degrade. Although this issue was also raised in Rel.17 coverage enhancement WI, we think to slove this issue is beneficial even in Rel.16 functionality to improve the DL spectral efficiency. |
| ZTE, Sanechips | We acknowledge that there are some scheduling restrictions for the concerned case. However, it is fully up to gNB implementation on how to perform the scheduling. There could be multiple ways to schedule a PDSCH after the UL grant scheduling a PUSCH without multiplexing the HARQ-ACK corresponding to the PDSCH on the PUSCH. Below are two examples.   1. Enable PUSCH repetition type B for PUSCH. By configuring some UL symbols/slots as invalid symbols/slots by *invalidSymbolPattern* for PUSCH repetition type B, the PUCCH carrying HARQ-ACK for the PDSCH scheduled after the UL grant can be transmitted on these invalid symbols/slots. This can be applied for scheduling both eMBB and URLLC traffic, as long as the UE can support PUSCH repetition type B.  * *“The UE may be configured with the higher layer parameter invalidSymbolPattern, which provides a symbol level bitmap spanning one or two slots (higher layer parameter symbols given by invalidSymbolPattern). A bit value equal to 1 in the symbol level bitmap symbols indicates that the corresponding symbol is an invalid symbol for PUSCH repetition Type B transmission. ”*  1. Schedule 7-symbol PUSCH per slot based on PUSCH repetition type A with potentially increasing the number of repetitions if necessary. In such case, the PUCCH carrying HARQ-ACK for the PDSCH scheduled after the UL grant can be transmitted on the remaining symbols, with or without enabling PUCCH repetition.   In addition, it seems the proposed optimization may introduce some specification impact which might be too big for a TEI. For instance, how to design the UL DAI, how to incorporate the case for UL skipping, and how to consider intra-UE multiplexing if PHY priority is considered as discussed in Rel-17 etc.  Overall, we think this TEI proposal can be further discussed and considered only if clear benefit is shown compared to the implementation methods based on the current spec. |
| Ericsson | As we expressed in previous meeting, in our view the restrictions on scheduling PDSCH after UL grant, impacts on system performance specially in TDD deployments. The impact is more emphasized in case of PUSCH repetition or triggering A-CSI as we explained in previous meeting.  **Therefore, from our view the issue is legitimate, and we should aim for a general solution, not specific to PUSCH repetiton.**  On the proposed solution for PUSCH repetition (TEI proposal #6), there are still issues that in our view leans towards the direction that focusing on a general solution is more appropriate.  In particular, the first bullet does not really solve the underlying issue that resulted to this restriction (i.e. DAI determination). In our view, timeline requirements should be respected anyway.  The second bullet aims to address the underlying issue (i.e. DAI determination). However, as other companies commented there is still issue because currently in case of PUSCH repetition, it s assumed that the t-DAI in UL grant is applicable to all repetitions. That means that eventually we would lean towards a solution that would be applied per PUSCH transmission and corresponding HARQ-ACK to be multiplexed in. And the dependency by coupling it to PUSCH repetition framework would be in principle irrelevant.  On the comments related to whehter this topic should be discussed under CE or TEI Rel-17, our view is that **the enhancement is out of scope of CE WID. Then it should be discussed in TEI Rel.17.**  In summary:   * **We are supportive of solving the scheduling restrictions issue in general and not specific to PUSCH repetiton under TEI Rel-17.** |
| Qualcomm | We are open to discuss this with lower priority. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  It was clarified in CovEnh session that this proposal can be discussed in TEI-17 agenda instead of CovEnh agenda.  Although there are multiple companies supportive to discuss on this proposal, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor. There are some comments that we should discuss on e.g., whether there is clear benefit compared with implementation based solution and whether the proposal can be extended to general solution for solving the scheduling restriction issues rather than specific to PUSCH repetition.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| Nokia | We share the Ericsson view in general. |
| Qualcomm | A few additional remarks:  As ZTE points out, its not clear how prevalent these issues are in TDD systems and how much these issues can be alleviated by appropriate scheduling decisions at the gNB. Additional clarification/justification on the need for these changes is required.  Unlike Ericsson, we prefer a more targeted solution that addresses the core issue at hand with as few changes as possible. Reusing the existing framework for CG-PUSCH repetitions would be a good starting point. |
| Huawei, HiSilicon (updated) | @ Vivo @ MediaTek  According to the discussion in coverage WI in this meeting, it seems the common understanding is that it will be discussed in Rel-17 TEI here.  @ NTT DOCOMO  The reason we propose to use DAI in the last DL assignment is to minize the specification impact/effort, since we are doing TEI. However, if there is any other better way, we are open to discuss as long as it can be suitable for a TEI. Companies are encouraged to share your solution for this issue also if any.  @ ZTE  Firstly, we cannot rely on PUSCH repetition type B for all cases, and enhancements should be designed for both PUSCH repetition type A and PUSCH repetition type B. In addition, for the example you provided by using invalid symbol with PUSCH repetition type B, it will have impact on PUSCH repetition transmission also, e.g. increase the delay for PUSCH transmission, especially if you configured repetition type B latency may be one of the main motivation.  Secondly, as the example you mentioned by scheduling PUSCH on part of the symbols in a slot, we think it is not efficient. Since usually when gNB schedules the PUSCH, it cannot predicate whether any/how many DL transmissions needed after the UL grant for scheduling the PUSCH, therefore it may result in additional DMRS overhead while achieve nothing because of splitting the PUSCH transmission.  Finally, as you can tell from our proposal, we are trying to minimize the specification impact by simple solutions. We don’t see the relationship with UL skipping either, if there is any issue you identify, we are happy to disucss also.  @ Ericsson @ Nokia  As we discussed before, the impact from the restriction for the case of A-CSI reporting is not that serious. And considering this is a TEI, we think may be better to focus on the most serious case (i.e. PUSCH repetition) first, to avoid too much discussion on the applicable scenario and potential more specification impact. However, we are open to consider other scenarios also as long as it can be suitable for TEI.  @ Qulacomm  As we reply to ZTE and also the analysis in our paper R1-2105536, it cannot always find a proper scheduling decision to avoid the overlapping between PUCCH and PUSCH in such case and scheduling does not resolve the issue entirely without any cost. In addition, our original intention is also to focus on some specific enhancement item to make it suitable for a TEI, and our proposal is actually the same as the existing framework for CG-PUSCH, i.e. using the DL DAI in DL assignment to generate the HARQ-ACK codebook. However, as you observed some other companies may want to extend the scenarios also, our thinking is that if still we can use some simple solution to solve the issue, we are open to extend to more cases. |

* 1. Enhancement on SSB resources for RLM

Following proposal is made in the contribution.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [1] | A UE is required to monitor the downlink radio link quality of the primary cell to indicate out-of-sync/in-sync status to higher layers. The reference signals for radio link monitoring (RLM) can be SSB or CSI-RS, which are configured by *RadioLinkMonitoringRS.* Each *RadioLinkMonitoringRS* corresponds to a resource, either SSB or CSI-RS, for the radio link failure detection.  For a UE that supports the use of CSI-RS for RLM, if the UE is not provided with *RadioLinkMonitoringRS*, the UE can use the CSI-RS provided for the active TCI state for PDCCH receptions as the RLM resources. However, not all UEs have the capability to support the use of CSI-RS for RLM. For a UE that does not have the capability, the UE can only use the SSBs explicitly configured through *RadioLinkMonitoringRS* as the RLM resources.  However, a UE can only be configured with up to  SSB resources for RLM as shown in Table 1, where  is much smaller than the maximum number of SSBs from a serving cell. In this case, a UE may undesirably declare the radio link failure (RLF), if it cannot detect the SSBs configured by *RadioLinkMonitoringConfig,* even if it can receive one or more other SSBs from the serving cell properly.  Table 1:  as a function of maximum number (TS 38.213)   |  |  | | --- | --- | |  |  | | 4 | 2 | | 8 | 4 | | 64 | 8 |     A potential solution for the above issue could be that if a UE cannot receive the SSBs configured by *RadioLinkMonitoringConfig* for radio link monitoring, but can detect the SSBs from the same serving cell, the UE will use the detected SSBs with the maximum RSRP from the same serving cell for RLM instead of declaring the RLF. With this approach, it will provide the gNB enough time to re-configure the *RadioLinkMonitoringConfig* with the SSBs reported from the UE in RRM measurements, and reduce the probability of triggering the unnecessary RLF procedure.  ***Proposal 1:*** ***If a UE cannot detect the SSBs configured in RadioLinkMonitoringConfig for radio link monitoring for a serving cell, but it can detect other SSBs from the same serving cell, the UE should use the detected SSBs with the maximum RSRP as the RLM resource.*** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #7**

* **If a UE cannot detect the SSBs configured in *RadioLinkMonitoringConfig* for radio link monitoring for a serving cell, but it can detect other SSBs from the same serving cell, the UE should use the detected SSBs with the maximum RSRP as the RLM resource**

This proposal is already supported by CATT.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| Company | Comment |
| vivo | In case the configured SSB is not detectable by the UE, the usefulness to use other SSBs for RLM is not clear, since those SSBs not configured to the UE does not reflect the link quality for PDCCH reception for the UE most likely. It is more robust to allow UE to trigger PRACH procedure so that network can reconfigure the RLM SSBs. |
| CATT | Response to vivo’s comments:  The issue is caused by the limitation of the number of SSBs that can be configured for RLM. For example, in FR2 a cell can have up to 64 SSBs, but only up to 8 can be configured for RLM. Thus, the chance is very high that a UE can measure the strong RSRP from non-RLM SSBs, but not RLM SSBs. In this case, the link quality for PDCCH reception is still good. Allowing UE to continue using the non-RLM SSB with maximum RSRP for RLM will not only avoid triggering unnecessarily RLF procedure, it also gives gNB the time to reconfigure the RLM SSBs based on the UE RRM measurements to avoid the connection interruption. |
| NTT DOCOMO | The current maximum number of SSBs to be monitored for RLM according to the RadioLinkMonitoringConfig was the outcome of extensive discussions and compromises in Rel-15 NR initial access and mobility sessions. Although we preferred to support larger maximum number in the discussion, this TEI proposal #7 would require some interaction between RLM procedure and other procedure which may detect “other SSBs from same serving cell” than those monitored for RLM. In addition, RLM is based on SINR measurement of the RLM-RS to derive hypothetical PDCCH BLER. Therefore, only when the “other procedure” performs SINR measurement of SSB, it may be possible to be utilized also for RLM. In that sense, applicable case of this proposal would be limited. |
| CATT2 | Response to NTT DOCOMO’s comments:  We fully agree with the statement “maximum number of SSBs to be monitored for RLM according to the RadioLinkMonitoringConfig was the outcome of extensive discussions and compromises in Rel-15 NR initial access and mobility sessions.” That is the main reason that we did not propose to increase the maximum number of RLM SSBs. Instead, our proposal is that if the UE cannot detect the SSBs configured in RadioLinkMonitoringConfig, and it has already detected other SSBs from the same serving cell when supporting RRM measurements, the UE uses the detected SSBs as RLM SSB. The impact of the proposal to UE’s implementation is simply to treat the SSB with maximum RSRP as if it were configured for RLM. Thus, we don’t see the need to change the existing RLM procedure. |
| Intel | If the UE is performing the measurement of non-configured SSBs for RLM, how does the gNB know the UE is performing this? RLM is an internal UE operation and nothing is signaled to gNB until RLF happens.  If UE is monitoring non-configured SSBs, and gNB does not know, how would gNB signal approratie PDCCH in the right CSS or update the TCI for USS? Its not clear from the TEI whether nothing else needs to be changed in order for the system to benefit from the additiona monitoring performed by the UE.  Additionally, if UE is also monitoring non-configured SSBs, this may potentially require UE to perform channel estimation and compute effective SINR from the SSB to derive the hypothetical PDCCH BLER rates. This operation is quite complex and expensive and the whole point of the RLM RS limitation was to limit the UE complexity.  If the proposed feature were to be introduced, there would need to be a corresponding UE capability for the UEs that are able to perform such complex operations. |
| MediaTek | We have some questions for clarification.   1. Is this an issue identified in field? 2. Is it in FR1 or FR2 or both? 3. Why does UE not trigger beam failure recovery (BFR) before declaring RLF? |
| Huawei, HiSilicon | To our knowledge, CFRA and CBRA based beam failure recovery procedures allow UE to send in RACH to report accessibility of “other SSBs” have been designed to address the observed problem. So this proposal seems not needed. However, let’s hear the clarifications from the proponenet first. |
| ZTE, Sanechips | We are open to discuss this TEI proposal. In most of the cases, the network can configure appropriate RS for RLM explicitly or implicitly according to the BM/BFR result to reflect the PDCCH reception status. We understand the proposal is applied in the scenario that the network cannot re-configure the RLM-RS timely when the PDCCH beam is changed outside the RLM-RS set. In this case, the unnecessary RLF declaration can be avoided. We can first discuss under what scenario the network configuration cannot catch up with the timing before the RLF declaration. |
| Ericsson | Support. This could reduce the risk for RLF. |
| Qualcomm | We share the same view as NTT DOCOMO. Note that the same discussion was discussed in R15. In general, NW can properly configure RLM resources to avoid the issue e.g., based on beam management report. Further it doesn’t suffice for the UE to autonomously switch to monitoring a different SSB without letting the gNB know about this switch. |
| CATT3 | To Intel’s comments:   1. In our proposal, UE is not required to measure non-configured SSBs for RLM when the UE can still measure the configured SSBs for RLM, and not required to measure extra non-RLM SSBs either. What we propose is when UE cannot detect configured RLM SSBs, the UE uses (already detected) non-RLM SSBs with maximum RSRP for RLM. In the proposed enhancement, there is no need for UE to inform gNB that UE has started to use other SSBs for RLM. gNB may find out it needs to reconfigure the RLM SSBs from other information, e.g., from the RRM measurement report. 2. As also mentioned in Intel’s comment, RLM is UE’s internal operation based on the *hypothetical* PDCCH BLER rates derived from UE based on SINR, the proposed enhancement has no impact on PDCCH signal. 3. We share the similar view as Intel that RLM operation is quite complex and expensive and the RLM RS limitation was to limit the UE complexity. In our proposal, UE only start monitoring the non-RLM SSB when the UE cannot detect RLM SSB. There is no increase of the number of RLM RS for the UE to monitor at any given time. 4. As explained above, we don’t see there is any significant increase in the complexity to support the proposed operation. *We would argue the proposed enhancement has the potential to reduce the RLM operation complexity if it is used properly*, since it may allow the reduce of the number of SSBs configured for some scenarios, e.g., for slow moving or stationary UEs. But, we are open to the discussion of UE capability for supporting it.   To MTK’s comments:   * The issue was identified in the field in FR1. It requires the gNB to very frequently re-configure the RLM SSBs for a moving UE. * The problem is expected to be much worse for FR2 because the DL beam width of FR2 is much narrower. A cell can have 64 SSBs, but the maximum RLM SSBs can only be only 8. * Our understanding for beam failure recovery is more related to support MIMO operation for data service, while RLM is used to determine whether the connection is reliable. They are separate procedures. RLM needs to work properly even there is no data service.   To Huawei’s comments:   * RLM is a procedure different from beam failure recovery procedures. RLM is based on UE’s evaluation of the *hypothetical* PDCCH BLER rates. In another word, UE performs the RLM operation regardless of whether there is a data service or PDCCH signaling for the UE. Thus, the UE may declare RLF for RLM even if there is no data service/no declaration of the beam failure. In addition, our understanding of CFRA and CBRA based beam failure recovery procedures are optional UE features (or mandatory with capability signalling). Even a new SSB is identified during the BFR procedure, RRC reconfiguration is still needed to reconfigure RLM RS which is not desirable.   To ZTE’s comments:   * Yes, the proposal is a remedy the scenario that the network cannot re-configure the RLM-RS timely. The proposal intends to avoid the unnecessary RLF declaration of RLM. Again, we would like to point out the RLM procedure uses the *hypothetical* PDCCH BLER rate that is estimated by the UE based on monitor the RLM RS. But, it is not based on the real PDCCH signaling and PDCCH beam state.   To Qualcomm’s comments:   * As we explained about, beam management and RLM are two separate procedures. We may not expect NW to depend on beam management procedure to resolve the issue of RLM. Also, as our response to Intel’s email, for simplicity we do not propose UE to inform gNB about of the switch. gNB may find out it needs to reconfigure the RLM SSBs from other information, e.g., from the RRM measurement report. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  Although the proponent tried to address concerns from companies, it seems we should continue discussion on this proposal, as there may still be question/concern from companies e.g., regarding applicable scenario and UE impact of this proposal. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | The configured RLM-RS shall be able to reflect the channel condition for PDCCH reception. Please note that limited TCI-states can be activated at a time and if configured SSB for RLM is not detectable by the UE, it is very likely that the UE is with poor channel for the configured PDCCH. Therefore, it is meaningless to use other detected SSB for RLM, which doesn’t reflect channel condition for PDCCH reception. |
| Qualcomm | A few additional remarks:  We are definitely not in favor of increasing the maximum number of beams in RLM configuration.  We are concerned that this proposal seems to go against the purpose of configuring RLM resources i.e., what is the point in configuring resources if the UE is expected to ignore the configuration anyway? If the network chose to use multiple beams and expects the UE to perform beam management, then the onus is on the network to properly configure and update the appropriate resources. Since the gNB has to reconfigure TRS upon beam change in response to a UE report indicting a new best serving beam, the gNB has no reason not to reconfigure the RLM resources as well, if needed, which simply avoids the issue that the proposal itended to address. |

* 1. Periodic SRS transmission outside DRX active time

Following proposal is made in the contribution.

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| [3] | According to NR Rel-15, when a UE is configured with DRX operation, the UE is not required to measure and report periodic and semi-persistent CSI outside the DRX active time. In Rel-16 UE power saving WI, as an enhancement for the DRX operation, a PDCCH-based wake-up signal (WUS), i.e., DCI format 2-6, has been introduced, based on which, the network can indicat the UE whether to start or skip a *drx-onDurationTimer* for a DRX cycle. In the later stage of Rel-16 discussion, an issue was identified with the periodic and semi-persistent CSI reproting when both DRX and DCI format 2\_6 are configured: if the UE is not indicated to wake-up by the network for a long time, e.g., due to DL traffic inactivity, the UE needs to stay outside DRX active time during at least a few DRX cycles, and cannot get a chace to measure and report CSI during that time. Thus, when a new DL traffic arrives later and the UE is woken-up by the network, even the most recent CSI report from the UE is a few DRX cycles ago and may already be stale. This may result in an increased decoding error rate of earlier data packets, until the CSI at the network is updated by a new CSI report from the UE.  To address this issue, in Rel-16, when both DRX and DCI format 2\_6 are configured, it was agreed to allow measurement and reporting for periodic CSI during the time duration indicated by drx-onDurationTimer outside DRX active time. Two new higher layer parameters, *ps-TransmitPeriodicL1-RSRP-r16* and *ps-TransmitOtherPeriodicCSI-r16*, are introduced for separately enabling CSI reporting for L1-RSRP (i.e., cri-RSRP and ssb-Index-RSRP) and other report quantities, respectively, outside DRX active time.  Like periodic and semi-persistent CSI reporting, in Rel-15, the UE is not required to transmit periodic SRS and semi-persistent SRS outside the DRX active time. Thus, when the UE is configured with DRX and DCI format 2\_6, the same issue aforementioned for CSI reporting persists for SRS transmission; the UE may not get an opportunity to transmit SRS for a very long time outside DRX active time. When SRS is used for either DL or UL channel sounding, this may impact the overall system performance. In Rel-16, nevertheless, only the issue of CSI reporting outside DRX active time was addressed, while the issue with SRS transmission was overlooked.  Although periodic CSI reporting outside active time can help keep the CSI updated, it may not be sufficient in some case. For example, without channel reciprocity, the network should rely on SRS to assess UL channels. With channel reciprocity, relying on SRS for DL channel sounding may be more power efficient from the UE perspective, since the UE is not required to measure CSI-RS and compute the CSI report. Also, for SUL, SRS may be the only resource that the network can assess the UL channel. Therefore, it seems necessary to allow a UE to transmit SRS outside DRX active time, when the UE is configured to monitor DCI format 2\_6.  Proposal 4: When UE is configured with DRX and to monitor DCI format 2\_6, it can also be configured to transmit at least periodic SRS outside DRX active time during the time duration indicated by *drx-onDurationTimer*. |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #8**

* **When UE is configured with DRX and to monitor DCI format 2\_6, it can also be configured to transmit at least periodic SRS outside DRX active time during the time duration indicated by *drx-onDurationTimer*.**

This proposal is already supported by Qualcomm.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| Company | Comment |
| NTT DOCOMO | We are open to discuss this issue. For DRX, WUS and SCell dormancy, there are many descriptions in RAN2 spec, and it should be clarified whether/what is RAN2 spec impact. |
| CATT | We discussed in Rel-16 power saving whether to support SRS transmission when UE is not indicated to wake up by DCI format 2\_6 at next DRX ON. However, very few companies considered it is useful since UL channel and interference change quite fast between DRX cycle. The SRS information measured at this DRX cycle is not useful for next DRX cycle. |
| MediaTek | In principle, we are fine with the proposal. But for clarity, we would like provide some editorial revision in the following.  **Proposal:** When UE is configured with DRX and to monitor DCI format 2\_6, it can be configured to transmit ~~at least~~ periodic SRS ~~outside DRX active time~~ during the time duration indicated *by drx-onDurationtimer* regardless of the detection of DCI 2\_6. |
| Huawei, HiSilicon | The same proposal was discussed in Rel-16, and finally it was agreed only CSI measurement/reporting supported outside DRX active time during the time duration indicated by *drx-onDurationTimer*. There may be no need to repeat the discussion, considering that this functionality can be supported by gNB implementation. For example, if gNB wants to trigger SRS transmission, gNB can indicate UE to wake up by DCI foramt 2\_6. And during the OnDuration, UE can transmit SRS by legacy procedure. There is no need to introduce the enhancement in TEI. |
| ZTE, Sanechips | We do see the benefits of allowing UE to transmitting periodic SRS outside DRX active. And we think the scope can be limited to periodic SRS only. |
| Ericsson | From our perspective, this is not critical enhancement. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  Although there are some companies supportive for this proposal, it seems this is similar situation as Rel-16 power saving where other companies did not see the need of this proposal. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | The SRS enhancement outside of DRX could have some benefits, but whether it worth the enhancement needs further evaluation. In Rel-15, it actually can be achieved by SRS after DRX on, with small latency increased. |
| Qualcomm | We support this proposal. It is well understood why it was decided that supporting periodic CSI outside of active time is beneficial. Periodic SRS serves the exact same purpose in TDD when the network relies on reciprocity-based CSI. Therefore, in our view the justification of applying the same conclusion to periodic SRS is straightforward.  As some companies have pointed out, in the Rel-16 UE power saving WI, we have discussed both periodic SRS and periodic/semi-persistent CSI measurement and reporting as being impacted by DCI format 2\_6. Since the discussion arose in RAN1#99 near the end of the Rel-16 WI, we didn’t have enough time, and compromised to agree on only allowing periodic CSI/L1-RSRP measurement and reporting outside active time. Thus, we think the discussion should be continued in TEI. |

* 1. Joint configuration of DRX groups and Rel-16 power saving features

Following proposal is made in the contribution.

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| [3] | The feature of DRX groups was discussed under TEI16 in RAN2 as a solution to reduce power consumption when UE is configured with FR1+FR2 CA, and agreed in RAN#88-e. During the discussion, RAN4 confirmed that there is minimal impact on their specs [4]. On the other hand, RAN1 could not reach a consensus [5] on whether it may have any impact on other Rel-16 power saving features. As a way-forward, it was agreed that in Rel-16 DRX groups cannot be jointly configured with WUS or SCell dormancy.  Later, in RAN #90-e, it was further discussed whether to continue the discussion on the enhancement of DRX groups in Rel-17 UE power saving WI, focusing on the joint configuration with WUS or SCell dormancy. However, due to the concern on the limited TU for Rel-17 UE power saving WI, no consensus was made in RAN #90-e. In our view, the discussion on the enhancement of DRX groups should be continued due to the evident power saving benefits, and Rel-17 TEI should handle it.  **Joint configuration of DRX group and WUS**  It is easily expected that additional power can be saved if DRX group and WUS can be configured together. For example, suppose WUS configured on SpCell indicates to UE whether it should wake up for next on duration or not. Then skipping on durations when there is no data can help UE save extra power on top of savings enabled by DRX groups, in the same way as how WUS saves UE power if there is only single DRX group. In Appendix A.2 of [6], we provide a quantitative analysis on the power savings that can be achieved by joint configuration, compared with the baseline in which WUS is not configured. The analysis shows that ~82% more power can be saved per DRX cycle than the baseline when there is no data and ~18% when there is data.  Observation 1: If WUS and DRX groups are jointly configured, UE can save extra ~82% power per DRX cycle when there is no data and ~18% when there is data.  If we have to minimize the impact of joint configuration of DRX group and WUS in RAN1, then the existing UE behaviors need to be reused as much as possible. More specifically,   * WUS should be configured only on SpCell, as in legacy; * Conditions for WUS monitoring is completely determined by DRX state of SpCell and independent from DRX state of the secondary DRX group. For example, UE monitors WUS if SpCell is not in DRX active time, even if secondary DRX group is in DRX active time at the same time. This requirement avoids changes to the RAN1 spec; * If WUS is not received or does not indicate wakeup, none of UE’s carriers should wake up, as in legacy; * If a WUS occasion is not monitored (e.g., SpCell is already in DRX active time) or WUS indicates wakeup, UE should start DRX on duration timers of both DRX groups at their respective next occurrence. This behavior can be captured in RAN2 MAC specification. Note that this behavior works even in the corner case where FR1 (SpCell) is outside DRX active time but FR2 is within DRX active time.   As one may see from the above, no new PHY-layer behaviors need to be defined. We only need to add the following clarifications to the RAN1 standards:   * Clarify that, if secondary DRX group is configured, DRX active time for a serving cell refers to DRX active time of its associated DRX group; * Clarify that DRX on-duration timer refers to those of all DRX groups in the text on WUS procedure.   Text proposal for the above clarifications can be found in [7].  Observation 2: Joint configuration between WUS and DRX groups can be supported with minimal change to RAN1 specs.  **Joint configuration with SCell dormancy**  In legacy, there are two scenarios in which SCell dormancy indication can be sent:   * Case 1. In a WUS occasion outside UE’s DRX active time, it can be sent together with WUS to indicate which SCell dormancy group(s) should switch to dormant BWP; * Case 2. When UE is in DRX active time, it can be sent in a non-fallback DCI to indicate which SCell dormancy group(s) should switch to dormant BWP.   Case 1 requires joint configuration with WUS. In case secondary DRX group is configured, it effectively overrides DRX state of a SCell. For example, if a FR2 carrier is in a SCell dormancy group and receives dormancy indication, then it does not need to monitor PDCCH until the next DRX cycle, i.e., before receiving the next WUS. Therefore, network can take advantage of this property and use SCell dormancy indication to selectively wakeup secondary DRX group. In Appendix A.2.2 of [6], we provide a quantitative analysis on the power saving gains that can be achieved in this scenario. Our analysis shows that ~18% more power can be saved than the baseline.  In this case, because SCell dormancy indication is sent together with WUS, we do not expect much changes to RAN1/2 standards other than those described above for WUS.  Observation 3: If SCell dormancy is jointly configured with DRX groups, dormancy indication sent outside DRX active time can help save ~18% power.  In Case 2, if secondary DRX group is also configured, we think SCell dormancy operation and DRX operation can be independent from each other. More specifically,   * If both DRX groups are in DRX active time, SCell dormancy procedure can be performed exactly the same as in legacy (i.e. only a single DRX group is configured); * If the secondary DRX group is outside DRX active time, UE can still switch active BWPs of any carriers in that DRX group according to the received indication (i.e. either from dormant to non-dormant BWP or from non-dormant to dormant BWP). It is only an implementation matter that UE first stores the new active BWP indication for a carrier and then uses it after the carrier starts the next DRX active time.   It is straightforward to see that this case also requires no spec changes. Even though joint configuration in this case may not enable extra power savings, we think it is still beneficial for operators if the two features can co-exist. Otherwise, it would not be desirable if operators are forced to choose one feature over the other. For example, DRX groups may be deployed earlier than other power saving features, including SCell dormancy, because operators typically have more field experience with DRX. Then the artificial exclusivity imposed by the current Rel-16 agreement could delay the deployment of SCell dormancy, which clearly is not desirable for both operators and UEs.  Observation 4: Joint configuration between SCell dormancy and DRX groups can be supported without any change to RAN1 specs.  Based on the above analysis, we propose to discuss the following proposal in Rel-17 TEI:  Proposal 5: Support joint configuration between DRX groups and WUS, SCell dormancy, or both, without changes to their PHY-layer configurations and procedures. |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #9**

* **Support joint configuration between DRX groups and WUS, SCell dormancy, or both, without changes to their PHY-layer configurations and procedures.**

This proposal is already supported by Qualcomm.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| Company | Comment |
| vivo | We are open to discuss this proposal |
| CATT | It was heavily discussed in RAN#89, and RAN#90 without consensus. The benefit of UE power saving with configuration of secondary DRX group and WUS is very small. However, the specification impact might not be small. A TEI is not able to accommodate the work. |
| MediaTek | As pointed out by Qualcomm’s contribution, this is a cross-WG (R1/R2/R4) issue. Hence, we don’t think it is fit for TEI. |
| Huawei, HiSilicon | The same proposal was discussed in RAN plenary and there was no consensus on the power saving benefit compared with Rel-16 power saving features, e.g. the dormancy adaptation in Rel-16.  Also, two DRX groups are defined in RAN2 MAC specification. It would be a cross-WG work to support joint configuration between two DRX groups and WUS, SCell dormancy.  We don’t think this should be discussed in Rel-17 TEI. |
| ZTE, Sanechips | Configuring dual DRX groups with WUS/SCell dormancy simulatenously would increase the implementation complexity for both gNB and UE, hence attractive power saving should be provided by the joint configuration on the top of the supported power saving features in Rel-15/Rel-16.  However, regarding the power saving gain observed in the referred Tdoc in RAN#90, we think similar power saving gain can be obtained with the configuration of single DRX + WUS/SCell dormancy. According to our understanding, the additional power saving gain from the joint configuration is limited. |
| Ericsson | We are OK to discuss this |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  Although there are some companies supportive for discussing this proposal, there is a concern from multiple companies that whether the specification impact of this proposal can fit into TEI as well as whether there is a sufficient gain. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | We are open to this issue and would also assume no RAN1 impact expected. |
| Qualcomm | We support this proposal. Based on numerical evaluation results that we provided in our contribution, the additional power saving gain of joint configuration of DRX groups and WUS/SCell dormancy is significant. In particular, the additional gain by WUS is significant, which goes up to ~80% in sparse traffic scenarios.  With all the power saving gain, we also think the joint configuration is beneficial for operators. For example, DRX groups may be deployed earlier than Rel-16 power saving features (WUS/SCell dormancy), because the operators may be more experienced with DRX. Thus, joint configuration allows cost-efficient and phased introduction of other Rel-16 power saving features in later stages. Otherwise, if the joint configuration is not allowed, it could further delay the introduction of Rel-16 power saving features.  Regarding the concern that this is a cross-WG issue, in our view, there is no RAN2 or RAN4 impact with the joint configuration. If any, it would be just editorial issues, such as revising the field description of *drx-ConfigSecondaryGroup* in TS 38.331. In our proposed TP presented in our contribution, we showed that RAN1 spec change is also limited, i.e.,   * Clarify that, if secondary DRX group is configured, DRX active time for a serving cell refers to DRX active time of its associated DRX group;   Clarify that DRX on-duration timer refers to those of all DRX groups in the text on WUS procedure. |

* 1. Removal of DM-RS restriction for DL MU-MIMO

Following proposal is made in the contribution.

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| --- | --- | --- |
| [4] | According to the Rel-15 NR specification, when PTRS is configured, the DM-RS antenna ports 1004-1007 and or 1006-1011 is not allowed for scheduling for the same and other UEs.   |  | | --- | | TS 38.214 [1]  If a UE receiving PDSCH scheduled by DCI format 1\_2 is configured with the higher layer parameter *phaseTrackingRS* in *dmrs-DownlinkForPDSCH-MappingTypeA-ForDCI-Format1-2* or *dmrs-DownlinkForPDSCH-MappingTypeB-ForDCI-Format1-2* or a UE receiving PDSCH scheduled by DCI format 1\_0 or DCI format 1\_1 is configured with the higher layer parameter *phaseTrackingRS* in *dmrs-DownlinkForPDSCH-MappingTypeA* or *dmrs-DownlinkForPDSCH-MappingTypeB*, the UE may assume that the following configurations are not occurring simultaneously for the received PDSCH:  - any DM-RS ports among 1004-1007 or 1006-1011 for DM-RS configurations type 1 and type 2, respectively are scheduled for the UE and the other UE(s) sharing the DM-RS REs on the same CDM group(s), and  - PT-RS is transmitted to the UE. |   In practical scenarios, this assumption is translated into restricted MU-MIMO support limited to a maximum of two UEs (with two MIMO layers per UE) for type 1 DM-RS (see Figure 4-a) and maximum of three UEs (with two MIMO layers per UE) for type 2 DM-RS. That restriction is not desirable considering efficient MU-MIMO support in FR2 with massive antennas, where MU-MIMO multiplexing dimension can be doubled without corresponding assumption (see Figure 4-b).    (a) MU-MIMO with DM-RS restriction (b) Proposed MU-MIMO w/o DM-RS restriction  Figure 1 Illustration of MU-MIMO support in FR2 with PTRS  It should be noted that in spite of the above restriction, two symbol front-loaded DM-RS configuration is still allowed by specification for transmission of DM-RS ports 1000-1003 and 1000-1005 for DM-RS type 1 and type 2 respectively. Moreover, transmission of the additional DM-RS symbol in the later part of the slot is also allowed.    Figure 2 Illustration of used DM-RS configurations for LLS evaluations  To demonstrate the performance impact on PDSCH due to use of different DM-RS antenna ports, a link-level evaluation of NR system in FR2 were carried out for single-symbol and two-symbols front-loaded DM-RS configuration (see Figure 2).  ~  The BLER vs SNR performance results for PDSCH are presented in Figure 3. It can be seen that DM-RS ports {0,4} shows better performance comparing to DM-RS ports {0,1}. The performance improvement can be explained by better channel estimation in the former DM-RS configuration. To this end, no clear impact of the phase noise tracking on the performance of DM-RS ports {0,4} comparing to DM-RS ports {0,1} was observed, questioning motivation of the exiting DM-RS restrictions.    Figure 3 Link-level performance of NR in the presence of phase noise for DM-RS antenna ports {0,1} and {0,4}  Based on the above results, the existing DM-RS restriction in NR specification which doesn’t not allow DM-RS ports 1004-1007 or 1006-1011 usage with PT-RS ports is not well justified and should be considered for removal, since it noticeably limits efficiency of MU-MIMO transmission in FR2.  ***Observation:***   * *DM-RS port restriction on use of ports 1004-1007 for type 1 and ports 1006-1011 for type 2 is not well justified while significantly limits MU-MIMO efficiency of NR system*   Based on the observations above the following proposal is made:  ***Proposal #1:***   * *For DL MU-MIMO enhancement in Rel-17:*   + *Remove restriction on use of DM-RS ports 1004-1007 for type 1 and 1006-1011 for type 2 when PTRS is transmitted to the UE*   + *Define new Rel-17 UE capability for that feature*   + *Adopt proposed TP in Section 1.2 as part of Rel-17 TEI* |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #10**

* **For DL MU-MIMO enhancement in Rel-17:**
  + **Remove restriction on use of DM-RS ports 1004-1007 for type 1 and 1006-1011 for type 2 when PTRS is transmitted to the UE**
  + **Define new Rel-17 UE capability for that feature**
  + **Adopt proposed TP in Section 1.2 in R1-2104939 as part of Rel-17 TEI**

This proposal is already supported by Intel.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| Company | Comment |
| vivo | it was discussed in Rel-15, orthogonality among DMRS ports within same CDM group with 2-symbol DMRS may not hold due to PN. It may be feasible, open for discussion. |
| Intel | RE: vivo.  When this rtestrcition was discussed, there were no evaluation in RAN1 that can quantify the performance loss for the restricted antenna ports. We have checked the performance for the restricted antenna ports and it looks there is no issues with PN tracking. |
| Huawei, HiSilicon | We understand the intention to improve MU MIMO performance in FR2. However, simply removing the restriction may not be friendly to UE implementation, may need to consider different possibilities such as modifying DMRS/PTRS pattern, and UL can be considered together with DL, could be beyond the scope of TEI. |
| ZTE, Sanechips | We are open to rediscuss this issue. However, just simply removing the restriction is not preferred.  Actually, we provided some simulation results in the tdoc R1-1715449, please see the figures below where DMRS TD-OCC cannot work well especially when phase noise is servious, i.e. when PTRS time density is high. In other words, when PTRS is configured in every symbol, the restriction should not be removed. When PTRS density is lower, i.e. in every 2 or 4 symbols (PN is less serious, DMRS using TD-OCC in two adjacent symbols has no much impact), so we are fine with removing the restriction in such case.    Fig 2.2-3 Performance show for scenarios with phase noise |
| Ericsson | We are supportive to consider this further as the restriction introduced in Rel.15 was not so well motivated by evaluations (or at all?). Some further investigations are needed until next meeting. |
| Qualcomm | We are open to discuss further and evaluate the feasibility, but we consider it lower priority. FR2 MU-MIMO with PTRS transmission and more than 6 ports, is still possible with non-orthogonal multiplexing; whether more than 6 orthogonal ports is urgent from deployment/market perspective is not clear to us. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  As some companies commented, it seems we should continue discussion on this proposal with further investigation e.g., on applicable cases and on UE implementation impact. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | We are open to the enhancement. However, there was only evaluation result for SU-MIMO. Since the restriction is applied to MU-MIMO, we need further evaluation with assumption of MU-MIMO and similar overhead. Though port {0,4} may provide better BLER than port {0,1}, it requires doubled DMRS overhead which would lead to THP loss. |
| Ericsson | After new evaluations, both with Rel.15 (Ex-2 from 38.803) and more modern phase noise models (as being discussed in RAN4), it seems phase noise is not a problem up to 64QAM@CR=0.5 for 100 MHz bandwidth and 30 GHz carrier frequency. So only 256 QAM needs PT-RS configured and enabled in this analysis. Then, since coverage is the main headache for FR2, and not capacity/MU-MIMO, it is not clear if PT-RS is needed at all, for scenarios when MU-MIMO/more than 4 layers is of interest. More discussions on the necessity of this TEI could be useful. |
| Qualcomm | A few additional remarks on MU-MIMO operation in FR2:  The use of PT-RS is more prevalent in FR2. However, in FR2, higher order MU-MIMO multiplexing is possible without more orthogonal DM-RS ports. In FR2, the UE cannot set analog Rx spatial filters for the purposes of better MU-MIMO interference suppression, therefore having more explicit MU-MIMO layers made measurable to the UE, which is the sole purpose of the proposal, may not improve performance. Note that FR2 MU-MIMO with more than six ports, is still possible with non-orthogonal multiplexing, without introducing the proposed addition. We therefore think further results to back up gains in MU-MIMO scenarios are needed before we determine this change to be essential. |

* 1. UL MU-MIMO enhancements for DSS

Following proposal is made in the contribution.

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| [4] | Dynamic spectrum sharing (DSS) has attracted a lot of attention in 3GPP as a tool that provides efficient migration from LTE to NR radio access technology. DSS allows LTE and NR to share the same carrier by dynamically allocating resources to LTE or NR users depending on the traffic loading conditions. In 5G NR DSS is supported starting from Rel-15 and was further enhanced in Rel-16 / Rel-17. So far, the DSS enhancements in 3GPP are mainly focused on downlink transmission. At the same time MU-MIMO is considered as key multiplexing option for uplink transmission. The multiplexing in spatial domain between LTE and NR users may not be feasible in the existing NR system due to incompatible DM-RS. As the result spectral efficiency of the NR / LTE systems in the uplink may be degraded. The performance, however, can be improved by allowing uplink MU-MIMO transmission of LTE and NR users (see Figure 4). To support efficient multiplexing, DM-RS enhancement based on orthogonal ports between LTE and NR is required.    (a) without uplink DSS (b) with proposed uplink DSS  Figure 4 Illustration of uplink MU-MIMO transmission scenarios  More specifically, to support DSS between LTE and NR users, 5G NR should support additional DM-RS pattern with the same DM-RS symbol positions as in LTE (see Figure 5). In addition, NR DM-RS sequence should be the same within uplink slot.    Figure 5 New DM-RS positions to support orthogonal multiplexing of DM-RS ports for LTE and NR  The orthogonal multiplexing between NR and LTE DM-RS can be achieved, by relying on Rel-10 LTE DM-RS with time domain OCC (i.e., {1,-1}) or using Rel-14 LTE DM-RS with comb structure. Since the corresponding DM-RS port multiplexing options (i.e. TD-OCC or different CDM group) can be supported for generic DM-RS sequences, the corresponding DM-RS multiplexing options should be applicable for different waveforms supported in NR (CP-OFDM) and DFT-s-OFDM (supported LTE and NR).  ***Proposal #2:***   * *For UL MU-MIMO enhancement in Rel-17:*   + *Support MU-MIMO between LTE and NR users using orthogonal DM-RS antenna ports*   + *Define new DM-RS position and the same DM-RS sequence in the slot for NR depending on higher layer configuration*   + *Adopt proposed TP in Section 2.2 as part of Rel-17 TEI* |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #11**

* **For UL MU-MIMO enhancement in Rel-17:**
  + **Support MU-MIMO between LTE and NR users using orthogonal DM-RS antenna ports**
  + **Define new DM-RS position and the same DM-RS sequence in the slot for NR depending on higher layer configuration**
  + **Adopt proposed TP in Section 2.2 in R1-2104939 as part of Rel-17 TEI**

This proposal is already supported by Intel.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| Company | Comment |
| vivo | need more clarification on deployment scenario, motivation. DSS is mainly for co-existence? |
| Intel | Re vivo  The key motivation is to allow SDM pairing of LTE and NR users in DSS in addition to TDM and FDM currently supported. We think that NE could not take full advantage of MU-MIMO in DSS deployments. |
| Huawei, HiSilicon | More discussion/clarification seems needed on the benefits from this proposal. For example, whether the proposal will introduce inter-RAT demodulation? If the answer is yes, then it is expected that such inter-RAT demodulation may cause much higher complexity of user pairing and inter-UE interference management than single-RAT MU-MIMO. |
| ZTE, Sanechips | We are open to the discussion if the scenario/motivation can be justified by more performance evaluation on the potential gain. |
| Ericsson | We don’t see this as an urgent issue to be corrected. |
| Qualcomm | It is a bit unclear how the proposal would work. In legacy LTE the DMRS sequence is not the same across slots if group/sequence hopping are enabled, so just having OCC on top would not be enough to make it work.  Regarding the usefulness, although we understand the motivation (support UL MU-MIMO between LTE and NR UEs), we don’t see this feature as urgent. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  Based on the comments from companies, it seems we should continue discussion on this proposal, including whether the proposed solution is sufficient and whether implementation impact is acceptable. Also, it seems this proposal has not yet met the criteria that the proposal is supported by at least 1 operator, 1 infra vendor and 1 UE vendor.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | We are not sure that MU-MMIO between LTE and NR UEs, e.g. using exactly the same REs, is a typicial use case in DSS. It is not easy for network to support MU-MIMO for UEs with different RATs  Secondly, the standardization impact is too large. It is unclear how much gain can be achieved using orghogonal DMRS ports compared to that using quasi-orghogonal DMRS ports (e.g. different scrambling). |
| Qualcomm | A few additional remarks on whether new NR DMRS sequences are needed for this proposal:  Our understanding is that this proposal would necessitate introducing new DM-RS sequences in NR. This is because of the following:   1. We cannot count on comb-based DM-RS being configured for legacy LTE UEs (not widely implemented) 2. We cannot count on cross-slot TD-OCC being configured for legacy LTE UEs (not widely implemented) 3. We cannot count on legacy LTE UEs transmitting the same DM-RS across the two slots of a subframe, unless group and sequence hopping are disabled for them, but which would have other negative consequences in practical deployments.   Introducing new DM-RS sequences in NR at this point doesn’t seem well justified and we therefore not supportive of this proposal. |

* 1. Mitigating half-duplex issue in NR V2X groupcast NACK-only case regime

Following proposal is made in the contribution.

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| [7] | In V2X sidelink resource allocation Mode-1 and Mode-2, UEs can use groupcast transmissions with NACK only feedback. In this mode of operation, receivers within target communication range from the transmitter provide NACK feedback in case of unsuccessful reception and do not provide ACK in case of successful reception. The susceptibility to half-duplex collisions can be illustrated by the following simple example:   1. UE1, UE2, and UE3 operate with groupcast NACK only feedback and are group members (i.e., within target communication range from each other). 2. UE1 and UE2 selected/were granted with resources in the same slot and transmitted in slot ‘*n*’. 3. UE3 has successfully received UE1 and UE2 transmissions and thus has not provided HARQ feedback. 4. UE1 and UE2 were not able to receive each other transmissions. 5. Due to lack of NACK feedback UE1 and UE2 assume successful reception by UEs within target communication range.    1. In Mode-1, the UE reports ACK to gNB, and gNB considers successful transmission on SL, thus do not grant retransmissions    2. In Mode-2, the UE reports ACK to higher layer, and the higher layer does not grant retransmissions 6. UE1 and UE2 stop transmissions of TBs without receiving each other transmissions.   The above problem was also confirmed by system level evaluations [1][3][4]. Figure 1 shows comparative analysis of the current Rel.16 design vs scenario when two blind retransmissions are used for groupcast communication with NACK only feedback according assumptions listed in Annex. As it can be seen, the Rel.16 solution does not achieve PRR equal to 1 even at short communication distances.    Figure 1: Illustration of the Rel.16 groupcast communication with NACK only feedback  Since the half-duplex collision is a fundamental issue in distributed communication systems, it may not be possible to completely avoid it. But it is possible to apply a simple enhancement which reduces the issue dramatically. Such an enhancement is to allow a UE to transmit at least two TB (re-)transmissions w/o considering the feedback, thus increasing the chances that at least one of the two control channels were successfully received, as illustrated in the analysis above.  **Observation**   * **Rel-16 groupcast sidelink communication with NACK-only is susceptible to half-duplex issue which could limit the achievable reliability even at very high SNR links**   To mitigate the illustrated half-duplex problem for groupcast NACK only sidelink communication, there could be different solution with difference spec impact. The following options are considered in descending order of spec impact / generalization:   * Option 1: Introduce a configurable minimum number of blind retransmissions N and support of mixing blind retransmissions and feedback-based retransmissions for a TB   + In this case, it is fully controllable by configuration whether a UE explicitly performs *N* blind retransmissions first and then switches to the feedback-based regime. Furthermore, when the feedback is not requested in SCI, redundant PSFCH are not generated on receivers.   + Specification in this case needs to introduce RRC signaling of the minimum number of blind retransmissions as well as MAC support for switching between blind and feedback-based modes for the same logical channel after the minimum number of blind retransmissions. * Option 2: Introduce a configurable minimum number of retransmissions *N* performed w/o considering the feedback from receivers   + In this case, it is fully controllable by configuration whether a UE implicitly performs *N* blind retransmissions first and then switches to the feedback-based regime.   + Specification in this case needs to introduce RRC signaling of the minimum number of blind retransmissions. But since the feedback can be ignored, there is no evident impact on MAC specification.     Figure 1: Illustration of Option 1 and Option 2 mitigation of half-duplex for NACK-only feedback regime   * Option 3: Introduce a fixed number of minimum two retransmissions and support of mixing blind retransmissions and feedback-based retransmissions for a TB   + This option is based on Option 1 without considering configurability of the minimum number of blind retransmissions, thus reducing or eliminating RRC spec impact but still requiring changes to MAC specifications as per Option 1   + The mechanism could be enabled/disabled by configuration or left up to UE implementation to decide. * Option 4: Introduce a fixed number of minimum two retransmissions performed w/o considering the feedback from receivers   + This option is based on Option 2 without considering configurability of the minimum number of blind retransmissions, thus reducing or eliminating RRC spec impact.   + The mechanism could be enabled/disabled by configuration or left up to UE implementation to decide.   All of the above options are backward compatible with Release-16 receivers in the same resource pool.  At this point of TEI proposal discussion, it seems all options are viable with Option 1 having the most flexibility and spec impact, and other options providing less flexibility with smaller spec impact.  **Proposal**   * **Agree on Release 17 TEI work to introduce mitigation of half-duplex issue for sidelink V2X communication in groupcast NACK-only feedback regime by introducing a fixed number of minimum two retransmissions performed without considering the feedback from receivers** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #12**

* **Introduce mitigation of half-duplex issue for sidelink V2X communication in groupcast NACK-only feedback regime by introducing a fixed number of minimum two retransmissions performed without considering the feedback from receivers**

This proposal is already supported by Intel and Qualcomm.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

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| --- | --- |
| Company | Comment |
| NTT DOCOMO | We support this proposal with following two comments.   * Option 2/4 seem MAC spec update so that TX UE does not flush the corresponding HARQ buffer and the retransmission is possible. But the impact would be not so large.   Our preference is Option 1/3 for any cast types with HARQ feedback, i.e. unicast/groupcast-1/groupcast-2. The reason is that mixed mechanism improves latency performance as well as reliability performance of groupcast-1. Without this feature, TX-UE shall wait PSFCH reception to do retransmission or HARQ-feedback is not applied. For better latency and reliability, two consecutive blind retransmissions + HARQ feedback + HARQ-based retransmissions will be a useful way. |
| CATT | We agree that groupcast sidelink communication in Rel-16 with NACK-only has to half-duplex issues, which could limit the achievable reliability even at very high SNR links. The proposed is the solution for this problem. We support this TEI. |
| Bosch | We understand that half-duplex issue for sidelink V2X groupcast (NACK-only) is a critical one. We also believe that this problem will be more sever in case of periodic reservation, which may lead to consecutive collisions.  Therefore, we support this TEI. In general, at least for this groupcast option, we recommend having a solution that avoids half-duplex problem even if inter-UE coordination is not configured (depending on possible conditions for having inter-UE coordination in Rel-17 SL Enh WI outcome).  Among the listed options, Option 1 is our preferred solution. However, we are also fine with Option 2/4 for simplecity. We also agree with NTT DOCOMO that the solution in Option 2/4 will be simply postponing flushing the HARQ buffer for N transmissions. In our opinion, this a manageable modification in the MAC.  Note: we suggest generalizing the proposal at this stage to have a minimum configurable number of retransmissions N (i.e., 2 or 3 as in blind transmission) w/o considering feedbacks. |
| Intel | We support the TEI proposal. In our view mitigation of half-duplex issue for sidelink V2X communication in groupcast NACK-only feedback is important to address for mission critical V2X applications.  We are open to discuss further the specific solution during TEI work. The proposal made in submitted contribution is based on consideration of performance benefits and minimum specification efforts/changes. |
| Huawei, HiSilicon | We do not support this, and it does not fit to TEI.  This kind of half-duplex issue is currently being discussed at WI level in R17 sidelink enhancement (AI 8.11.1.2). However, so far, there is no consensus whether this issue needs to be addressed or not. Some companies, including us, point out that such kind of half-duplex issue only happens in very rare case since it requires all the following conditions are met:   * Condition#1: within a group, two UEs (UE-B and UE-C) choose to transmit on the same slot * Condition#2: all the other group members have successfully decoded the packet   We also had simulation results (see R1-2104237 section 4.3) to prove that there is no obvious performance gain by solving this kind of half-duplex issue.  Meanwhile, the current TEI proposal#12 introduce a fixed number of minimum two retransmissions, which have the drawbacks of unnecessary transmission in some cases, resulting in waste of resources and increased latency.  In addition, given that sensing procedure is performed in PHY layer and resource for transmission is selected in MAC layer, cross-WGs have to be involved in updating their specs. Furthermore, both blind (re-)transmissions and HARQ-based (re-)transmissions would require same HARQ RTT timing restrictions as long as the resource pool is configured with PSFCH resource. This means there is no latency improvement at all for mixed blind and HARQ-based (re-)transmissions and no point to have this proposal, unless there are structural changes in MAC layer to remove this HARQ RTT timing restriction. Note that this issue is being discussed in [105-e-NR-5G\_V2X-07]. Consequently, this proposal would produce workload on both RAN1 and RAN2 for PHY and MAC, putting it beyond the scope of TEI.  In summary, the benefits of this TEI proposal#12 is unclear and requires workload cross WGs, thus we do not support it. |
| ZTE, Sanechips | In Rel-16, for groupcast transmissions, three types of HARQ feedback for sidelink are supported: blind retransmission, HARQ with NACK only, HARQ with ACK and NACK. The purpose of supporting the three feedback types is to deal with different communication requirement, i.e., in some cases, UE can determine one proper HARQ feeback type for current TB transmission, e.g. in the case of the half-duplex issue above, HARQ with ACK/NACK seems more suitable.  Besides, to complete the TEI, more spec work of RAN2 is desired.  In addition, considering the performance issue in some cases(e.g. at very low SNR links ), the type of blind retransmission has more serious problem than the type of HARQ with NACK only. Obviously a TEI for blind retransmission is not necessary.  In conclusion, we don’t think this TEI is necessary. |
| Ericsson | We are supportive of this TEI work but it seems that the proposal is to specify option 4 directly. Our view is that RAN1 should specify a flexible solution that fits within the TEI framework. Along the lines of DCM’s comments, we think it is necessary to carefully consider the impact to the specifications of the different options.  We think it is reasonable to limit the scope of the TEI by limiting the scope to GC Option 1. The applicability to other cast modes or options and the gains are not clear.  Our suggestion would be to make the following modifications. **TEI proposal #12**  * **Introduce mitigation of half-duplex issue for sidelink V2X communication in groupcast NACK-only feedback regime by introducing a minimum ~~fixed~~ number of ~~minimum two~~ retransmissions performed without considering the feedback from receivers.** |
| Qualcomm | We’d like to note that the TEI (e.g. Option 4) could be implemented without any impact on MAC spec if PHY reports NACK for the initial transmission to MAC. The TP in R1-2104890 is an example of this approach. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  Based on the comments from companies, although the proposal is supported by multiple companies including operator, infra vendor and UE vendor, it seems we should continue discussion on this proposal including which option is preferred and whether there is any impact to other WGs (other than signaling/capability introduction).  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| OPPO | We are unsure that this TEI in RAN1 is necessary for two reasons. In R16 V2X, NACK-only feedback was introduced based on extensive evaluation that it works and provides benefits and gains over the ACK/NACK based feedback for connection-less based groupcast. And hence it was introduced and designed in such way with PSFCH. At that time, there was no PRR performance issue due to half-duplex because Tx UEs are sufficiently randomized. Secondly, from the proposed solution options, it is foreseen that all the spec impacts are related to the MAC spec in RAN2, from making the decision on whether to ignore the HARQ feedback, changing the logical channel definition and attributes to enable mixed blind and HARQ-based retransmission, whether or not to support resource (re)selection based on SL HARQ feedback of a MAC PDU or PSFCH resources, to deciding the minimum number of retransmissions. The currently RAN1/L1 design in R16 can already support all of these functions. It should be up to RAN2 to judge and decide whether this TEI proposal is feasible and beneficial. |

* 1. Support of 2 Tx codebook configuration to 4Tx capable UE in UL

Following proposal is made in the contribution.

|  |  |
| --- | --- |
| [10] | Rel-15 NR specified 4Tx UL MIMO transmission while supporting various UE implementations. Depending on hardware implementation, UE Tx chains could be fully-coherent, partially-coherent or non-coherent and hence corresponding codebook subsets are specified. Rel-15 also supports coherent or non-coherent codebook subsets for 2Tx UL MIMO corresponding to coherent or non-coherent Tx chains capability. If an UE is capable of coherent 4Tx chains supporting coherent codebook subset for 4Tx UL MIMO, it can be straight forward to assume that the same UE can support coherent codebook subset for 2Tx UL MIMO from 2 out of 4 antennas; similarly UE supporting non-coherent 4Tx codebook subset can support non-coherent 2Tx codebook subset. However, for an UE capable of partial-coherent 4 Tx chains, it could support either coherent 2Tx codebook subset with 2 coherent Tx chains or non-coherent 2Tx codebook subset with 2 non-coherent Tx chains.  In 38.214, following is specified,  “A UE reporting its UE capability of 'partialAndNonCoherent' transmission shall not expect to be configured by either *codebookSubset* or *codebookSubsetForDCI-Format0-2* with 'fullyAndPartialAndNonCoherent*'*.”  The intention of the above statement is to prevent gNB configuring 4Tx full-coherent codebook subset to an UE capable of 4Tx partial-coherent chains. It is not clear from the current spec whether 2Tx coherent codebook subset can be configured for an UE supporting 4Tx partial codebook subset.  Furthermore, NR Rel-16 specified UL full power transmission schemes with mode0, mode1 and mode2. UL full power transmission is mainly introduced for non-coherent and partial-coherent UEs. 4Tx partial-coherent UE supporting UL full power transmission mode0 can support 2Tx coherent or non-coherent and UL full power transmission mode0 since power scaling s=1 is specified in 38.213. Similarly, 4Tx partial-coherent UE supporting UL full power transmission mode2 can support 2Tx non-coherent UL full power mode2 with antenna virtualization or full power TPMI indication. Following is specified in 38.214  “When higher layer parameter ul-FullPowerTransmission is set to 'fullpowerMode2'and the higher layer parameter codebookSubset or the higher layer parameter codebookSubsetForDCI-Format0-2 is set to 'partialAndNonCoherent', and when the SRS-resourceSet with usage set to "codebook" includes at least one SRS resource with 4 ports and one SRS resource with 2 ports, the codebookSubset associated with the 2-port SRS resource is 'nonCoherent'.”  And, power scaling s=1 for full power TPMIs or scaled by the ratio of number of non-zero PUSCH ports to number SRS ports corresponding SRS resource.  In current spec, when 2-port SRS is configured for an UE supporting 4Tx in UL, no matter the codebook subset is coherent or non-coherent, the UE cannot deliver full power with mode1 since the power is scaled by the ratio of non-zero PUSCH ports number to maximum number of SRS ports supported by the UE in one SRS resource, for non-coherent rank=1 transmission the output power is scaled either by 1/4 or 2/4 depending on indicated TPMI.  gNB may configure 2-port SRS for an UE supporting 4Tx in UL for different reasons; it could be for UE power saving purpose, gNB may configure fewer number of SRS ports than max number of ports UE supported in different BWPs, or it could be due to overall SRS overhead in the cell.  For 4Tx partial-coherent UE not supporting Rel-16 UL full power transmission, if configured with 2-port SRS, maximum deliverable output power could be different with coherent codebook subset and non-coherent codebook subset. Let’s assume PC3 UE, 2Tx non-coherent codebook subset contains only antenna selection TPMIs, that means the maximum output power for rank=1 transmission is scaled by 1/4, if 2Tx coherent codebook subset can be configured then the maximum output power for rank=1 transmission with non-antenna selection TPMIs is scaled by 2/4 since there are 2 non-zero PUSCH ports, which means 3dB more power.  For example, as shown in figure 1 below, for 4Tx partial-coherent UE (with 17dBm PAs), by virtualizing 2 antennas it can operate as 2Tx coherent or non-coherent UE. If it is assumed 2Tx non-coherent UE after virtualization, due to power scaling mechanism, for rank=1 transmission the maximum output power is 1/4 of Pc\_max, i.e. 17dBm for PC3 UE and if assuming 2Tx coherent UE after virtualization, the non-antenna selection TPMIs can deliver 1/2 of Pc\_max, i.e. 20dBm for PC3 UE. On the other hand, if such an UE chooses two coherent antenna pair without antenna virtualization for 2Tx operation, the non-antenna selection TPMIs can also deliver 1/2 of Pc\_max.    Figure 1, 4Tx partial-coherent UE operating as 2Tx UE  Hence, following proposal is made.  Proposal 1:   * For 4Tx partial-coherent capable UE, 2Tx coherent codebook subset is supported when the network configures 2-port SRS (for codebook) and SRS resource set includes 1 SRS resource or configured with same number of ports for all resources.   For 4Tx UEs with architecture as shown in Figure 2, it is also possible to support full power transmission through antenna selection. For example, for 4Tx partial-coherent or non-coherent UE supporting only Rel-16 UL full power transmission mode1, UE may select Tx chains to operate as 2Tx non-coherent UE (as shown in figure 2), to deliver full power with rank=1 and 2. Power scaling can be enhanced accordingly.    Figure 2, 4Tx partial-coherent UE operating as 2Tx non-coherent UE  Proposal 2:   * For 4Tx partial-coherent or non-coherent UE supporting UL full power transmission mode1, UL full power mode1 can be supported with 2-port SRS configured.   + New UE capability is introduced |

Based on the above contribution, following TEI proposal can be discussed in RAN1#105-e meeting.

### **TEI proposal #13**

* **For 4Tx partial-coherent capable UE, 2Tx coherent codebook subset is supported when the network configures 2-port SRS (for codebook) and SRS resource set includes 1 SRS resource or configured with same number of ports for all resources.**
* **For 4Tx partial-coherent or non-coherent UE supporting UL full power transmission mode1, UL full power mode1 can be supported with 2-port SRS configured.**
  + **New UE capability is introduced**

This proposal is already supported by vivo, ZTE, CMCC, Samsung.

Companies are encouraged to check above TEI proposal and to provide feedback if any in below.

|  |  |
| --- | --- |
| Company | Comment |
| NTT DOCOMO | Support. We believe it is benefitial for gNB to understand UE can support coherent codebook with less number of antenna ports. |
| CATT | We are fine with the first bullet. Regarding the second bullet, in our view, current spec does prevent such configuration. That is, UL full power mode1 and 2-port SRS can be configured simultaneously for a 4Tx partial or non-coherent UE. |
| vivo | @CATT  Yes, it is possible to configure UL full mode1 and 2-ports SRS simultaneously for 4Tx UE, however max output power will be 1/2 for new rank 1 TPMI and rank2 as the power scaling mechanism is same as in Rel-15, text in 38.213 section 7.1 is copied below for reference, where “maximum number of SRS ports supported by the UE in one SRS resource” is 4 for 4Tx UE. Hence, power scaling mechism needs to be revised to deliver max output power in such case.  -----  if *ul-FullPowerTransmission* in *PUSCH-Config* is set to *fullpowerMode1*, and each SRS resource in the *SRS-ResourceSet* with *usage* set to 'codebook' has more than one SRS port, is the ratio of a number of antenna ports with non-zero PUSCH transmission power over the maximum number of SRS ports supported by the UE in one SRS resource  ----- |
| Huawei, HiSilicon | We are open to further discussion, e.g. for the first bullet. However, for the second bullet, we don’t see a clear motivation of enhancement by introducing new UE capability to mix antenna selection and full power transmission since it may complicate existing Rel-16 MIMO UE capability discussion/ design. |
| vivo2 | @Huawei, HiSilicon, one of the motivations is power saving by turning off PAs, and since current spec already allows gNB to configure 2-port SRS to 4Tx UE, then from network perspective if the UE can deliver max ouput power is always better from coverage perspective. |
| Ericsson | Presuming that TEIs should address a product driven need, we do not find optimizations for partial coherent UEs to be particularly urgent, however we would appreciate UE vendors comment on this.  Supporting a coherent codebook subset for a partially coherent UE configured for 2 Tx is a simple fix to an ongoing design bug, and may have some performance benefit.  However, we would like to further discuss the need for enhancing 2 port SRS for mode 1, since mode 2 already solves most of the problems. If SRS overhead optimization is the concern, that can be addressed separately.  So overall, while we would not prioritize it highly, support for a coherent codebook subset for a partially coherent UE configured for 2 ports is a reasonable TEI-17 candidate, but we do not support the mode 1 enhancement at this time. |
| Intel2 | For the 1st bullet:   1. Regarding Figure 1, how does the virtualization to 20+20 case work? After virtulizatoin, the two ports are still non-coherent, in this case how to configure 2-port full coherent codebook subset? 2. As explained in the tdoc, the 4-Tx UE could be configured with 2-port SRS for power saving purpose. In this case, why do we need to configure the UE with full coherent codebook subset to deliver more power? 3. Does the 1st bullet apply to UE supporting full power or not?   For the 2nd bullet:   1. Since the UE can deliver full power with 4-Tx, why do we need to enable full power operation for 2-port case? |
| Qualcomm | We first make a quick note that a separate capability will be required for the first proposal as well since UE antenna virtualization in fallback mode may depend on UE implementation.  In general, although we see the potential benefit, we see no urgency to make this change. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks and discussion!  Although the proposal is supported by multiple companies including operator, infra vendor and UE vendor, it seems we should continue discussion on this proposal including whether the second bullet proposal is necessary/acceptable and also more clarification on the first bullt proposal.  So, as moderator, I recommend continuing discussion on this proposal in this quarter and do not recommend trying to make agreement on this proposal in this quarter. |
| vivo3 | @Ericssson, one of the motivations of enhancing 2 port SRS for mode1 SRS configuration, 2 SRS resources has to be configured for mode2 in Rel-16. Turning off antennas can save power too.  @Intel, current spec allows configuration of 2Tx non-coherent codebook subset, figure1 is showing that even after virtualization the output is power scaled by 1/4 for rank=1 non-coherent TPMI which is not a good configuration. With full-coherent codebook subset UE can achieve 2/4 of output power for coherent TPMIs. Power is save by turning off PAs, which saves more than transmitting larger power on few antennas. 1st bullet is ~~not~~ non-full power.  With second bullet turning OFF antennas can save power.  @Qualcomm, regarding comment on first proposal, whether 2Tx codebook is configured as coherent or non-coherent fallback mode operation for 4Tx partial coherent UE should be same as there is no power scaling when schedculed by DCI 0\_0 |
| OPPO | Further clarifications on the motivation and feasibillity. For 4Tx partial-coherent capable UE, if 2Tx coherent codebook subset is configured, UE would be assmed to transmit SRS and PUSCH using two coherent TXs. However, in some case, for example when one of the transmit antennae is blocked, UE may switch the antenna to a non-coherent antenna which is not blocked. In this case, gNB may still schedule coherent transmission, resulting in bad performace. One more example is that when UE is at cell edge, UE is likely to virtualize two antennas for each SRS port in order to achieve more transmit power and diversity gain. But if 4 ports SRS is transmitted, there is no such issue since the cohecence between antennae/ports would not chage.  For 4Tx partial-coherent and non-coherent UE, UL full power can already be supported by mode 2 if we understand correctly. |
| vivo4 | @OPPO, coherent codebook subset also includes antenna selection TPMIs, in the case of blocking based on SRS measurement gNB can indicate antenna selection TPMI. Considering blockage, coherent codebook subset and non-coherent codebook subset performs similar. With non-coherent codebook subset as explained above there are only antenna selection TPMIs for rank=1, then it is power scaling is always 1/4 for these TPMI. As depicted in the figure1, although antenna vertulization is equivalent to larger PA however the power scaling of 1/4 for rank=1 will not lead to more output power.  Regarding second bullet on UL full power for 2Tx, yes mode2 can support full power however more SRS resources are required. |
| Qualcomm | @Vivo, regarding our comment on UE capability, when a UE needs to switch from 4tx to 2tx mode, it could downsize to 2tx in more than one way. For example, it could choose to use two antennas within the coherent pair or choose one antenna from each pair of coherent antennas.  This choice could depend on UE implementation and the set of PAs used by a UE.  This is the reason we think a capability may be needed for the first proposal as well.  In general, we think that’s its best for a UE to report two copies of its capability for full power tx in uplink --- one assuming 4 tx operation and another assuming 2 tx operation. This should then make it clear what the UE is capable of in each mode and subsequent choice of codebooks and scale factors could be derived in a straightforward manner. This may be a more holistic approach to addressing the issue you raise. |

1. Conclusion

TBD

Reference

[1] R1-2104473 Discussion on SSB resources for RLM CATT

[2] R1-2104596 TEI-17 proposal on NR codeword mapping ZTE

[3] R1-2104705 Rel-17 TEI Qualcomm Incorporated

[4] R1-2104939 On Rel-17 TEI enhancement Intel Corporation

[5] R1-2105536 Enhancements on the scheduling of PUSCH over multiple slots Huawei, HiSilicon, China Unicom

[6] R1-2105739 Views on TEI-17 proposal targeting the false PMI reporting issue MediaTek Inc.

[7] R1-2105778 Rel-17 TEI proposal for mitigating half-duplex issue in NR V2X groupcast NACK-only case regime Intel Corporation, Qualcomm Inc.

[8] R1-2105804 NR positioning support for TA-based positioning in E-CID (TEI) NTT DOCOMO INC., Ericsson, Polaris Wireless, Verizon, China Telecom, FirstNet, Deutsche Telekom, Intel Corporation, CATT

[9] R1-2105813 TEI-17 proposal targeting the false PMI reporting issue Ericsson, NTT DOCOMO, Softbank, Verizon, T-Mobile USA

[10] R1-2105951 Support of 2Tx codebook configuration to 4Tx capable UE in UL vivo, ZTE, CMCC, Samsung

[11] RP-191602 Handling of TEI & contribution submission in RAN WGs for NR and LTE 3GPP RAN TSG and WG1/2/3/4 Chairmen

[12] RP-210826 Handling of TEI CRs ETSI MCC

Appendix: TEI guidance in [12]

**A. TEI Work Item codes shall only be used for small technical enhancements and improvements.**

This is how TEI was and is defined and it means that bigger topics should be done in an own WI.

**B. A TEI CR set shall be fully completed within one TSG cycle/quarter in all affected WGs.**

This requirement from TR 21.900 was never challenged. It also clarifies that only complete sets can be approved.

**C. TEI Work Item codes shall not be used where another appropriate Work Item code exists.**

This repeats the rule from TR 21.900 and it means that TEI cat.F CRs shall be an exception. Note: The CR author is supposed to find out which former CR introduced an error in the spec and the cat.F correction should then use the same WI code. So in theory, cat.F TEI CRs should only be needed to correct cat.B/C TEI CRs of the past.

D. Inter-TSG aspect:

**D1. Normally, for TSG SA/CT work that requires cat.B/C CRs from RAN WGs a RAN WI is required..**

This is what RAN applied in the last decade (if not longer). This also covers the strong discouragement of cross TSG TEI CRs expressed in RP-191602 slide 3.

**D2. In case the RAN work triggered via a TSG SA/CT WI\* is small and it affects only one RAN WG, then the RAN WG CR(s) shall use the WI code\* of the TSG SA/CT WI that triggered this work.   
NOTE: \*: provisional WI codes, companion WIDs/"mini-WIDs" are not meant here but already TSG approved proper WIs.**

This is what RAN applied in the last decade. Note: As TSG RAN has no agenda items for all SA/CT WIs, this sort of CRs were usually submitted under a TEI agenda item but for traceability we shall not use a TEI WI code on such a CR.  
(Note: D2. could work also in the other direction, i.e. if there is a RAN WI for which is turns out that only a small change would be needed in one SA WG or one CT WG. But you better consult TSG SA/CT before trying this approach.)

**D3. It is not possible to trigger work in RAN WGs via TEI CRs coming from TSG SA/CT or SA/CT WGs. The same applies for the reverse direction.**

Otherwise "small" (TEI) but affecting multiple TSGs would contradict each other. (Apart from this, inter-TSG TEI CRs would also not work well together for cat.B/C CRs if SA/CT use a companion WID but RAN does not.).

E. Inter-RAN WG aspects:

Section E. is addressing the problem that multiple RAN WGs work on the same feature but it is still intended to not have an own WI for this but to cover this feature under cat.B/C TEIxx (this is challenging time-wise and coordination-wise and therefore not a recommended approach but it is not forbidden). As RAN5 has introduced specific rules regarding the testing of TEI CRs, see RP-200931 [5] and since they use a different WI code (TEIxx\_Test) and testing work is usually coming at a later stage, this section E. is considering linked TEI CRs of RAN1/2/3/4.

In a similar way: RAN1/2/3/4 Core part work happens usually in the same time interval while RAN4 Perf. part work usually happens at the end of or after the RAN4 Core part work. In other words, having a TEI CR package that combines Core and Perf. part work requires a very careful timing to not violate requirement B.

RP-191602 [2] provided some guidance on Cross-WG TEI CRs in RAN WGs:

- Cross WG TEI CRs are strongly discouraged

- RAN1/2 TEI proposals with RAN4 impact to core requirements are strongly discouraged

- **RAN2 impact of RAN1/4-led TEI CRs shall be limited to RRC signalling of configuration parameters and UE capabilities (no MAC impact, no RRC procedural impact, etc.)**

Note: Ideally one RAN WG would take the decision about whether a TEI feature should be introduced or not and other RAN WGs then accept this decision and contribute their TEI CRs.

But as this guidance was not forbidding Cross-WG TEI CRs in RAN WGs some more requirements had to be defined how to guarantee traceability, consistency and visibility of this sort of CRs.

The basic requirements discussed in section E. were endorsed by TSG RAN in RP-202867 [7] but further clarification/guidance is provided here.

**E.1 It is mandatory to fill out the "other specs affected" for all CRs, i.e. either Yes or No shall be ticked and  
 if Yes is ticked at least the TS/TR shall be indicated and this for the present WG and all other WGs that have CRs linked to the present CR.  
 TEI CRs missing this information or having wrong information shall not be approved.**

These requirements were always there. But some clarification is required.

- "other specs affected" is used to link CRs that belong together which is essential for cat.F CRs and for cat.B/C TEI CRs to guarantee that a complete set of CRs is approved. Note: For cat.B CRs of other WIs, we have an extra RAN agenda item for each of them and we usually approve all stage 3 CRs together. But for closed WIs or TEI CRs we have normally just one agenda item collecting a larger number of CRs and then the relation of the CRs becomes unclear if "other specs affected" is not filled out properly.  
 NOTE: Other specs affected should also list inter-TSG related CRs if it is clear that these CRs can only be applied together. This usually involves a conditional approval at TSG level

- "Other core specifications" under "Other specs affected" on the CR cover: Going back to RAN #46 of Dec.2009 where TSG RAN decided to have separate Core part WIs and Perf. part WIs (in RP-091374) you can see from comparing with CR form v9.6 that the term "Other core specifications" is only intended to distinguish those specs from "Test specifications" and "O&M specifications" but not to exclude Perf. part related specs from "Other specs affected": This means as long as CR form is not updated "Other core specifications" should cover Core part specifications AND Perf. part specifications as defined in TSG RAN.

- "Test specifications" under "Other specs affected" on the CR cover: Testing under TSG RAN is either done in RAN4 or in RAN5. Since RAN5 has separate WIs for testing that usually are also just started after RAN4 work is completed, it would not make much sense to reference RAN5 specs on a RAN4 CR as it is clear that the RAN5 CR will just follow later (here it is more appropriate to review the corresponding RAN5 WI when it becomes available).  
 Examples where it could make sense to fill out this field: For RAN4 CRs to a WI that involve BS testing for the same WI/a linked CR. For CRs to SI TRs to which RAN4 and RAN5 contribute together with CRs. For a cat.B/C TEI CR of RAN1/2/3/4 that has a corresponding CR in RAN5 under TEIx\_Test.

- "O&M Specifications" under "Other specs affected" on the CR cover: O&M specifications are handled by SA5. SA5 has usually separate WIs for their changes and RAN CRs are not submitted to TSG SA or SA5, therefore the benefit of this field is higher within TSG SA. Nevertheless, there may be cases of tighter cooperation of RAN WGs with SA5 (like Minimization of drive tests) where it will be beneficial to indicate a related SA5 change coming to the same TSG meeting.

- What needs to be done if WGx is assuming that TS/TR ab.cde of WGy is affected but they are not sure?  
 WGx should list under "other comments" on the CR cover: "WGx thinks that also TS/TR ab.cde of WGy could be impacted by this CR." Depending on the probability WGx would tick Yes (and mention the spec) or No.  
 CR proponents shall check this with WGy (e.g. by sending an LS from WGx to WGy, submitting a Tdoc in WGy, talking to the chairman of WGy) so that at the TSG meeting where WGx submits this CR for approval it is either clear that there is no impact or that the WGy CR is available as well for approval.  
 NOTE: MCC has the possibility to correct CR covers before RAN submission (e.g. remove a potential impact comment if it turned out that there is no impact). But CR proponents need to inform MCC about this.  
 Incomplete CR sets (i.e. WGx CR there but linked WGy CR not available) can not be approved at TSG level and since cat.B/C TEI CRs have to be completed within one quarter, this is time critical.   
 Therefore very good preparation of cat.B/C TEI CRs which affect multiple WGs is essential.

**E.2 Each TEI cat.B/C CR and each TEI cat.F/A CR that corrects functionality related to an earlier TEI cat.B/C CR shall have a unique TEI identifier in square brackets [ ] at the end of the CR title on the CR cover sheet.  
 TEI cat.B/C CRs without such a unique TEI identifier cannot be approved at RAN.**

This principle was endorsed in RP-202867 [7] and further guidance for this approach is provided here:

- The TEI identifier should be short (4 to 18 characters using letters and/or digits or using \_ or - but avoiding blanks or other special characters which will complicate searches) and characterize the CR.

- The originating company takes care that related CRs in other WGs use the same TEI identifier.

- Unique identifiers are not added retroactively: Cat.F/A CRs for TEIs which did not have a unique identifier by RAN #91e will not get a unique identifier.

- Apart from plain TEI CRs, the unique TEI identifiers shall also be applied to NR\_newRAT-Core, TEIxx CRs because NR\_newRAT-Core was the huge WI for 5G.

- As the unique idendifiers are part of the CR title, they will be automatically stored in the CR database. Therefore CR authors have to make sure that the complete CR title in 3GU is in line with the title on the CR cover.

- For cases where it is not 100% clear whether a linked CR was agreed in another WG, it is the task of the CR author to double-check the situation in the week after the WG meeting and to inform MCC in case any updates of CR titles are required otherwise they risk that not properly linked CRs are rejected at RAN level.

**E.3 WG chairman reports report to TSG RAN about all agreed and technically endorsed cat.B/C TEI CRs of the last quarter. For each unique TEI identifier all related CRs of the considered WG are listed plus the corresponding CRs in the other WGs (if there are any) or the potential impacts on other WGs.**

How this is done is up to the chairman (e.g. it can be a slide with a table like the examples below, it can be an extra Excel table included in the zip file of the WG status report). The WG chairman could request inputs from MCC (Tdoc list filtered for agreed/endorsed TEI CRs) and all CR authors of the WG who had agreed/endorsed TEI CRs (to clarify whether there were related CRs in other WGs) and this could be condensed in such an overview.

Examples:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **unique TEI identifier** | **feature** | **Rel** | **CRs in own WG** | **CRs in/impacts on other WGs** |
| [HDUPLEX\_unpaired] | Modification to half duplex in unpaired spectrum | Rel-16 | R1-211234 (38.213, cat.C) | R2-2112345 (38.331 cat.C) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **unique TEI identifier** | **feature** | **Rel** | **CRs in own WG** | **CRs in/impacts on other WGs** |
| [intRAT\_HO\_NR\_ENDC] | Introduction of inter-RAT handover NR to ENDC | Rel-16 | R2-2123456 (38.306, cat.B)  R2-2123457 (38.331, cat.B) | potential impact on 38.133 for .... ? |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **unique TEI identifier** | **feature** | **Rel** | **CRs in own WG** | **CRs in/impacts on other WGs** |
| [E2E\_delay\_meas] | E2E delay measurement for QoS monitoring for URLLC | Rel-16 | R3-211234 (38.413, cat.B)  R3-211235 (38.423, cat.B)  R3-211236 (38.463, cat.B) | none |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **unique TEI identifier** | **feature** | **Rel** | **CRs in own WG** | **CRs in/impacts on other WGs** |
| [DRX\_coord] | Introduction of DRX coordination | Rel-16 | R4-2123456 (38.133, cat.B) | R2-2112345 (38.331, cat.B) |

- what's the main goal of this activity? To have a checkpoint in each WG (RAN1/2/3/4) where after the WG meeting it is checked whether a complete CR set is available for all cat.B/C TEI features for TSG RAN; by comparing the tables of different WGs a cross-check is possible.

- should this activity be limited to cat.B/C TEI CRs only? It would be useful to also list cat.F/A TEI CRs to correct formerly as cat.B/C TEI introduced features (corresponding CRs will have [ ] at the end of the Tdoc title and CR proponents will inform the WG chairman if there were any agreed/endorsed CRs lile this)

- what about CRs for WI code combinations like "<WI code>, TEIxx"?  
 These CRs appear when <WI code> was a WI of a Rel-yy with yy<xx.  
 These CRs are usually well identified via <WI code> and would therefore not need any more tracking.  
 But one exception should be made for <WI code> = NR\_newRAT-Core as this was the generic NR WI that introduced the whole 5G and if we do not track "NR\_newRAT-Core, TEIxx" as well, it could be used as a way to bypass this tracking activity.

- How big is the expected effort: Double-checking TEI16 CRs of 2020, we had about 110 cat.B/C CRs from RAN1/2/3/4 together with ~50% TEI16, ~25% "NR\_newRAT-Core, TEIxx" and ~25% other WI code, TEI16 CRs. So this means ~20 CRs per TSG RAN meeting plus a few cat.F/A corrections to former cat.B/C TEIxx CRs.

- What is TSG RAN supposed to do with the tables of TEI CRs from the WG chairmen? The impacts on other WGs have to be carefully reviewed (the earlier the tables from the WG chairmen are available the better, ideally at latest 1 week after the WG meeting): If WGx expected a CR from WGy but WGy did not provide such a CR, then there are 2 possibilities: The CR from WGy was not needed (then this will be documented e.g. in the RAN minutes or in a revised WG chairman's report) or WGy did not manage to conclude on a CR which means we have an incomplete CR set that cannot be approved. It is then up to TSG RAN to discard the incomplete CR set or to request a company CR for the WGy spec (if it is easy to solve) or to consider the start of a new WI (if the problem is more complex).

**E.4 MCC will support this tracking activity with a list of TEI CRs for a considered release that were handled at RAN and that have the unique TEI identifier.**

- The resulting Tdoc list of each RAN meeting includes already a complete list of all CRs handled in this meeting. An additional list will be added after RAN #92e listing the TEI CRs with unique TEI identifiers in [ ].  
 After RAN #93e, a further list will be appended to the TEI CR list so that in the end a list for all TEI cat.B/C CRs (and their corresponding cat.F/A corrections) will develop that allows easy search and filtering for new TEI features.

- Such a list could be generated per release and will allow an improved visibility and tracing of new TEI features.  
 Note: Due to the unique TEI identifiers and the proper documentation as outcome of the RAN meetings, also 3GU will allow to search for TEI CR sets.