**3GPP TSG RAN WG1 #112 R1-230xxxx**

**Athens, Greece, February 27th – March 3rd, 2023**

**Agenda item:** 9.17

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

**Title:** [draft] Summary #2 on Rel-18 TEIs

**Document for:** Discussion and Decision

1. Introduction

This contribution summarizes the discussions and proposals in AI 9.17 for Rel-18 TEI related discussion and following email discussion.

[112-R18-TEI] To be used for sharing updates on online/offline schedule, details on what is to be discussed in online/offline sessions, tdoc number of the moderator summary for online session, etc – Shinya (DOCOMO)

Based on the discussions summarized in Section 2, following TEI proposals are identified in AI 9.17. According to the guidance in [10], 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. Detailed feedback/question on each TEI proposal can also be provided in Section 2.**

* **TEI proposal #1: Periodicity of the scheduling request**
	+ Supported by Ericsson, Qualcomm, FUTUREWEI, CATT, vivo
* **TEI proposal #2: Multi-PxSCH scheduling with single DCI**
	+ Supported by Ericsson, Qualcomm, Huawei, HiSilicon
* **TEI proposal #3: UE capability with up to 6-layer DL MIMO**
	+ Supported by OPPO, CMCC, China Telecom, NTT DOCOMO, Lenovo, Qualcomm, [Nokia, NSB]
* **TEI proposal #4: PDCCH skipping with DL HARQ retransmission**
	+ Supported by vivo, Ericsson, MediaTek, Google, China Telecom, Qualcomm, FUTUREWEI, Huawei, HiSilicon
* **TEI proposal #5: PUSCH antenna switching**
	+ Supported by vivo, CMCC, Ericsson, CATT
* **TEI proposal #6: 1-symbol PRS**
	+ Supported by ZTE, CMCC, CATT, xiaomi, Sanechips, FUTUREWEI, Huawei, HiSilicon
* **TEI proposal #7: PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI**
	+ Supported by ZTE, China Telecom, Sanechips, CATT
* **TEI proposal #8: Extensions to FR1 TRS configurations**
	+ Supported by Nokia, Nokia Shanghai Bell, ZTE, [Huawei, Hisilicon]
* **TEI proposal #9: Enhanced PDCCH reception for mDCI based mTRP**
	+ Supported by Qualcomm, FUTUREWEI, CATT, ZTE, Nokia, NSB
* **TEI proposal #10: Enhancement for scheduling request**
	+ Supported by Qualcomm, ZTE (third bullet)
* **TEI proposal #11: UE reporting of power offset for SRS antenna switching**
	+ Supported by Qualcomm, Huawei, HiSilicon
* **TEI proposal #12: RAT-independent Positioning Enhancements**
	+ Supported by Qualcomm, ZTE
* **TEI proposal #13: BWP without CD-SSB for normal UE**
	+ Supported by MediaTek, FUTUREWEI, ZTE
* **TEI proposal #14: Enhancement for HARQ multiplexing on PUSCH**
	+ Supported by Huawei, HiSilicon, Ericsson, China Unicom, FUTUREWEI, DOCOMO
1. Discussion on Rel-18 TEI proposals
	1. Periodicity of the scheduling request

Following proposal is made in the contribution.

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| --- | --- |
| [1] | This TEI proposal aims to amend the supported values of the Scheduling Request (SR) periodicity as the current values creates a problem in all used deployments with SCS=120 kHz. The issue is that the periodic SRs does not support 5 (and 10 slot) periodicities in FR2 while at the same time, all the three used FR2 TDD patterns have 5 slot periodicities. For example, the most common pattern DDDSU for SCS=120 kHz which doesn’t match the supported 2,4,8,16,20,40,… slot periodicities of SR. Other popular patterns for SCS=120 kHz is DDSUU and DSUUU, which also have a 5 slot repetitionThe scheduling request resource configuration in TS 38.331 support these configurations for the periodicity and it is noted that 5 slot is supported for some SCS but not for all.When an SR period is chosen from the supported periodicities up to 40 slots, then periodic SR on PUCCH occasionally ends up on different type of slots (U slot and S slot) and is cancelled in D slots. This means SR is no longer periodic, instead effectively 4 slot / 16 slot between occasions which is not optimal for latency (assuming a 4 slot parameter setting with DDDSU). Furthermore, this makes it difficult to avoid symbol overlap with other channels like PUCCH-ACK, PUSCH, PRACH, SRS and the handling of multiplexing between SR-PUCCH and other channels considering many different UE capabilities adds complexity to the gNB.The proposal for TEI-18 is to add 5 and 10 slot SR periodicity to 120 kHz and also to 30 kHz SCS (as it will also face the same issue when a 5 slot TDD pattern is used). **Proposal 1 A TEI-18 is supported to introduce 5 and 10 slot periodicities to the periodicityAndOffset in SchedulingRequestResourceConfig for 120 kHz and 5 slot for 30 kHz SCS**Practically, since TS 38.331 is under RAN2 control, RAN1 can agree on the proposal above and send an LS to RAN2 indicating that RAN1 has identified the need for these new SR periodicities and kindly ask RAN2 to take further action.  |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #1**

* **Introduce 5 and 10 slot periodicities to the periodicityAndOffset in SchedulingRequestResourceConfig for 120 kHz and 5 slot for 30 kHz SCS**

This proposal is already supported by Ericsson.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y | Support for R18 |
| FUTUREWEI | Y |  |
| CATT | Y | We are supportive of this TEI proposal. When the periodicity of SR is configured with 2, 4, 8, 16 slot for 120kHz, the possibility of collosion between SR and D/S slot will increase. It’s better to introduce 5 and 10 slot periodicities for 120kHz SCS and 5 slot for 30 kHz SCS. |
| ZTE |  | If it is for low latency, we are wondering what’s the issue to be configured with shorter periodicities (e.g.,1 slot), or multiple SR configurations (e.g., 4 SR configurations with one slot offset and periodicity of 4 slots for each configuration)?  |
| vivo | Y |  |
| Moderator |  | According to the above comments, this proposal is supported by Ericsson, Qualcomm, FUTUREWEI, CATT, vivo, and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to answer the question from ZTE. |

* 1. Multi-PxSCH scheduling with single DCI

Following proposal is made in the contribution.

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| [1] | In Rel-16, the feature multi-PUSCH scheduling was introduced whereby a single DCI 0\_1 can schedule up to 8 PUSCHs. The feature is agnostic to subcarrier spacing, frequency range, and whether or not shared spectrum access is required for the frequency band. The only restriction in Rel-16 specifications is that the multiple scheduled PUSCHs occur in contiguous slots. The corresponding Rel-16 UE feature parameter is as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***multiPUSCH-UL-grant-r16***Indicates whether the UE supports scheduling up to 8 PUSCH with a single DCI 0\_1. This capability is also applicable to a frequency band that does not require shared spectrum access. | Band | No | N/A | N/A |

In Rel-17, multi-PUSCH scheduling was extended to support non-contiguous slots in addition to contiguous slots. In contrast this feature is not agnostic to frequency range; it is limited to FR2 which includes sub-ranges FR2-1 (up to 52.6 GHz) and the newly introduced FR2-2 (up to 71 GHz). For FR2-1 the UE feature is limited to 120 kHz only. The corresponding Rel-17 UE feature parameter for FR2-1 is given is as follows:

| ***multiPUSCH-SingleDCI-FR2-1-SCS-120kHz-r17***Indicates whether the UE supports multi-PUSCH scheduling by single DCI for the operation with 120kHz SCS in FR2-1 with non-contiguous allocation. | Band | No | N/A | N/A |
| --- | --- | --- | --- | --- |

In our view, it would be beneficial to extend multi-PUSCH scheduling with non-contiguous slots also to FR1. The extension is important for XR uses cases. The XR video traffic in UL includes variable and large packets, arriving in bursts. Therefore, dynamic scheduling is a reasonable approach for data transmission. Considering the large size of the packets, multiple PUSCHs are needed to be scheduled for sending the data. Hence, scheduling these PUSCHs with a single DCI has clear benefit and advantage, over scheduling each PUSCH with a single DCI. A limitation to contiguous slots would be problematic in case of transmission over TDD bands. We note there is no RAN1 specification impact from this; it is only a matter of introducing an additional UE capability. With this capability, multi-PUSCH with either contiguous or non-contiguous slots would then be available in all frequency ranges and all subcarrier spacings defined so far:**Proposal 2 A TEI-18 is supported to introduce a UE feature for multi-PUSCH scheduling with single DCI 0\_1 for non-contiguous slots in FR1 for all defined SCSs. Note: there is no RAN1 impact.**Similar to multi-PUSCH scheduling, multi-PDSCH scheduling with single DCI 1\_1 for both contiguous/non-contiguous slots was specified in Rel-17. Similarly, this feature was limited to FR2 including both sub-ranges FR2-1 and FR2-2, and for FR2-1 it is limited to 120 kHz only. The corresponding Rel-17 UE feature parameter for FR2-1 is given is as follows (see [2]):

| ***multiPDSCH-SingleDCI-FR2-1-SCS-120kHz-r17***Indicates whether the UE supports multi-PDSCH scheduling by single DCI for the operation with 120kHz SCS in FR2-1 and HARQ enhancements for both type 1 and type 2 HARQ codebook. | Band | No | N/A | N/A |
| --- | --- | --- | --- | --- |

In our view it is beneficial to also extend multi-PDSCH scheduling for contiguous/non-contiguous slots to FR1. Similarly to UL for the case of multi-PUSCH, this extension is important for XR uses cases to serve XR video traffic in DL which includes variable and large packets, arriving in bursts. Again, there is no specification impact from this; it is only a matter of introducing an additional UE capability. With this capability, multi-PDSCH with either contiguous or non-contiguous slots would then be available for all frequency ranges and all subcarrier spacings defined so far.**Proposal 3 Introduce a UE feature for multi-PDSCH scheduling with single DCI 1\_1 for contiguous/non-contiguous slots in FR1 for all defined SCSs in the same TEI-18 as for multi-PUSCH with non-contiguous slots for FR1. Note: there is no RAN1 impact.**  |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #2**

* **Introduce a UE feature for multi-PUSCH scheduling with single DCI 0\_1 for non-contiguous slots in FR1 for all defined SCSs**
	+ **Note: there is no RAN1 impact**
* **Introduce a UE feature for multi-PDSCH scheduling with single DCI 1\_1 for contiguous/non-contiguous slots in FR1 for all defined SCSs**
	+ **Note: there is no RAN1 impact.**

This proposal is already supported by Ericsson.

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

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| Company | Suppport (Y/N) | Comment |
| QC | Y | A minor comment: There seems no need to extend NR-U contiguous PUSCH scheduling design to FR1 as long as FR2-2 design (for both contiguous and non-contiguous slots) is extended to FR1.  |
| DOCOMO |  | This proposal was discussed in Rel-18 XR SI while no consensus was achieved because the gain is unclear. It is appreciated if proponent can show how much capacity gain can be achieved by this proposal |
| CATT | N | It has achieved a conclusion in RAN1#110bis as following:ConclusionNo further discussion in RAN1 for Rel-18 XR to extend the support of legacy single DCI scheduling multi-PDSCHs for FR2-2, to other SCS in FR1/FR2-1.According to the conclusion, it is not necessary to extend the multi-PUSCH/PDSCH to other SCS in FR1/FR2-1 for XR service.Moreover, for multi-PDSCH/PUSCH scheduling, the same MCS is applied to all the PDSCH/PUSCHs scheduled by a DCI. If it is extended to other SCS in FR1/FR2-1, i.e. 15kHz, using the same MCS for up to 8 PUSCH/PDSCH may affect the performance of PUSCH/PDSCH. Thus, we prefer not to extend the multi-PUSCH/PDSCH to other SCS in FR1/FR2-1. |
| ZTE |  | More clarification on the motivation is needed, e.g., support of multi-PUSCH/PDSCH scheduling in non-contiguous slots for FDD.  |
| Nokia, NSB | N | Already concluded not to consider this further (see CATT comment) TEI18 should not be used as a second attempt for features that did not make it to a Rel-18 WI they were originally proposed for. |
| vivo |  | It has been studied in Rel-18 XR, no consensus on the achieved gain |
| MediaTek | N | We are skeptical about the use case for this TEI. In R17 UE feature discussion, the proposal was discussed but not agreed to extend to FR1. In R18 XR study, extending multi-slot-PxSCH scheduling by single DCI from FR2 to FR1 was again discussed and majority of companies are inclined to think there is no obvious XR capacity gain. We are hence curious what is the main benefit or application scenario for this extension to FR1 considering FR1 has a much longer slot length than FR2. |
| Huawei, HiSilicon | Y | Support the proposal#2 in general. Considering the proposal and existing FGs in NRU and above 52.6GHz, there is only 60kHz SCS in FR2-1 not supporting multiple PDSCH/PUSCH scheduling by single DCI. Not sure why it is treated differently from the other SCS and FR. During the discussion on R17 UE features, extension of 32 HARQ processes (already supported in above 52.6GHz and NTN) to FR2-1 and FR1 were discussed together with the FGs of multiple PDSCH/PUSCHs scheduled by single DCI to solve the starvation of HARQ processes. We propose to extend support of 32 HARQ processes to FR2-1 and FR1 for all supported SCSs.  |
| Moderator |  | According to the above comments, this proposal is supported by Ericsson, Qualcomm, Huawei, HiSilicon, and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies. |
| OPPO | N | Agee with CATT’s comment |

* 1. UE capability with up to 6-layer DL MIMO

Following proposal is made in the contribution.

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| [2] | **Background**In Rel-15 NR, the MIMO schemes with up to 8 layers were introduced to boost the DL throughput. Based on UE capability, NW may configure MIMO transmission with up to 8 layers for a UE. According to the existing RRC signaling, the number of MIMO layer can be configured as 1, 2, 3, 4, 5, 6, 7, or 8.

|  |
| --- |
| PDSCH-Config ::= SEQUENCE { dataScramblingIdentityPDSCH INTEGER (0..1023) OPTIONAL, -- Need S dmrs-DownlinkForPDSCH-MappingTypeA SetupRelease { DMRS-DownlinkConfig } OPTIONAL, -- Need M dmrs-DownlinkForPDSCH-MappingTypeB SetupRelease { DMRS-DownlinkConfig } OPTIONAL, -- Need M ..., [[ maxMIMO-Layers-r16 SetupRelease { MaxMIMO-LayersDL-r16 } OPTIONAL, -- Need M minimumSchedulingOffsetK0-r16 SetupRelease { MinSchedulingOffsetK0-Values-r16 } OPTIONAL, -- Need M …}MaxMIMO-LayersDL-r16 ::= INTEGER (1..8) |

Meanwhile, the existing UE capability signaling allows a UE to report the support of up to 2-layer DL MIMO, up to 4-layer DL MIMO or up to 8-layer DL MIMO.

|  |
| --- |
| FeatureSetDownlinkPerCC ::= SEQUENCE { supportedSubcarrierSpacingDL SubcarrierSpacing, supportedBandwidthDL SupportedBandwidth, channelBW-90mhz ENUMERATED {supported} OPTIONAL, maxNumberMIMO-LayersPDSCH MIMO-LayersDL OPTIONAL, supportedModulationOrderDL ModulationOrder OPTIONAL}MIMO-LayersDL ::= ENUMERATED {twoLayers, fourLayers, eightLayers} |

In the early stage of 5G commercial deployment, it is common for smartphones to use 4 Rx antennas. As hardware and design improve, some advanced smartphones are starting to trend towards using more Rx antennas to improve the DL performance. For example, some foldable phones have already implemented 6 Rx antennas. That brings in the following benefits to 5G system:* B1: A more advanced receiver exploiting more Rx antennas to mitigate interference for DL MIMO transmission with up to 4 layers that can
* B2: providing higher peak data rate through supporting higher number of DL MIMO layers (e.g., 5 or 6 layers). Fig.1 illustrates the LLS performance for DL MIMO schemes. “rank4” and “rank6” in the figure refer to the dynamic rank adaptation with up to 4 layers and up to 6 layers, respectively.

Figure 1. Performance comparison of up to 4-layer and up to 6-layer DL MIMOThe benefit B1 can be achieved by advanced implementation of chipset with no spec impact. But, unfortunately, the benefit B2 cannot be obtained under the current specification. According to the existing UE capability signaling, a UE with 6 Rx antennas can only report either “twoLayers” or “fourLayers”. With reporting either one, the system is not able to configure 6-layer DL MIMO transmission to the UE, even though the UE is capable of 6-layer DL MIMO. **Solution**Therefore, in order to achieve higher DL throughput by fully exploiting the capability of UE with 6 Rx antennas, it is proposed to introduce a new UE capability so that an advanced smart phone with 6 Rx antennas can report its support of up to 6-layer DL MIMO transmission.***Proposal 1: Introduce a new candidate value, sixLayers, for the UE capability of supported maximal number of DL MIMO layers to support up to 6-layer DL MIMO transmission.***

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|  | **Prerequisite feature groups**  | **Need for gNB to know whether thefeature is supported by the UE** | **per** | **Candidate values** |  |
| Supported maximal number of DL MIMO layers | 2-1 | Yes | FSPC | twoLayers, fourLayers, ***sixLayers***, eightLayers | Optional |

***Note1: R15 NR has already supported the candidate values of twoLayers, fourLayers and eightLayers via the RRC parameter MIMO-LayersDL ::= ENUMERATED {twoLayers, fourLayers, eightLayers}. It’s up to RAN2 for the signaling design of the corresponding UE capability.******Note2: A 6Rx UE can report a capability of two, four or six layers of maximum number of DL MMO layers. An 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layers.*** |
| [7] | In the current UE capability signalling maxNumberMIMO-layersPDSCH for DL MIMO, there are two unnecessary limitations. * Limitation 1: the allowed values for maxNumberMIMO-layersPDSCH are {twoLayers, fourLayers, eightLayers} where sixLayers are missing. Given that there is no product on market to support more than fourLayers for DL MIMO, the caveat is not a problem for now. But in the future, this is a problem for UE vendors to build new devices beyond 4 layers, because the new devices have to support up to 8 layers directly. It is quite challenging to build device which improves from supporting max of 4 layers to max of 8 layers directly. It is beneficial, from both market demand and UE implementation perspective, to allow UE vendors improve devices from max of 4 layers to max of 6 layers, then to max of 8 layers.
* Limitation 2: In Rel-15, number of Rx and number of max layers supported for DL MIMO is unnecessary tied together. For example, a 4 Rx UE is mandated to support 4 layers DL MIMO. We don’t intend to break the coupling for existing legacy devices which are already deployed, although we don’t think the couple is necessary. However, for future devices that can support more than 4 layers, it would be beneficial to untie the coupling of number of Rx and number of max DL MIMO layers, to allow more flexible UE implementation on market.

To address the first limitation, a very simple proposal is made. **Proposal 2: Add a new UE capability of maxMIMO-LayersPDSCH-r18 with candidate values {2,4,6,8}.**

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| --- | --- | --- | --- | --- |
|  | Description | Per |  | Candidate values |
| maxMIMO-LayersPDSCH-r18 | Supported maximum number of DL MIMO layers | FSPC |  | {2,4,6,8} |

To address the second limitation, the following proposal is made. **Proposal 3: In UE capability maxNumberMIMO-layersPDSCH-r18, a 6-Rx UE can report a capability of twoLayers, fourLayers, or sixLayers, and an 8-Rx UE can report a capability of twoLayers, fourLayers, sixLayers, or eightLayers.**  |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #3**

* **Introduce a new candidate value, sixLayers, for the UE capability of supported maximal number of DL MIMO layers to support up to 6-layer DL MIMO transmission**
	+ **Prerequisite feature group is FG 2-1**
	+ **“Need for gNB to know whether the feature is supported by the UE” is “Yes”**
	+ **Reporting type is per FSPC**
	+ **“Mandatory/Optional” is Optional with capability signalling**
	+ **Note1: R15 NR has already supported the candidate values of twoLayers, fourLayers and eightLayers via the RRC parameter MIMO-LayersDL ::= ENUMERATED {twoLayers, fourLayers, eightLayers}. It’s up to RAN2 for the signaling design of the corresponding UE capability.**
	+ **Note2: A 6Rx UE can report a capability of two, four or six layers of maximum number of DL MMO layers. An 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layers.**

This proposal is already supported by OPPO, CMCC, China Telecom, NTT DOCOMO, Lenovo, Qualcomm.

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

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| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y |  |
| DOCOMO | Y (w/ update) | Support the proposal in principle, however current Note 2 has a problem.From Rel.15, 4 layers is mandatory for the bands where 4Rx is mandatory (except for RedCap). However, the note2 is contradicting with this Rel.15 rule.TR38.822:*For single CC standalone NR, it is mandatory with capability signalling to support at least 4 MIMO layers in the bands where 4Rx is specified as mandatory for the given UE*Hence, we suggest to update the note 2 as:Note2: A 6Rx UE can report a capability of two, four or six layers of maximum number of DL MMO layers except for the bands where 4Rx is specified as mandatory for the given UE. A 6Rx UE can report a capability of four or six layers of maximum number of DL MMO layers for the bands where 4Rx is specified as mandatory for the given UE. An 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layer except for the bands where 4Rx is specified as mandatory for the given UE. A 8Rx UE can report a capability of four, six or eight layers of maximum number of DL MMO layers for the bands where 4Rx is specified as mandatory for the given UE. |
| CATT | N | In addition to UE capability, corresponding RAN4 work is also needed to enable up to 6-layer DL MIMO in practical system. The feature has major impacts to other working group, and may not suitable for a TEI. |
| ZTE | N | Firstly, in general, introducing a new UE type should be fully justified, and then a new corresponding WID rather than TEI seems much more suitable. It is not just relevant to spec impact, but also much relevant to NW implement efforts on supporting above. Secondly, in technical, we think the following may be clarified:* + - Besides for SU-MIMO, we are wondering whether MU-MIMO should be supported or not. If only supporting SU-MIMO, from NW perspective, SU-MIMO with up to 6 layers vs MU-MIMO with up to 8/12 layer should be evaluated.

Then, if having up to 6 layer UE, the pattern of DMRS ports should be studied in our views. |
| Nokia, NSB | [Y] | In principle we’d support allowing 6-Rx UEs, but would like to understand the CATT and ZTE concerns better. The specification already supports 6-layer MIMO, so if the proposal is simply to introduce a UE that can be scheduled with 6 layers, but never more than 6 layers, on the face of it there doesn’t seem to be a need for new functionality.We agree with DOCOMO revisions. |
| vivo |  | Maybe RAN4 is the correct WG to discuss this TEI proposal |
| MediaTek | N | We do not support this proposal. We believe that introducing this level of flexibility into the specifications is not justified for a device that can support 8 Rx antennas. We also do not see the practical benefits of introducing 6 layers and 6Rx for a smartphone form factor. A similar discussion also took place when prioritizing RAN4 work items for Rel-18 at RAN plenary. So agreeing this now in RAN1 would contradict with that outcome, and does not have any solid justification as to why this flexibility is practically useful.  |
| Huawei, HiSilicon | See comments | We have several questions over this proposal:* We are not clear on the benefits. For CSI reporting based transmission, 6 layers have limitations, e.g., no type-II high resolution codebook for 6-layer, coarser codebook compared with 4-layer. This can also be reflected in the simulation results that for SNR less than 30dB, there’s marginal difference between 4-layer & 6-layer. For reciprocity-based transmission, spec has supported UE reporting of 1t6r or 2t6r for antenna switching, thus in practice the 6-layer can be supported in practice.
* To fully use 6R, it seems the requirement for 6R in RAN4 will be needed. Does the proposal include some RAN4 work?
 |
| Moderator |  | According to the above comments, this proposal is supported by OPPO, CMCC, China Telecom, NTT DOCOMO, Lenovo, Qualcomm, [Nokia, NSB], and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponents are encouraged to address the concern from companies.Proposal is updated based on the comment as follows:* **Introduce a new candidate value, sixLayers, for the UE capability of supported maximal number of DL MIMO layers to support up to 6-layer DL MIMO transmission**
	+ **Prerequisite feature group is FG 2-1**
	+ **“Need for gNB to know whether the feature is supported by the UE” is “Yes”**
	+ **Reporting type is per FSPC**
	+ **“Mandatory/Optional” is Optional with capability signalling**
	+ **Note1: R15 NR has already supported the candidate values of twoLayers, fourLayers and eightLayers via the RRC parameter MIMO-LayersDL ::= ENUMERATED {twoLayers, fourLayers, eightLayers}. It’s up to RAN2 for the signaling design of the corresponding UE capability.**
	+ **Note2: A 6Rx UE can report a capability of two, four or six layers of maximum number of DL MMO layers. An 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MIMO layers.**
	+ **Note2: A 6Rx UE can report a capability of two, four or six layers of maximum number of DL MMO layers except for the bands where 4Rx is specified as mandatory for the given UE. A 6Rx UE can report a capability of four or six layers of maximum number of DL MMO layers for the bands where 4Rx is specified as mandatory for the given UE. An 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MIMO layer except for the bands where 4Rx is specified as mandatory for the given UE. A 8Rx UE can report a capability of four, six or eight layers of maximum number of DL MMO layers for the bands where 4Rx is specified as mandatory for the given UE**
 |
| OPPO | Y | We are fine with the updated proposal.Re CATT: We agree that RAN4 work may be needed for 6Rx. However, the RAN4 work is not necessary to be finished in Rel-18. Even 8Rx requirement was just finished in Rel-17. Once RAN1 can agree on the feature, RAN4 can finish it in future release. Re ZTE: The TEI is only related to UE capability, while gNB can still follow legacy configuration if it doesn’t want to implement the feature. At least in scenarios where there are not so many UEs in a cell (low probability of MU), UE supporting 6 layers transmission can provide higher peek SE. Regarding DMRS, we think current DMRS design is sufficient and no enhancement is needed. Re vivo: RAN4 work can start after the UE feature is introduced. Re MediaTek: It is not about flexibility. For a 6Rx UE, without this UE capability, it can only down-report the capability of 4 layer transmission, which would impact the peek SE for some UE with high SINR.Re Huawei: Since the feature is mainly applied to UE with SU-MIMO, we think type-II high resolution codebook for 6-layer may not be needed. For reciprocity-based transmission, though UE can report 1T6R or 2T6R, it can only report max layers of 4. gNB can obtain full channel information with 6RX, but it cannot schedule more than 4 layers even with high SINR. For RAN4 work, please see the response to CATT. |

* 1. PDCCH skipping with DL HARQ retransmission

Following proposal is made in the contribution.

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| [4] |  To ensure the reliable transmission, network needs to be able to schedule HARQ retransmission if the initial transmission fails. However, according to the latest TS 38.213 quoted as below, when PDCCH skipping is enabled, the PDCCH skipping indication is applied by the UE immediately after the indicated scheduling PDCCH reception, without considering the potential scheduling for retransmission due to the failure of initial transmission. Stated plainly, the current specification does not support PDCCH skipping interacting with HARQ retransmission.

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| --- |
| **TS 38.213 V17.4.0 (2022-12)**\*\*\* Unchanged text is omitted \*\*\*When the PDCCH monitoring adaptation field indicates to a UE to skip PDCCH monitoring for a duration on the active DL BWP of a serving cell, the UE starts skipping of PDCCH monitoring at the beginning of a first slot that is after the last symbol of the PDCCH reception providing the DCI format with the PDCCH monitoring adaptation field.\*\*\* Unchanged text is omitted \*\*\* |

It has been argued during R18 XR SI discussion that several gNB implementation based solutions (as in Appendix A-1) could be used to alleviate the above mentioned issue for current PDCCH skipping design. however, as have evaluated (shown in Appendix A-2), these existing gNB implementation solutions will either cause severe system capacity issue (impossible for timely retransmission), or excessive UE power consumption. Given that, the current PDCCH skipping feature is difficult for gNB to apply, especially for XR services with stringent latency and reliability requirement. **Figure 112. Example of PDCCH monitoring resuming for DL HARQ retransmission in case of PDCCH skipping** Based on the above analysis, for both data transmission robustness and UE power saving, it is desirable to enhance PDCCH skipping by interacting with HARQ retransmission. For DL HARQ retransmission, in order to compensate for the lack of retransmission consideration in the existing PDCCH skipping design, the proposed enhancement is illustrated as shown in **Figure 1**. The PDCCH skipping indication is indicated by a scheduling DCI that schedules the initial transmission of the last packet of a DL traffic burst. If there is a NACK for the received PDSCH, UE is supposed to resume PDCCH monitoring for HARQ retransmission. When DRX is configured, if UE would resume PDCCH monitoring due to NACK transmission and *drx-HARQ-RTT-TimerDL* is still running, UE does not monitor PDCCH until *drx-RetransmissionTimerDL* starts. In this case, network can perform retransmission for the UE if the initial transmission for the UE failed. There is good trade-off between UE power consumption and capacity performance. In addition, DCI based PDCCH skipping indication has less delay than MAC based termination of PDCCH monitoring within DRX active time. Simulation results show that the proposed method can achieve higher power saving gains that the existing methods. More details can be found in the Appendix A-2.Based on the above discussion, we have the following proposal.**Proposal 1: Upon detecting a DCI indicating PDCCH skipping, UE resumes PDCCH monitoring if the UE transmits NACK after the PDCCH skipping starts.**For information, below table shows the potential spec impact to 38.213.

|  |
| --- |
| **-------------------TP for 38.213---------------------**10.4 Search space set group switching and skipping of PDCCH monitoring\*\*\* Unchanged text is omitted \*\*\*When the PDCCH monitoring adaptation field indicates to a UE to skip PDCCH monitoring for a duration on the active DL BWP of a serving cell, the UE starts skipping of PDCCH monitoring at the beginning of a first slot that is after the last symbol of the PDCCH reception providing the DCI format with the PDCCH monitoring adaptation field. If the UE transmits a PUCCH providing a positive SR, or a PUCCH or a PUSCH providing a NACK value after the UE detects a DCI format providing the PDCCH monitoring adaptation field indicating to the UE to skip PDCCH monitoring for the duration on the active DL BWP of the serving cell, the UE resumes PDCCH monitoring, as described in [11, TS 38.321], starting at the beginning of a first slot that is after a last symbol of the PUCCH transmission. During the time of *ra-ResponseWindow* or *msgB-ResponseWindow* or the duration where *ra-ContentionResolutionTimer* is running, the UE shall not skip PDCCH monitoring on SpCell. If the DRX group of the serving cell is configured and enters outside Active Time, the UE terminates PDCCH skipping for the serving cell.\*\*\* Unchanged text is omitted \*\*\* |

 |
| [7] | PDCCH skipping was specified in NR Rel-17 for UE power saving operations. It can be triggered by the gNB around the end of the transmission of a data cluster. In particular, in the scheduling DCI for the last PDSCH of the cluster (e.g., a XR video frame), the gNB can indicate the UE to skip PDCCH monitoring. Application delay for PDCCH skipping indication was not explicitly defined which means once the UE receives the PDCCH skipping indication, it immediately stops monitoring associated PDCCH candidates. This allows UE to terminate the CDRX active time before the CDRX activity timer expires. By properly configuring the set of PDCCH skipping values, a UE can continuously sleep until the start of the next CDRX cycle. The downside of this design is the UE may have to wait until the On Duration of the next DRX cycle to receive the retransmission of a failed PDSCH that is scheduled before the UE started PDCCH skipping. This was not considered a major issue during Rel-17 power saving discussions but becomes detrimental for XR traffic that has large packet size and tight packet delay budget (PDB) requirement. The additional delay to the retransmission may cause the UE to drop the entire video frame if the UE cannot successfully receive the retransmission before the delay deadline expires when the XR DL video periodicity (16.67 ms) is typically longer than the 10 ms PDB. To resolve the issue above for the XR DL video traffic, a simple design fix can be introduced by the following proposal:**Proposal 4: UE resumes PDCCH monitoring after PDCCH skipping has started if the UE sent the NACK for a PDSCH decoding failure*** **This is an optional UE feature based on UE capability report**
 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #4**

* **Upon detecting a DCI indicating PDCCH skipping, UE resumes PDCCH monitoring if the UE transmits NACK after the PDCCH skipping starts**
	+ **This is an optional UE feature based on UE capability report**

This proposal is already supported by vivo, Ericsson, MediaTek, Google, [China Telecom], Qualcomm.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y |  |
| FUTUREWEI | Y |  |
| CTC | Y |  |
| CATT | N | PDCCH skipping with HARQ-ACK, which has been discussed in Rel-17 and Rel-18 XR. |
| ZTE |  | This proposal can be considered if there is attractive energy saving gain from the enhanced PDCCH skipping on the top of the existing solutions like dummy PDSCH, MAC CE based go-to sleep. |
| vivo | Y |  |
| MediaTek | Y | We support this proposal, which makes the PDCCH skipping feature more robust and applicable to more scenarios which require low data latency. |
| Huawei, HiSilicon | Y |  |
| Moderator |  | According to the above comments, this proposal is supported by vivo, Ericsson, MediaTek, Google, China Telecom, Qualcomm, FUTUREWEI, Huawei, HiSilicon, and hence meets the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor.Proponents are encouraged to address the concern from companies. |

* 1. PUSCH antenna switching

Following proposal is made in the contribution.

|  |  |  |
| --- | --- | --- |
| [4] |  **Background**Current NR spec supports flexible configuration of SRS resources for different purposes with usage defined as for codebook, for antenna switching etc. However, the SRS resources for different usages are configured independently and not shared. SRS resources with usage for codebook are for PUSCH transmission, while SRS resources with usage antenna switching are for PDSCH transmission (channel reciprocity, TDD). Depending on UE capability SRS for antenna switching can be configured with 1T2R, 1T4R, 2T4R etc. gNB can configure a UE with SRS for codebook and SRS antenna switching independently, simultaneously. In the following examples, it can be noticed that PUSCH antenna switching is supported in some of the scenarios.* example 1, a UE can be configured with same two 1/2-port SRS resources for codebook and two 1/2-port SRS resources for 1T2R or 2T4R
	+ PUSCH antenna switching is supported
* example 2, a UE can be configured with four 1-port SRS resources for 1T4R, however configuration of four SRS resources is not supported for CB except UL full power mode 2
	+ PUSCH antenna switching is partially supported
* example 3, a UE can be configured with one 2-port SRS resource for codebook (ID 0) and two 2-port SRS resources (ID 0, ID 1) for 2T4R antenna switching.
	+ PUSCH antenna switching is not supported.
* example 4, in FDD, SRS antenna switching may not be supported/configured, however two (four) SRS resources for CB can be configured
	+ Antenna switching for SRS and hence PUSCH is partially possible

**Discussion**Currently, antenna selection for PUSCH is UE implementation, and partially supported in spec by configuring multiple SRS resources for CB. UE implementation could vary significantly and may not be very dynamic. Network doesn’t know when and how PUSCH antenna switching is implemented at the UE which may lead to degraded network implementation. Network controlling TX antenna can improve antenna selection mechanism, dynamically selecting best antenna for SRS and PUSCH transmission, improving overall system performance. Figure 2 shows evaluation results, the UE is equipped with 1Tx chain but 4 antennas, PUSCH antenna is switched from the antenna which is completely blocked (index 1) to another antenna which not blocked. Blocking occurs at dashed vertical line and reaction time means the time delay in switching to best antenna (not blocked) after the blocking occurs. The reaction time is the time period required for UE switching to better antenna by implementation. If the UE can instantly switch to better antenna (0ms reaction time), then the UE switches to better antenna for SRS transmission and the following PUSCH transmission. For example, for 80ms (or longer) reaction time, after antenna blocking happens (at dashed line 30ms), the UE takes 80ms to switch to better antenna, during this period the UE uses blocked antenna for SRS and the following PUSCH transmission. In this evaluation, only 1 SRS resource is assumed for CB based transmission. It can be noticed that longer the delay (reaction time) in PUSCH antenna switching performance gets worse. Figure 2 Impact of PUSCH antenna switching delay on performanceFrom above discussion and evaluation results, following observations can be made * It is beneficial to support spec based PUSCH antenna switching
* If SRS for antenna switching and for codebook share same resources, only minor spec change for 1T4R is needed.
* For FDD, assuming the network doesn’t configure antenna switching SRS for the UE, network can configure two 1/2-port SRS resources
	+ Some enhancement on SRS configuration is needed, i.e., introduce “gap symbol” between two SRS resource for codebook
* For 1Tx, 4Rx UE, assuming the network doesn’t configure antenna switching SRS for the UE
	+ To support PUSCH antenna switching, for TDD/FDD, four 1-port SRS resources are needed with gap symbol in between, and SRI is indicated in DCI.

**Proposals and potential spec impact**Based on the motivation and discussion above, it is proposed to support more than 2 SRS resources in a set for usage codebook. It is also proposed to introduced new a UE capability on gap symbol between SRS resources.**Proposal 2:*** **Support to configure maximum of 4 SRS resources for codebook based transmission for PUSCH antenna switching**
* **Introduce following new UE capabilities for PUSCH antenna switching**
	+ **Support of max 4 SRS resources in a set for codebook based UL transmission**
		- **With 1 or 2 ports in each resource, and excluding nTnR switching**
	+ **Support of gap symbol(s) between SRS resources in a set for usage codebook**
		- **Number of gap symbol(s) are same as for SRS resources for antenna switching**

Below table shows the potential spec impact to 38.214.

|  |
| --- |
| 38.214 Section 6.1.1.1 ..For codebook based transmission, only one SRS resource can be indicated based on the SRI from within the SRS resource set. ~~Except when higher layer parameter~~ *~~ul-FullPowerTransmission~~* ~~is set to 'fullpowerMode2', t~~The maximum number of configured SRS resources for codebook based transmission is ~~2~~4. If aperiodic SRS is configured for a UE, the SRS request field in DCI triggers the transmission of aperiodic SRS resources. |

 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #5**

* **Support to configure maximum of 4 SRS resources for codebook based transmission for PUSCH antenna switching**
* **Introduce following new UE capabilities for PUSCH antenna switching**
	+ **Support of max 4 SRS resources in a set for codebook based UL transmission**
		- **With 1 or 2 ports in each resource, and excluding nTnR switching**
	+ **Support of gap symbol(s) between SRS resources in a set for usage codebook**
		- **Number of gap symbol(s) are same as for SRS resources for antenna switching**

This proposal is already supported by vivo, CMCC, Ericsson.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | N | We have some concerns on this proposal. 1. Current UE implementation based 1Tx sounding works fine and it offers UE some flexibility to choose antenna. Please notice some UE Tx related parameters/procedures are not aware at gNB such as SAR, accurate/instant PHR, etc. For example, for 2T case, if antenna A/B are far apart, while C/D are clsoder, then UE might prefer to use A/B more to meet SAR requirements.
2. The functionality of this new mode can be achieved with non-codebook based PUSCH already.
3. If this proposal is adopted, GAP symbol need to be introduced on back-to-back PUSCH, if gNB indicate two different antenna port for these two PUSCH.
 |
| FUTUREWEI |  | Unclear benefit over current implementations |
| vivo | Y | @QC, please find comments below1. In current spec up to 2 SRS resources can be configured in SRS resource set for usage codebook, which allows some flexibility. For UE specific implementation as you mentioned for 2T case, the UE can map the SRS ports to corresponding antennas anyway
2. Non-codebook based PUSCH is optional in current spec
3. In the proposal GAP symbol depends on UE capability, if the UE reports the capability without GAP, gNB can configure SRS resources without GAP symbols, for the UEs without this capability gNB can choose configure GAP symbols or not to configure 4 SRS resources. In current spec, there is no GAP symbols between 2 SRS resources for codebook.

@FUTUREWEI, could you please clarify what do you mean by “current implementations”? We have shown in the simulation results that antenna switching delay has impact on PUSCH performance. |
| DOCOMO |  | We understand this proposal is basically to improve the performance of a PUSCH transmission by optimizing antenna port selection while making a sacrifice of some UL symbols at least for the corresponding SRS transmissions (e.g., Y+1 symbols for additional antenna port). We are currently not sure whether/how much the proposal could be beneficial from system perspective. It may be good to clarify such “system-wise” benefit at first.  |
| CATT | Y | We are supportative of this TEI proposal. We have one question for clarification. When each resource is configured with 2 ports, there is no need to configure 4 SRS resources in a set. Is that correct understanding? |
| ZTE |  | As mentioned by other companies, the following may need to be clarified, otherwise it is difficult for us to justify the necessity and NW-implementation impact of this TEI proposal.* Q1: When/whether the SRS ports for CB from different resources can be different or not, for instance, if fully overlapping with SRS resource for AS, or a new RRC parameter/rule can be introduce for indicating that SRS ports for CB can be different ports from different resources.
* Q2: Whether/when a gap between PUSCH scheduled by DCI format 0\_1/2 and PUCCH/PUSCH scheduled by DCI format 0\_0 is needed? How to assume the PUCCH port and PUSCH port scheduled by DCI format 0\_0  in such case.

Q3: Whether we can assume that there is a fix mapping between SRS for AS? For instance, after RRC reconfiguration, SRS for CB is fully overlapped from SRS resource #0 for AS to resource #3, can we assume that the antenna port for SRS for CB is switched from physical UL-Tx antenna port 0 to 3 accordingly. |
| vivo2 |  | @DOCOMO, our initial evaluation shows the impact of switching delay. It is intuitive that more flexibile dynamic antenna selection for SRS (PUSCH) is beneficial. And, from network perspective there is flexibility in configuring number of SRS resources in a set for usage codebook@CATT, thanks for question, current proposal is to support 4 SRS resources in a set with 2 ports each. We can discuss 1 port and 2 port SRS separatelly @ZTE, reply to Q1, the proposal has nothing to do with SRS for AS, current spec supports configuration of up to 2 SRS resources in a set for usage codebook, number of SRS port(s) for codebook is same. [for your information UL full power mode2 support up to 4 SRS resources with different number of ports]reply to Q2, the proposal for SRS configuration with or without GAP is UE capability. Regarding “gap between PUSCH scheduled by DCI format 0\_1/2”, current spec allows configuring 2 SRS resources, which means SRI indicates which PUSCH follows which antenna ports are used for SRS transmission, partial PUSCH antenna switching is already supported by spec. when scheduled by DCI format 0\_0, there is no SRI/TPMI field in DCI, UE behavior is single port transmission, which same as in current spec with 2 SRS resources configured.Reply to Q3, this proposal has nothing to do SRS for AS, according to spec PUSCH transmission follows SRS transmission for codebook.  |
| MediaTek | N | We do not support this proposal. The UE implementation-specific approach to Tx antenna switching works well in our understanding, and gives flexibility to the UE. We see no need to change this paradigm and believe that adding network control would make the whole procedure more cumbersome. |
| Huawei, HiSilicon | N | The antenna switching for PUSCH can already be achieved to the most extent by implementation. For example, the blocked antenna can be measured by DL reference signal, and UE can choose to switch the physical antenna utilized to transmit the SRS resource based on the measurement result if necessary.Furthermore, introduce SRS resource set with usage “codebook + antenna switching” will bring non-negligible spec. effort. |
| Moderator |  | According to the above comments, this proposal is supported by vivo, CMCC, Ericsson, CATT, and hence meets the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor.Companies are encouraged to check the reply comments from proponent (vivo) and to provide further comments, if any.Also, proponents are encouraged to address the concern from companies not answered yet. |
| OPPO |  | The benefit over current implementation-based solution is not so clear to us and needs to be justified.  |

* 1. 1-symbol PRS

Following proposal is made in the contribution.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [5] | **Background**In Rel-16, wireless positioning methods were introduced in NR, where DL PRS and UL SRS for positioning are supported. For positioning SRS, the number of SRS symbols can be configured with {1, 2, 4, 8, 12}. However, the candidate numbers of PRS can only be {2, 4, 6, 12}, and 1-symbol PRS was not supported in the specification because of some concerns that the observation window for PRS measurement in time domain is reduced to half compared with two PRS symbols. For example, when comb 2 is used, the observation window of 1-symbol PRS measurement is only half of OFDM symbol. Due to potential long distance between target UE and some TRPs especially in outdoor scenarios such as RMa, UMa, the half OFDM symbol of the observation window may not be enough. In Rel-17, the commercial use cases and IIOT use cases are more on indoor scenarios, such as InF-DH and InF-SH where the room size is only 300x150 m2 or 120x60 m2. In such cases, the distance between the target UE and TRPs are usually near enough. Hence, a half of OFDM symbol for observation window is quite enough.In Rel-18, support of 1-symbol PRS was discussed in LPHAP agenda in the study item of expanded and Improved NR Positioning. In the study item, the conclusion was captured in TR 38.859 as follows. Some companies raised concern on support of 1-symbol PRS because the proposal was not only for power saving purpose in RRC inactive mode, the more benefit is to increase the PRS capacity both for RRC connected and inactive state. There was no technical concern raised.

|  |
| --- |
| 38.859:Enhancements on simplified DL PRS configuration with 1-symbol PRS can be studied further and if needed, specified during normative phase |

In RAN#98e meeting, a WID on Expanded and Improved NR Positioning was approved for Rel-18 and 1-symbol PRS was not included because of high RAN1 workload. There was still not technical concern raised.**Discussion**In this section, we list the benefit of support of 1-symbol PRS. * PRS overhead reduction

The main motivation of support of 1-symbol PRS is to reduce PRS overhead. As mentioned in section 2.1, 1-symbol PRS is sufficient in indoor scenarios because of short distance between UE and TRPs. * Increasing PRS capacity

As we know, wireless-dependent positioning techniques are more promising to be deployed in indoor scenarios because of GNSS coverage issue. However, high positioning accuracy are not easily achievable because there may be many obstacles in the indoor scenarios, and LOS conditions between the target UE and TRPs cannot be satisfied. To get LOS links between the target UE and more TRPs, high density TRPs should be deployed in the indoor factory, shopping mall or indoor office. To avoid serious PRS interference from TRPs, more time and frequency domain resources are needed, and PRS capacity will be an issue. 1-symbol PRS is beneficial for handling this issue especially on high frequency bands in which TDMed beam sweeping is needed. * Power saving

Because UE only needs to measure 1-symbol PRS rather than 2 or more, power saving gain can be achieved because of less buffering time, less processing period. The evaluation can be found in TR 38.859. From gNB side, less power consumption is also obtained.* Beneficial for RedCap UE positioning

In Rel-18 RedCap UE positioning, PRS hopping will be specified. UE can aggregate multiple PRS hops and get an effective large PRS bandwidth to improve location accuracy. However, due to the fact that multiple hops should be transmitted in TDMed manner, the time gap between the PRS hops should be short enough to ensure phase/timing coherent, i.e. to avoid serious impact of Doppler, phase offset, timing offset, power imbalance among hops. Support of 1-symbol PRS is helpful in such case since the duration of each PRS hop is reduced, and the total time gap among PRS hops is reduced accordingly.***Proposal 1:*** *Support 1-symbol PRS.* * *Without impact on legacy comb sizes, i.e. reuse comb size 2, 4, 6, 12*

Appendix 1 - Potential CR on 38.211 for 1-symbol PRS7.4.1.7.3 Mapping to physical resources in a downlink PRS resourceFor each downlink PRS resource configured, the UE shall assume the sequence  is scaled with a factor and mapped to resources elements according to when the following conditions are fulfilled:- the resource element is within the resource blocks occupied by the downlink PRS resource for which the UE is configured;- the symbol is not used by any SS/PBCH block used by a serving cell for downlink PRS transmitted from the same serving cell or any SS/PBCH block from a non-serving cell whose time frequency location is provided to the UE by higher layers for downlink PRS transmitted from the same non-serving cell;- the slot number satisfies the conditions in clause 7.4.1.7.4.and where - the antenna port - is the first symbol of the downlink PRS within a slot and given by the higher-layer parameter *dl-PRS-ResourceSymbolOffset*;- the size of the downlink PRS resource in the time domain is given by the higher-layer parameter *dl-PRS-NumSymbols*;- the comb size is given by the higher-layer parameter *dl-PRS-CombSizeN-AndReOffset* for a downlink PRS resource configured for RTT-based propagation delay compensation, otherwise by the higher-layer parameter *dl-PRS-CombSizeN* such that the combination is one of {1, 2}, {1, 4}, {1, 6}, {1, 12}, {2, 2},{4, 2}, {6, 2}, {12, 2}, {4, 4}, {12, 4}, {6, 6}, {12, 6} and {12, 12}*;*- the resource-element offset is obtained from the higher-layer parameter *dl-PRS-CombSizeN-AndReOffset*;- the quantity is given by Table 7.4.1.7.3-1.If the downlink PRS resource is configured for RTT based propagation delay compensation as described in clause 9 of [6, TS 38.214], the reference point for is subcarrier 0 in common resource block 0; Otherwise, the reference point for is the location of the point A of the positioning frequency layer, in which the downlink PRS resource is configured where point A is given by the higher-layer parameter *dl-PRS-PointA*.**Table 7.4.1.7.3-1: The frequency offset as a function of .**

|  |  |
| --- | --- |
|  | **Symbol number within the downlink PRS resource**  |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| 2 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 4 | 0 | 2 | 1 | 3 | 0 | 2 | 1 | 3 | 0 | 2 | 1 | 3 |
| 6 | 0 | 3 | 1 | 4 | 2 | 5 | 0 | 3 | 1 | 4 | 2 | 5 |
| 12 | 0 | 6 | 3 | 9 | 1 | 7 | 4 | 10 | 2 | 8 | 5 | 11 |

 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #6**

* **Support 1-symbol PRS.**
	+ **Without impact on legacy comb sizes, i.e. reuse comb size 2, 4, 6, 12**

This proposal is already supported by ZTE, CMCC, CATT, xiaomi, Sanechips.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC |  | We are open to discuss this proposal. One technical question is the following: Such PRS will create time domain aliasing. If expectedRSTD-uncertainty is small enough, then it may not result to degraded performance. We would be more supportive if such a statement is included. For example: * Introduction of unstaggered 1-symbol PRS with legacy comb sizes, assuming that the expectedRSTD windows that LMF provides to the UE is such that peak ambiguity is addressed, otherwise no measurement accuracy requirements are expected to be met.
 |
| FUTUREWEI | Y |  |
| ZTE | Yes | To address UE vendor’s concern, we are OK for Qualcomm’s suggestion in principle. Since there is no staggered pattern for 1-symbol, it seems the word of 'unstaggered ' is redundant. Our suggestion is as follows**Proposal: Introduce 1-symbol PRS with legacy comb sizes*** **UE expects the suitable expectedRSTD windows provided by LMF such that peak ambiguity is addressed. Otherwise no measurement accuracy requirements are expected to be met.**
 |
| Nokia, NSB |  | We are open to discuss this further. The proposal likely also needs new configuration signalling in addition to the RAN1 changes. |
| vivo |  | the motivation is unclear and not sure how much gains such 1 symbol PRS would provide for network operation. |
| Huawei, HiSilicon | Y | In general, we are supportive of the enhancement.We would prefer to clarify the scope beyond RAN1, the TEI should only cover the LPP/NRPPa signaling, including UE capabilities. Any RAN4 RRM requirement, including core/performance, should not be impacted. |
| Moderator |  | According to the above comments, this proposal is supported by ZTE, CMCC, CATT, xiaomi, Sanechips, FUTUREWEI, Huawei, HiSilicon, and hence meets the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor.Proponents are encouraged to address the concern from companies not answered yet. |

* 1. PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI

Following proposal is made in the contribution.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [5] | **Background**In Rel-17 CE SI, most UL channels are identified as the coverage bottleneck channels in many scenarios, e.g., Rual 700MHz FDD NLOS O2I scenario [5]. Up to Rel-17, PUSCH repetition Type A is supported when transmitting PUSCH scheduled by a grant among the following cases. * DCI format 0\_1 or 0\_2 in PDCCH with CRC scrambled with C-RNTI, MCS-C-RNTI, or CS-RNTI with NDI=1;
* RAR UL grant, i.e., Msg3 initial transmission;
* DCI format 0\_0 with CRC scrambled by TC-RNTI, i.e., Msg3 re-transmission.

In Rel-18, PRACH repetition [6] and repetition of PUCCH carrying Msg4 HARQ-ACK [7] will be further supported. PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI is the only UL channel does NOT support repetition transmission. In this contribution, the coverage performance of PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI, e.g., Msg5 PUSCH, is evaluated. And potential issues and corresponding mechanisms to support Msg5 PUSCH repetition are also discussed. **Coverage analysis**As shown in Figure-1, after a UE performing 4-step RACH procedure, the network would schedule Msg5 PUSCH transmission to complete the RRC setup. Typically, the network performs the first RRC reconfiguration according to the UE capability information. Before the UE capability is reported, some functions that need to be determined based on the UE capability information cannot be configured. Therefore, before the first *RRCReconfiguration* message is received, DCI formats other than 0\_0 cannot be used for UL scheduling. So, Msg5 PUSCH, which is scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI, cannot be scheduled with repetition. ***Observation 1****: Msg5 PUSCH, which is scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI, is the only uplink channel does not support repetition transmission in Rel-18.* Figure-1: Higher layer procedure for a UE accessing the networkIt is observed that Msg5 transmission is the coverage bottleneck according to the real filed test. The situation would get worse when repetition transmission of PRACH/Msg3/Msg4 HARQ-ACK is enabled. This is because more UEs would access to the network after the RACH procedure while congested during Msg5 transmission. ***Observation 2****:* *Msg5 PUSCH is the coverage bottleneck according to the real filed test.*Msg5 PUSCH is now the only channel does not support repetition transmission in Rel-18. However, it may have even worse coverage than some other UL channels (e.g., Msg3 PUSCH according to the evaluation below). Therefore, no support of Msg5 PUSCH repetition would jeopardize the commercialization of other Rel-17 and Rel-18 coverage related features, especially for repetition based features including the ones for NTN. ***Observation 3****:* *No support of Msg5 PUSCH repetition would jeopardize the commercialization of other Rel-17 and Rel-18 coverage related features.*To further evaluate the transmission performance of the Msg5 PUSCH, some link-level simulations are performed. Regarding the information carried by the Msg5 PUSCH, the packet size is assumed as 118 Bytes, which contains *RRCSetupComplete* (~102 Bytes), potential PHR and BSR (10 Bytes), and sub-layer (including, PDCP, RLC and MAC) header overhead (6 Bytes). As shown in Figure-2, TDD frame structure ‘DDDDD DDSUU’ with 30kHz SCS is used in the simulation. Then, there will be at most 2 times of transmission during one radio frame. The other detail simulation assumptions can be found in the Appendix 2. Figure-2: TDD frame structure used in the simulationIn the simulation, the Msg5 PUSCH transmission performances under different maximum transmission times are evaluated. For example, ‘Msg5 with max 2 (re-)transmissions’ represents that there are at most 2 transmissions for Msg5 PUSCH, including initial transmission and retransmission. The performance of Msg3 PUSCH transmissions with different repetition factors (i.e., 1, 2, 4 and 8) are taken as baseline. The simulation results are showed in Figure-3 and Table-1. Figure-3: Performance for Msg3 and Msg5 PUSCH transmissionTable-1: Performance for Msg3 and Msg5 at BLER = 0.1.

|  |  |  |
| --- | --- | --- |
| Simulation cases | Target SNR (dB) w/o power normalization | Target SNR (dB) w/ power normalization to one PRB |
| Msg3 without repetition | -7.31 | -4.3 |
| Msg3 with 2 repetitions | -11.24 | -8.23 |
| Msg3 with 4 repetitions | -13.66 | -10.65 |
| Msg3 with 8 repetitions | -15.91 | -12.9 |
| Msg5 with max 2Tx (re)-transmissions | -9.21 | 5.84 |
| Msg5 with max 4Tx (re)-transmissions | -10.25 | 4.8 |
| Msg5 with max 8Tx (re)-transmissions | -11.18 | 3.87 |

According to the above simulation results, significant performance gap can be observed between Msg5 PUSCH and Msg3 PUSCH, even though HARQ retransmissions are enabled for Msg5 PUSCH while not for Msg3 PUSCH. It means that Msg5 PUSCH has more severe coverage issue than Msg3 PUSCH and therefore is the coverage bottleneck. ***Observation 4****: The performance gap between Msg5 PUSCH transmission and Msg3 PUSCH transmission is large, which is summarized in the following table.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Performance gap(dB) between Msg5 and Msg3 at BLER = 0.1*  | *Msg3 without Repetition* | *Msg3 with 2 Repetitions* | *Msg3 with 4 Repetitions* | *Msg3 with 8 Repetitions* |
| *Msg5 with max 2 (re)-transmissions* | *>10* | *>10* | *>15* | *>15* |
| *Msg5 with max 4 (re)-transmissions* | *9.1* | *>10.* | *>15* | *>15* |
| *Msg5 with max 8 (re)-transmissions* | *8.17* | *>10* | *>10* | *>15* |

Similar coverage issue could be observed for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI even after UE capability reporting. Thus, we propose to support PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI. ***Proposal 2-1:*** *Support PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI.* **Proposed enhancement**Both Msg5 PUSCH and Msg3 retransmission are scheduled by DCI format 0\_0, and the only difference is the RNTIs used. That is, TC-RNTI is used to scramble CRC of the DCI format for Msg3 retransmission scheduling, while C-RNTI is used Msg5 PUSCH. Therefore, from our perspective, similar repetition mechanism can be reused to support Msg5 PUSCH repetition, and the standardization effort would be limited. In this context, we can consider the following solution for support of PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI. * For the transmission schemes, reuse the same approach as Msg3 re-transmission which is scheduled by DCI format 0\_0 with CRC scrambled by TC-RNTI, including repetition indication, RV determination, available slot determination and frequency hopping etc.
* During initial access, a UE can request repetition transmission for PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI via Msg3 PUSCH transmission.
	+ Alternatively, using separate PRACH resources for the request can also be considered, while this would result in further PRACH partition and therefore not preferred.
	+ This is similar as the discussion in Rel-18 NTN WI, where the request of PUCCH repetition for Msg4 HARQ-ACK is also proposed to be carried in Msg3 PUSCH.

***Proposal 2-2****: For support of PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI, adopt the following solution.* * *For the transmission schemes, reuse the same approach as Msg3 re-transmission which is scheduled by DCI format 0\_0 with CRC scrambled by TC-RNTI, including repetition indication, RV determination, available slot determination and frequency hopping etc.*
* *During initial access, a UE can request repetition transmission for PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI via Msg3 PUSCH transmission.*
 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #7**

* **Support PUSCH repetition type A for a PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI.**
	+ **For the transmission schemes, reuse the same approach as Msg3 re-transmission which is scheduled by DCI format 0\_0 with CRC scrambled by TC-RNTI, including repetition indication, RV determination, available slot determination and frequency hopping etc.**
	+ **During initial access, a UE can request repetition transmission for PUSCH scheduled by DCI format 0\_0 with CRC scrambled by C-RNTI via Msg3 PUSCH transmission**

This proposal is already supported by ZTE, China Telecom, Sanechips.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | N | We don’t support this proposal for now. But we are open to discuss it. From our observation in field, msg5 reception seems not an issue.  |
| CATT | Y | The motivation may be good, so we are open to discuss further. |
| ZTE | Y | Support. RAN1 somehow missed the evaluation on Msg5 transmission before. Based on our observation in real field, Msg5 is the actual bottleneck channel among channels before UE capability reporting, i.e. PRACH, Msg3 and PUCCH for Msg4 HARQ-ACK, which would all support repetition transmission in Rel-18. As the evaluation results shown in our tdoc, we found re-transmission cannot make up the performance gap between Msg3 and Msg5 due to much larger payload of Msg5. We see it is promising to implement Rel-17/18 CE features in near future, e.g., for NTN scenarios or vertical scenarios. Thus, it is critical to make Msg5 repetition available together with other repetition-based features.  |
| Nokia | N | This proposal may need a substantial amount of time to work out all the details related to a possible solution to the problem. We see the technical merit of this matter ,but we prefer deferring a discussion to a later time, when sufficient time to handle it properly would be available, e.g., next release, if applicable. |
| vivo |  | First of all, pusch-RepetitionMultiSlots is a UE mandatory feature with capability signalling in Rel-15 and DCI 0\_1 is also mandatory in Rel-15, which means that Msg5 repetition is already possible to be scheduled by DCI 0\_1 with repetition.In addition, we have following comments:1. PUSCH scheduled by RAR in CFRA, MsgA (PRACH + PUSCH) in 2-step RACH are not supported with repetition either. 🡪 observation 1 is wrong.
2. Cell coverage is determined by the worst channel. Bottleneck channel is still PUSCH eMBB even after Rel-17/18 coverage enhancement.
3. Retransmission can be used for coverage extension of Msg5 though latency is a bit larger compared to repetition.

According to above, Msg5 repetition seems not necessary. In addition, this enhancement may require early UE feature indication which has large spec. impacts. |
| MediaTek | N | We would like to understand why segmentation is not sufficient to cover message 5 in case there is a coverage limitation issue. It seems strange that after 2 Releases of SI and two follow up Wis that this is a sudden realised as an important bottleneck. |
| Huawei, HiSilicon | N | In our observation, the so called Msg5 reception seems not an issue in field. Additionally, since the first message after initial access is targeted in the proposal, a network may not be aware of the UE capability yet. An early identification for the new feature seems necessary and requires special RAN2 impacts which seems not a task involving only single WG. |
| Moderator |  | According to the above comments, this proposal is supported by ZTE, China Telecom, Sanechips, CATT, and hence meets the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor.Proponents are encouraged to address the concern from companies. |

* 1. Extensions to FR1 TRS configurations

Following proposal is made in the contribution.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [6] |  For Rel-15 3GPP defined a set of possible configurations for CSI-RS for tracking (TRS). At the time the supported configurations were a compromise between the UE’s need for RS for time/frequency synch, and the overhead and energy consumption imposed to the network. The TS 38.214 subclause 5.1.6.1.1 defines the CSI-RS for tracking to have two symbols per slot in a one or two slot configuration, but hard-codes the FR1 to always transmit the TRS in the two-slot configuration, while FR2 is designed to work with a onw-slot TRS configuration.

|  |
| --- |
| - **For frequency range 1, the UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS-ResourceSet* consists of four periodic NZP CSI-RS resources in two consecutive slots with two periodic NZP CSI-RS resources in each slot**. If no two consecutive slots are indicated as downlink slots by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigDedicated*, then the UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS-ResourceSet* consists of two periodic NZP CSI-RS resources in one slot. - For frequency range 2 the UE may be configured with one or more NZP CSI-RS set(s), where a *NZP-CSI-RS-ResourceSet* consists of two periodic CSI-RS resources in one slot or with a *NZP-CSI-RS-ResourceSet* of four periodic NZP CSI-RS resources in two consecutive slots with two periodic NZP CSI-RS resources in each slot. […]- the time-domain locations of the two CSI-RS resources in a slot, or of the four CSI-RS resources in two consecutive slots (which are the same across two consecutive slots), as defined by higher layer parameter *CSI-RS-resourceMapping*, is given by one of- , , or for frequency range 1 and frequency range 2,- , , , , ,  or  for frequency range 2. |

The TS 38.306 appears to imply that there was an intent to support a one-slot TRS configuration for all frequency ranges, and the UE capability text indicates that UEs are required to support 1-slot TRS config, when 38.214 removes the 1-slot possibility from FR1.

|  |
| --- |
| ***csi-RS-ForTracking***Indicates support of CSI-RS for tracking (i.e. TRS). This capability signalling comprises the following parameters:- *maxBurstLength* indicates the TRS burst length. Value 1 indicates 1 slot and value 2 indicates both of 1 slot and 2 slots. In this release UE is mandated to report value 2;- *maxSimultaneousResourceSetsPerCC* indicates the maximum number of TRS resource sets per CC which the UE can track simultaneously;- *maxConfiguredResourceSetsPerCC* indicates the maximum number of TRS resource sets configured to UE per CC. It is mandated to report at least 8 for FR1 and 16 for FR2;- *maxConfiguredResourceSetsAllCC* indicates the maximum number of TRS resource sets configured to UE across CCs. If the UE includes the field in an FR1 band, it shall set the same value in all FR1 bands. If the UE includes the field in an FR2 band, it shall set the same value in all FR2 bands. The UE supports a total number of resources equal to the maximum of the FR1 and FR2 value, but no more than the FR1 value across all FR1 serving cells and no more than the FR2 value across all FR2 serving cells. The UE is mandated to report at least 16 for FR1 and 32 for FR2.The UE is mandated to report *csi-RS-ForTracking*. |

The symbol locations and the requirement for two-slot configuration in FR1 complicates the TRS multiplexing with PDSCHs sent before the UE has a dedicated configuratin (SI, paging, RAR), and the need for two-slot config limits the network energy saving when there is only light traffic in the system.In this TEI18 document we propose additional FR1 TRS configurations to better facilitate multiplexing with common PDSCH transmissions and increase the opportunities for network energy savings.The currently allowed TRS configurations for FR1 are depicted in Figure 1. It is evident that UEs not aware of the TRS cannot use the PRBs with TRS except by brute-force puncturing the TRS REs, and in many cases on FR1 carriers this means that the slots cannot be used at all for paging, system info or random access response. It is also not possible to multiplex TRS in the SSB slots if more than 1 SSB is used by the network.In low-loaded environment this means that instead of being able to concentrate the TRS transmissions with common channels, different set of slots need to be used, increasing the network’s on-time.**Figure 1: Allowed FR1 TRS configurations since Rel-15**Possible enhancements allowing better multiplexing of PDSCH and SSB with TRS: * Support TRS symbols at the end of the slot so that the beginning of the slot can be used for PDSCH. E.g. symbol configurations {9, 13}, {11, 13} and {12, 13}
* Support a single-symbol TRS configuration at the end of the slot, leaving the beginning of the TRS slot for PDSCH and SSB
* Support one-slot TRS configurations as with FR2, preferably together with the option of placing the TRS symbols at the end of the slot, e.g. symbol configurations {9, 13}, {11, 13} and {12, 13}

**Figure 2: Possible new TRS configurations friendlier to PDSCH multiplexing**

|  |  |
| --- | --- |
| **Configuration** | **Benefit over TRS configurations supported in Rel-15** |
| {9,13} | Allows muxing of PDSCH with TRS. Same TRS RE distance as with existing TRS configs. |
| {11,13} | Allows better multiplexing of PDSCH with TRS |
| {12,13} and {13} | Allows multiplexing with >1 SSBs and even better multiplexing with PDSCH |

 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #8**

* **Support following TRS configurations for FR1**
	+ **TRS symbols at the end of the slot so that the beginning of the slot can be used for PDSCH.**
		- **Symbol configurations {9, 13}, {11, 13} and {12, 13}**
	+ **Single-symbol TRS configuration at the end of the slot.**
		- **At least symbol configuration {13}**
	+ **One-slot TRS configurations**
		- **With existing symbol configurations {4,8}, {5,9} and {6,10}**
		- **With new symbol configurations {9, 13}, {11, 13} and {12, 13}**

This proposal is already supported by Nokia, Nokia Shanghai Bell.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | N | Regarding the new entries, we have the following comments. 2x{9,13}: it might be useful. We are open to consider 2x{8,12}, 2x{7,11} as well. Single slot TRS for FR1: We have concern on its performance. FR1 is expected to have richer scattering. With 1 slot TRS there is only 1 equation to solve both the doppler spread and CFO. So, it does not seem to be the right thing.2x{13}: freq error pull in range will be smaller than LTE. 2x{11,13}, 2x{12,13}: The other two patterns do offer smaller pilot spacing. But they will impact freq error resolution, i.e., less accuracy on freq error estimation. |
| FUTUREWEI | N | Most of the proposed patterns may have worse T/F tracking performance.{9, 13} may work. |
| DOCOMO | N | If this proposal had applied to Rel.15, it may be beneficial. However, even if we introduce new TRS configuration in Rel.18, gNB cannot stop transmitting Rel.15 TRS for Rel.15-17 UEs. Hence, the proposed new TRS should be transmitted in addition to Rel.15 TRS, which causes additional resource overhead. In that sense, we thinis this proposal is not useful in real operation. |
| CATT | N | The justification of the proposed enhancement is NOT convincing. |
| ZTE | Y with a comment | We are wondering how to handle co-existence UEs from Rel-15 to Rel-17. |
| Nokia, NSB | Y | We wanted to list all the new TRS configs that we’d see useful from the network operation’s perspective, but we’d be more than happy to narrow down the proposal to what is more generally agreeable.E.g. focusing just to 2x{9,13}, FFS if others are to be added would be fine with us@DOCOMO, CATT, ZTE: We specifically see this beneficial for the (fairly typical) case where we have a limited number of UEs in RRC connected. If the feature gains support in Rel-18 UEs, then in those cases when new UEs are the ones active we can use the new pattern. It is true that if we have “legacy” UEs in RRC connected, then the new pattern does not give us the benefits we are after. |
| vivo | - | Introducing new TRS patterns is big, could not be handled as TEI |
| MediaTek | N | We believe that most of these configurations will impact on tracking performance, and impact Rx performance. Therefore they are not agreeable. We also have the same question as NTT DOCOMO in relation to how the energy saving gains can be envisaged considering the presence of legacy UEs in the system, requiring legacy TRS configurations. Thanks for Nokia’s response to DCM’s question, in this case, we are very doubtful about the useness of this proposal.  |
| Huawei, Hisilicon | Y(Partially) | **For the first sub-bullet:**Don’t support configuration {11, 13} and {12, 13}. 1. Time gap between two CSI-RS resources in a slot is too short. The accuracy of doppler shift measurement cannot be guaranteed. 2. It may introduce RAN4 impact, e.g., requirement on accuracy of doppler shift measurement with time gap smaller than 4 symbols.Configuration {9, 13} is acceptable for us as the time gap between two CSI-RS resources in a slot is still 4 (i.e., same as legacy pattern).**For the second sub-bullet:**Don’t support. With only one symbol in each slot, the two CSI-RS resources used for doppler shift measurement is the two CSI-RS in two slots with a 14-symbols time gap which is too large. The accuracy of doppler shift measurement will be degraded.**For the third sub-bullet:**One-slot TRS configuration can provide better flexibility for gNB implementation. However, it may degrade the accuracy of doppler shift measurement of UE. It should be up to UE capability to support it or not. So, we can support if a corresponding UE capability is introduced. |
| Moderator |  | According to the above comments, this proposal is supported by Nokia, Nokia Shanghai Bell, ZTE, [Huawei, Hisilicon] and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Companies are encouraged to check the reply comments from proponent (Nokia, NSB) and to provide further comments, if any.Also, proponents are encouraged to address the concern from companies not answered yet. |

* 1. Enhanced PDCCH reception for mDCI based mTRP

Following proposal is made in the contribution.

|  |  |
| --- | --- |
| [7] |  Multi-DCI based multi-TRP is specified in Rel-16 with the following relevant features:* Two PDSCHs associated with different *coresetPoolIndex* values can be partially/fully overlapping in time in the same CC
	+ The max number of PDSCH per slot (in TDM manner) is defined per *coresetPoolIndex*, which can be indicated by UE capability.
* For PDCCH monitoring in multi-DCI based multi-TRP, the following are supported:
	+ The maximum number of CORESETs per BWP is increased to 5 CORESETs, with a maximum of 3 CORESETs per *coresetPoolIndex* value.
	+ The maximum number of BDs / CCEs is doubled subject to UE capability, with a limit per *coresetPoolIndex* value that is same as a single-TRP CC.

Furthermore, in Rel-18, it is agreed that two PUSCHs associated with different *coresetPoolIndex* values can be partially/fully overlapping in time in the same CC (for simultaneous transmission in MIMO AI).In order for the network to schedule overlapping PDSCHs / PUSCHs, the two TRPs need to transmit the two corresponding DCIs in any scheduling instance (e.g., in any slot or PDCCH monitoring occasion). As discussed above, the PDCCH monitoring capabilities (number of BDs / CCEs) are also enhanced accordingly. However, the following two issues make it practically infeasible for UE to receive two DCIs at the same time (issue 1 for FR2) or even in the same slot / PDCCH monitoring occasion (issue 2):* **Issue 1**: This issue is related to QCL-TypeD prioritization for overlapping CORESETs, which is specific to FR2. Based on the procedure defined in 38.213 Section 10.1, the UE selects one CORESET (based on a priority rule), and only that CORESET and other CORESETs with the same QCL-TypeD priorities are monitored when multiple CORESETs overlap in time.
	+ During the maintenance phase of Rel-16, extending this rule for multi-DCI based mTRP (to make it per TRP) was discussed. Such discussions were postponed with the understanding that Rel-17 can potentially address the issue. However, Rel-17 only enhanced this QCL-TypeD prioritization rule for the case of PDCCH repetition and for the case of SFN PDCCH, but it was not extended for the case of multi-DCI based multi-TRP.
* **Issue 2**: Even though the number of BDs / CCEs that the UE monitors is doubled (and number of CORESETs is increased to 5) in Rel-16, the capability to process DL DCIs or UL DCIs was not extended accordingly. That is, the UE can only monitor more PDCCH candidates, but cannot actually receive and process more DCIs.
	+ For basic PDCCH capability (FG 3-1), the UE can process one DL DCI and one UL DCI per slot for FDD, and one DL DCI and two UL DCIs per slot for TDD.
	+ For more advanced PDCCH monitoring capabilities such as FG 3-5a or FG 3-5b, the number of DL DCIs or UL DCIs that the UE can process is defined per PDCCH monitoring occasion or per PDCCH span. For these advanced PDCCH monitoring capabilities, it is possible to receive more than one DL DCI and more than one UL DCI per slot, but there is additional complexity associated with PDCCH monitoring as well.
	+ In either case, the max number of DL DCIs or UL DCIs is not extended accordingly for the case of multi-DCI based multi-TRP.
	+ Hence, in order to be able to receive DCIs from different TRPs in a slot in the case of multi-DCI based multi-TRP, the UE has to support one of these advanced UE capabilities, which is not reasonable. This can be a barrier for wide deployment of this feature. Effectively, the larger number of BDs / CCEs specified in Rel-16 for multi-DCI based multi-TRP cannot be utilized in practice to actually transmit more DL / UL DCIs from the two TRPs.

These two issues result in inefficient operation of multi-DCI based multi-TRP feature as they impose unnecessary restrictions on transmissions of DCIs from corresponding TRPs. **Observation 1: Multi-DCI based multi-TRP operation based on existing specifications suffers from the following two issues:*** **Issue 1: Existing QCL-TypeD prioritizations for overlapping CORESETs does not allow the UE to monitor PDCCHs with different beams from corresponding TRPs on the same / overlapping OFDM symbols.**
* **Issue 2: Even though the PDCCH monitoring capabilities (number of BDs / CCEs) are increased for multi-DCI based multi-TRP, the capability related to number of DL/UL DCIs that the UE can actually receive and process is not enhanced correspondingly.**

To address Issue 1, we propose to perform the legacy QCL-TypeD prioritization rules separately for *coresetPoolIndex* value 0 and for *coresetPoolIndex* value 1. An example of the change needed in 38.213 Section 10.1 is shown in the following TP:============TP for 38.213 Section 10.1 ====================================--Unchanged part omitted------------------------If a UE - is configured for single cell operation or for operation with carrier aggregation in a same frequency band, and- monitors PDCCH candidates in overlapping PDCCH monitoring occasions in multiple CORESETs that have been configured with same or different *qcl-Type* set to 'typeD' properties on active DL BWP(s) of one or more cellsthe UE monitors PDCCHs only in a CORESET, and in any other CORESET from the multiple CORESETs that have been configured with *qcl-Type* set to same 'typeD' properties as the CORESET, on the active DL BWP of a cell from the one or more cells - the CORESET corresponds to the CSS set with the lowest index in the cell with the lowest index containing CSS, if any; otherwise, to the USS set with the lowest index in the cell with lowest index- the lowest USS set index is determined over all USS sets with at least one PDCCH candidate in overlapping PDCCH monitoring occasionsIf a UE - is not provided *coresetPoolIndex* for first CORESETs, or is provided *coresetPoolIndex* with value 0 for first CORESETs, and - is provided *coresetPoolIndex* with value 1 for second CORESETs, and- is provided [*twoQCLTypeDforMulti-DCI*]the UE applies procedures described above independently across the first CORESETs and the second CORESETs.--Unchanged part omitted------------------------===============================================================To address issue 2, we propose to introduce a UE capability that can indicate the UE can process more DL / UL DCIs for a CC that is configured with two *coresetPoolIndex* values. Such capability may be separately indicated for DL DCI versus UL DCI. Also, this capability may explicitly indicate a number of DL/UL Dis that the UE can monitor, or can simply indicate that the number of DL/UL DCIs per *coresetPoolIndex* for the CC is the same as the number of DL/UL DCIs for a CC that is not associated with two *coresetPoolIndex* value (which is determined based on legacy UE capabilities). These details can be discussed as part of Rel-18 UE capability sessions. **Proposal 1: For multi-DCI based multi-TRP operation, support the following:*** **QCL-TypeD prioritization rules for overlapping CORESETs is performed per *coresetPoolIndex* value. The TP above can be used for this purpose.**
* **Introduce a UE capability that can indicate the UE can process more DL / UL DCIs for a CC that is configured with two *coresetPoolIndex* values.**
	+ **The details include whether separate FGs are needed for DL DCIs versus UL DCIs can be discussed in Rel-18 UE feature sessions.**
 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #9**

* **For multi-DCI based multi-TRP operation, support the following:**
	+ **QCL-TypeD prioritization rules for overlapping CORESETs is performed per coresetPoolIndex value.**
	+ **Introduce a UE capability that can indicate the UE can process more DL / UL DCIs for a CC that is configured with two coresetPoolIndex values.**
		- **The details include whether separate FGs are needed for DL DCIs versus UL DCIs can be discussed in Rel-18 UE feature sessions.**

This proposal is already supported by Qualcomm.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y | As we described in detail in our Tdoc (as copied above by FL), this TEI is needed to be able to benefit from multi-DCI based mTRP feature in practice. Otherwise, not only PDCCH transmissions will be the bottleneck, but also scheduling PDSCH from both TRPs in multiple consecutive slots becomes infeasible for UEs that do not support advanced (e.g., span-based) PDCCH monitoring even though the UE may already support more BDs/CCEs/CORESETs as specified in Rel-16 for multi-DCI. |
| FUTUREWEI | Y |  |
| CATT | Y | The issue and solution shown by QC are reasonable to us. |
| ZTE | Y |  |
| Nokia, NSB | Y |  |
| vivo | - | To understand better, how does UE know which coresetPoolIndex while decoding PDCCH which are overlapped? |
| MediaTek |  | We question the real value of this proposal compared to the flexibility already in the specifications today. Also such a proposal may also impact on existing Rel-18 mTRP work. The original MIMO WI scope was already reduced compared to the original set of proposals, so we question how we can justify adding this proposal to the R18 scope. |
| Moderator |  | According to the above comments, this proposal is supported by Qualcomm, FUTUREWEI, CATT, ZTE, Nokia, NSB, and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies. |

* 1. Enhancement for scheduling request

Following proposal is made in the contribution.

|  |  |
| --- | --- |
| [7] |  In Rel-17, when PDCCH skipping is configured for a UE, it is allowed that an SR transmission from the UE during a PDCCH skip duration can override the previous PDCCH skipping indication and the UE resumes PDCCH monitoring. The underlying principle of this behavior is that, when an SR is pending at the UE during a PDCCH skip duration, the network can realize it only after receiving an SR transmission from the UE. By terminating PDCCH skipping after the SR transmission, the UE and network do not need to wait until the end of the indicated PDCCH skip duration and, thus, a latency benefit is achieved,For the SR enhancement associated with the latency reduction, there are some remaining issues:* **Issue 1:** During an indicated PDCCH skip duration, the UE can transmit a regular BSR on PUSCH without sending an SR. For example, a BSR MAC CE may be piggybacked on a DG PUSCH, which has been scheduled by a PDCCH received before the PDCCH skip duration starts and comes before the next nearest SR occasion. In another example, a BSR MAC CE may be piggybacked on a CG PUSCH transmitted during the PDCCH skip duration. In both cases, the pending SR is cancelled after transmitting the BSR. However, unlike the case of the SR transmission, PDCCH skipping is not terminated in this case. Thus, the UE and network should wait until the end of the PDCCH skip duration to serve the UL traffic, which increases the latency.
* **Issue 2**: In addition to PDCCH skipping, search space set group (SSSG) switching, which is another UE power saving feature for licensed band, has been introduced in Rel-17. For example, when a UE is configured with two SSSGs, the first SSSG may be configured with frequent PDCCH monitoring, while the second SSSG may be configured with sparse PDCCH monitoring. In a heavy traffic situation, the UE may be indicated to monitor PDCCH according to the first SSSG. Otherwise, for UE power saving, the UE may be indicated to monitor PDCCH according to the second SSSG. If an SR is pending while the UE is monitoring PDCCH according to the first (i.e., dense) SSSG, the UE would receive a PDCCH scheduling an UL transmission quite soon after the SR transmission. However, if the UE is monitoring PDCCH according to the second (i.e., sparse) SSSG, the UE should wait for the next PDCCH monitoring occasion after the SR transmission, which could increase the latency.
* **Issue 3**: In order to harvest the latency benefit of SR overriding PDCCH skipping and/or SSSG switching, it may be desirable for the gNB to configure SR transmission occasions frequently over time. For FR2, since gNB may not be able to receive uplink transmissions from different UEs with different beam directions on the same OFDM symbol, the gNB may align the SR resources such that UEs with the same beam are scheduled on the same set of OFDM symbols. However, in NR, the beam direction of a SR transmission (or PUCCH in general) may be changed via MAC-CE (e.g., via the PUCCH spatial relation Activation/Deactivation MAC CE). If on a set of OFDM symbols, the beam direction of one SR resource is changed, then the beams are not aligned anymore. In the current system, the only mechanism to make re-align the SR resources is to reconfigure SR resources for these users via RRC, which operates at a much lower pace. The problem is illustrated in Figure 5‑1: after the beam change on the SR PUCCH resource 3, the beam alignment between PUCCH resource 1, 2, 3 (from different UEs) are not maintained anymore. As a consequence, the gNB may not be able to receive all SRs at the same time.

**Figure 5‑1 Illustration of Issue 3**To address Issue 1 and Issue 2, the feature of SR overriding PDCCH skipping should be extended. That is, in order not to delay the UL transmission, it should be allowed that an SR or a Regular BSR transmission overrides PDCCH skipping, as well as SSSG switching.**Proposal 5: If a UE is indicated a skipping of PDCCH monitoring, the UE terminates the skipping of PDCCH monitoring from the first slot after the last OFDM symbol of a PUSCH carrying a MAC CE for a Regular BSR.****Proposal 6:** **If a UE is indicated to monitor PDCCH according to search space sets with a group index other than a designated index, the UE stops PDCCH monitoring according to search space sets with the group index and start PDCCH monitoring according to search space sets with the designated group index from the first slot that is at least symbols after the last symbol of a PUCCH carrying an SR or a PUSCH carrying a Regular BSR.**To address Issue 3, we propose to allow the MAC-CE that signals the beam change to also indicate the change/update of PUCCH resource(s) associated with an SR transmission. **Proposal 7: For each spatial relation information or TCI state associated with a PUCCH resource for SR, the gNB configures a UE with a corresponding time domain offset (in #symbols or #slots). If a UE is indicated by the Rel-15 PUCCH spatial relation Activation/Deactivation MAC-CE, or Rel-16 Enhanced PUCCH Spatial Relation Activation/Deactivation MAC CE, or the Rel-17 Unified TCI States Activation/Deactivation MAC CE to update the spatial relation/TCI state associated with a PUCCH resource used for SR transmission, the UE performs the spatial relation/TCI state update and applies the time domain offset to the PUCCH resource.** * **The gNB may additionally configure a frequency domain offset or a code domain offset (e.g., OCC offset, cyclic shift offset) for each spatial relation information or TCI state. In this case, the UE shall also apply the frequency domain offset or code domain offset to the PUCCH resource.**
 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #10**

* **If a UE is indicated a skipping of PDCCH monitoring, the UE terminates the skipping of PDCCH monitoring from the first slot after the last OFDM symbol of a PUSCH carrying a MAC CE for a Regular BSR.**
* **If a UE is indicated to monitor PDCCH according to search space sets with a group index other than a designated index, the UE stops PDCCH monitoring according to search space sets with the group index and start PDCCH monitoring according to search space sets with the designated group index from the first slot that is at least symbols after the last symbol of a PUCCH carrying an SR or a PUSCH carrying a Regular BSR.**
* **For each spatial relation information or TCI state associated with a PUCCH resource for SR, the gNB configures a UE with a corresponding time domain offset (in #symbols or #slots). If a UE is indicated by the Rel-15 PUCCH spatial relation Activation/Deactivation MAC-CE, or Rel-16 Enhanced PUCCH Spatial Relation Activation/Deactivation MAC CE, or the Rel-17 Unified TCI States Activation/Deactivation MAC CE to update the spatial relation/TCI state associated with a PUCCH resource used for SR transmission, the UE performs the spatial relation/TCI state update and applies the time domain offset to the PUCCH resource.**
	+ **The gNB may additionally configure a frequency domain offset or a code domain offset (e.g., OCC offset, cyclic shift offset) for each spatial relation information or TCI state. In this case, the UE shall also apply the frequency domain offset or code domain offset to the PUCCH resource.**

This proposal is already supported by Qualcomm.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y |  |
| CATT | N | These are implementation issues, which gNB should not indicate the PDCCH skipping before completion of the UL data transmission |
| ZTE | Not supportive for the first two bullets | For the third bullet, we are supportive. The benefit of re-aligning the spatial relation information associated with SR from multiple UEs can be observed.For the second bullet, the capacity benefits from switching to e.g., a denser SSSG (with a designated group index) after transmission of PUCCH carrying SR/regular BSR, is not clear. Also, it seems there is no consensus on which SSSG is configured with dense PDCCH MO.For the first bullet, similar with the second bullet, the benefits are not clear since PDCCH skipping will be terminated by SR. |
| vivo |  | This is actually three independent TEIs, although they all somehow related to SR. We could be open to the 1st and 2nd bullet. For 3rd bullet, we undersdand the spec impacts are significant, while it is not clear to us if sufficient gain is justified.  |
| MediaTek |  | We have concerns on this proposal. This TEI requires additional coordination between L2 functions (BSR, MAC-CE) and L1 functions (PDCCH skipping, SSSG switching, beam management). We want to first understand how much gain can be obtained by this TEI. If RAN1 are going to treat this TEI, at least the application delay needs to be discussed/revisited due to the additional L1/L2 coordination. |
| Huawei, HiSilicon | N | For the first bullet of the proposal, it is not necessary to introduce this optimition. It was already supported in Rel-17 UE power saving to configure multiple PDCCH skipping duration lengths, which can be dynamically indicated by gNB for PDCCH skipping. If the latency of uplink scheduling matters, gNB shall configure at least one proper PDCCH skipping duration length. Meanwhile, it was already supported by Rel-17 that the PDCCH skipping shall be cancelled when a positive SR is transmitted and is pending. This could already cover the most cases, and we didn’t see the need to further optimize other corner cases where SR cannot be transmitted but BSR can be transmitted.For the second bullet, we have similar concerns. It was already supported in Rel-17 that three SSSGs can be configured. At least one of them can be configured with a proper PDCCH monitoring periodicity which is smaller than the required latency of uplink service, if gNB thinks the latency would be important for the uplink scheduling of this UE.For the third bullet, we are open to discuss the issue. But we don’t think it is proper to discuss it as a TEI issue as it involves big spec impact of RAN 1 (UE behavior description), RAN 2 (time/frequency/code domain offset configuration, offset indication signling, e.g., MAC-CE, DCI), RAN 4 (e.g., new requirement). Suggest to discuss in Rel-19. |
| Moderator |  | According to the above comments, this proposal is supported by Qualcomm, ZTE (third bullet), and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies. |

* 1. UE reporting of power offset for SRS antenna switching

Following proposal is made in the contribution.

|  |  |  |
| --- | --- | --- |
| [7] |  Release 17 introduced SRS antenna switching for 6Rx and 8Rx devices, namely {1T8R, 2T8R, 4T8R, 1T6R and 2T6R} to enable DL CSI acquisition across all Rx antennas. However, antenna switching for 6/8Rx devices comes at the cost of extra RF switching circuitry that introduces insertion loss. For some UE implementation, the insertion loss may be large which causes big mismatch between the actual DL channel and the one estimated by the gNB from UL sounding. This results into different Tx power between antenna ports or equivalent power offset between SRS antenna ports. gNB is unaware of the power offset between the SRS ports which will impact channel reciprocity reducing the quality of DL-CSI and DL beamforming by the gNB. RAN4 specification allows for some relaxation of SRS transmit power for any ports other than first port and is given by a parameter, ∆TRxSRS, as shown in the text below from 38.101-1 version 17.8.0.

|  |
| --- |
| 6.2.4 Configured transmitted powerThe UE is allowed to set its configured maximum output power PCMAX,f,c for carrier f of serving cell c in each slot. The configured maximum output power PCMAX,f,c is set within the following bounds:PCMAX\_L,f,c ≤ PCMAX,f,c ≤ PCMAX\_H,f,c with PCMAX\_L,f,c = MIN {PEMAX,c– ∆TC,c, (PPowerClass – ΔPPowerClass) – MAX(MAX(MPRc+∆MPRc, A-MPRc)+ ΔTIB,c + ∆TC,c +∆TRxSRS, P-MPRc) }PCMAX\_H,f,c = MIN {PEMAX,c, PPowerClass – ΔPPowerClass }…∆TRxSRS is applied during SRS transmission occasions with usage in SRS-ResourceSet set as ‘antennaSwitching’ when1. UE transmits SRS on the second SRS resource in every configured SRS resource set when the SRS-TxSwitch capability is indicated as 't1r2' or 't1r1-t1r2'
2. UE transmits SRS on the second, third and fourth SRS resources of the total 4 SRS resources from all configured SRS resource set(s) consisting of one SRS port when the SRS-TxSwitch capability is indicated as 't1r4' or, 't1r4-t2r4' or 't1r1-t1r2-t1r4' or, 't1r1-t1r2-t2r2-t1r4-t2r4'
3. UE transmits SRS from the second SRS port pair on the second SRS resource in every configured SRS resource set consisting of two SRS ports when the SRS-TxSwitch capability is indicated as ' t2r4' or ' t1r4- t2r4', or 't1r1-t1r2-t2r2-t2r4' or 't1r1-t1r2-t2r2-t1r4-t2r4', or
4. UE transmits SRS to a DL-only carrier

The value of ∆TRxSRS is 4.5dB for bands whose FUL\_high is higher than the FUL\_low of n79 and 3 dB for bands whose FUL\_high is lower than the FUL\_low of n79 when the device is capable of power class 3 or power class 5 or power class 1.5 in the band, or when the device is capable of power class 2 in the band and ΔPPowerClass = 3 dB, or when UE indicating txDiversity-r16.The value of ∆TRxSRS is 7.5dB for bands whose FUL\_high is higher than the FUL\_low of n79 and 6 dB for bands whose FUL\_high is lower than the FUL\_low of n79 during SRS transmission occasions with configured SRS resources consisting of one SRS port when the device is capable of power class 2 in the band and ΔPPowerClass = 0 dB and not indicating txDiversity-r16. For other SRS transmissions ∆TRxSRS is zero; |

Considering 1T4R UE architecture as a baseline for extending to 8Rx antennas, an extra RF switching circuitry is needed to route the Tx path to the extra Rx antennas. An example of such architecture is shown in the Figure 6‑1 below. It is important to note that there will be X1 to X2 dB extra insertion loss (i.e. power offset) for antenna ports 4-7 as compared to the first 4 antenna ports. **Figure 6‑1 Example of 8Rx UE RF architecture with single Tx chain***To overcome this mismatch, the UE can report to the network the power offset between the antenna ports which can help the network to compensate the UL/DL channel mismatch*. To evaluate the effectiveness of such reporting, a link-level evaluation was done for an 8Rx UE with 1T8R SRS antenna switching using CDL-C 300ns, 3km/hr and 20MHz DL/UL BW. The results are shown in Figure 6‑2 in which we compare three different schemes: legacy 4Rx with 1T4R, 8Rx UE with 1T4R and 8Rx with 1T8R for both scenarios of power offset compensation enabled and disabled at the gNB. The power offset across the extra four antenna ports is assumed to be [ 1 1 2 2] dB. For the case of 1T8R with gNB reporting of power offset, the throughput performance is close to the ideal scenario of no power offset across the antenna ports.**Figure 6‑2: Power offset reporting and compensation****Observation 2: UE reporting of power offset can help the gNB to compensate of the power offset between the UL and DL channels and improve the DL throughput.****Proposal 8: For SRS antenna switching, Support UE capability of reporting of relative power offset of SRS antenna ports with respect to the first SRS port.**  |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #11**

* **For SRS antenna switching, Support UE capability of reporting of relative power offset of SRS antenna ports with respect to the first SRS port**

This proposal is already supported by Qualcomm.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y |  |
| CATT | N | This proposal is not necessary. gNB is able to estimate the power imbalance of UE antennas through UL measurement |
| ZTE | N | Besides for Tx power, our concerns are much relevant to phase consistency across different SRS ports. For instance, if there is additional phase offset for each Tx-Rx chain and also it may vary along with the change of Tx power, the DL precoding performance based on UL-DL reciprocity should be justified in such case. |
| vivo | - | Power offset for SRS antenna switching should be discussed in RAN4, RAN4 has expertise in insertion loss. |
| MediaTek | N | We wonder how much practical gain this proposal can bring taking power tolerance into account. We should also consult RAN4 if this TEI is to be agreed. |
| Huawei, HiSilicon | Y | The performance degradation caused by the power imbalance among SRS antenna ports has been shown in our tdoc during RAN4 discussion. In order to avoid this/similar kind of performance degradation, following factors need to be considered:1) Other potential reasons breaking the perfect channel reciprocity, e.g., power imbalance among receiving antenna ports;2) Whether the guidance about the candidate value of power imbalance from RAN4 is needed. |
| Moderator |  | According to the above comments, this proposal is supported by Qualcomm, Huawei, HiSilicon, and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies. |
| OPPO |  | To show the benefit of power offset reporting, performance of 1T8R with power offset but without reporting may be needed.  |

* 1. RAT-independent Positioning Enhancements

Following proposal is made in the contribution.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [7] |  LPP protocol (TS 37.355) enables Control plane based positioning across multiple technologies, as shown in the following table:

|  |  |
| --- | --- |
|  | LPP Supported Positioning Methods |
| Method | UE-based | UE-assisted |
| LTE/NB-IoT | OTDOA | No | Yes |
| E-CID | No | Yes |
| RAT-Independent | A-GNSS | Yes | Yes |
| Sensor | Yes | Yes |
| WLAN | Yes | Yes |
| Bluetooth | No | Yes |
| TBS | Yes | Yes |
| NR | DL-TDOA | Yes | Yes |
| DL-AoD | Yes | Yes |
| Multi-RTT | No | Yes |
| NR E-CID  | No | Yes |
| UL-TDOA(1) | No(2) | No(2) |
| UL-AoA(1) | No(2) | No(2) |
|  | NOTE 1: Only LPP Capability TransferNOTE 2: NW-based method |

With regards to RAT-independent technologies, beyond GNSS, specification enhancements for the remaining technologies has been rather limited. Such signaling enhancements (in RAN2) can be done without the need of significant time and effort. Such enhancements will help expand the role of the multi-technology 3GPP-based positioning protocol and increase its value in the overall positioning ecosystem.

|  |  |
| --- | --- |
| **Potential RAT-independent Enhancement** | **Motivation** |
| **UWB Ranging** | A high-bandwidth (>=500 MHz) technology that can support secure and accurate ranging capability which has received a lot of product and ecosystem attention lately. UWB Technology is not included in LPP |
| **BT 5.1** | Bluetooth positioning in LPP is based on Bluetooth 4.2. Enhancements based on Bluetooth 5.1 (e.g. AoA/AoD positioning) could be introduced, along with UE-based Positioning |
| **WiFi 802.11az FTM** | WiFi RTT has been added in an earlier release (Rel-13). Enhancements needed to pick up the required changes for devices supporting the latest IEEE 802.11az FTM. |

**Proposal 9: Send an LS to RAN2 to add the necessary signalling enhancements for the following RAT-independent Positioning Enhancements:** * **Introduction of UWB Ranging/Positioning,**
* **update of BT positioning with Angular measurements and UE-based BT Positioning**
* **Updates on the WLAN Positioning for devices supporting IEEE 802.11az FTM.**
 |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #12**

* **Send an LS to RAN2 to add the necessary signalling enhancements for the following RAT-independent Positioning Enhancements:**
	+ **Introduction of UWB Ranging/Positioning,**
	+ **update of BT positioning with Angular measurements and UE-based BT Positioning**
	+ **Updates on the WLAN Positioning for devices supporting IEEE 802.11az FTM.**

This proposal is already supported by Qualcomm.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Y |  |
| FUTUREWEI | N | Not for RAN1 |
| DOCOMO |  | This proposal can be discussed directly in RAN2. |
| CATT | N | The proposed potential RAT-independent enhancements (UWB, Bluetoorth, WiFi RTT) mainly impact RAN2’s work, but not RAN1. The proposal should be discussed in RAN2. |
| ZTE | Yes with comments | ZTE is also quite interested in this feature as UWB positioning is helpful to provide higher location accuracy because of very large bandwidth. Becides the enhancement of LPP as Qualcomm proposed, we also prefer to enhance NRPPa to support TRP report UWB positioning results to LMF. Specifically, the function of UWB positioning can be installed at gNB side, then gNB can get UWB results and further report the results to LMF. LMF can combine the existing RAT-dependent measurement results and UWB positioning results to calculate the target UE’s location. In short, we think it is better to introduce UWB/BT ranging/positioning in both NR PPa and LPP as the following figureHere is our suggested update:* **Send an LS to RAN2 and RAN3 to add the necessary signalling enhancements for the following RAT-independent Positioning Enhancements:**

**Introduction of UWB and BT Ranging/Positioning in LPP and NRPPa**  |
| vivo | - | we are not sure it should be discussed in RAN1 if only signaling enhance, and prefer to consider it in future release other than TEI |
| MediaTek | N | It seems strange that this TEI proposal comes to RAN1 when there is actually no RAN1 spec impact claimed by the proponents, and requires mainly RAN2 work. Furthermore, the Positioning WI scope in R18 is already too heavy in our view, so do not believe it is a good practice to overload them even more. |
| Huawei, HiSilicon | N | This should not be discussed by RAN1. We do not see it as RAN1 responsibility to confirm the necessity or any RAN1 spec impact. |
| Moderator |  | According to the above comments, this proposal is supported by Qualcomm, ZTE, and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies. |

* 1. BWP without CD-SSB for normal UE

Following proposal is made in the contribution.

|  |  |  |  |
| --- | --- | --- | --- |
| [8] | **Background and status**It has been discussed for several meetings in both WGs and RAN plenaries about how to support FG6-1a, i.e., BWP operation without CD-SSB, by normal (i.e., non-RedCap) UEs. At RAN#98e, in the final round of discussion, the moderator asked the following questions:

|  |
| --- |
| 1. Can RAN agree that we specify:
	* both "B-1-1 without early implementability" and C, both as optional features, in Rel 18?
		+ B-1-1 and C are as described in the RAN 4 LS in RP-222725=R4-2220437
2. If yes, how to handle the subsequent (small) work?
 |

In Question 1), the proposal with Option B-1-1 and Option C received significant support at the meeting. Therefore, we think TEI proposals are perfect answers to Question 2) for handling subsequent (small) work. * Option B-1-1: Using larger BW covering SSB outside active BWP without interruptions
* Option C: NCD-SSB approach which would work with existing UE hardware architectures (FG6-1) and be compatible with existing RAN4 specifications for BM/RLM/BFD

For Option B-1-1, the main design change is about UE capability design which is under RAN2’s scope. Hence, in the following section, we focus on Option C (NCD-SSB approach) which we think should be led by RAN1.**NCD-SSB (Option C) rationale**The concept of Non-cell-defining SSB blocks (NCD-SSB) was introduced in NR Rel-15, but was not specified to be configured to the UE until Rel-17 RedCap was introduced. There is a high commercial interest and rapid deployment plan expected for RedCap, and we expect NCD-SSB to be supported in the field by both RedCap UEs and network infrastructure. Though NCD-SSB is configured to RedCap UEs via dedicated per-UE BWP configuration, NCD-SSB is actually deployed and operated in a per-cell manner. Therefore, once a network has activated NCD-SSB for RedCap UEs in a cell, it is very reasonable to enable normal UEs to also use it. With a normal UE’s support for FG6-1a, the following combined benefits are identified:1. The network has scheduling flexibility to configure such a UE to operate with a *narrowband* BWP in any part of the channel (that does not contain CD-SSB) and avoids congestion to the RBs around the CD-SSB.
2. Simultaneously, UE power saving gain can be achieved from the network operating a *narrowband* BWP for this UE.

This combination of benefits allows further gain compared to the operation of a UE only supporting FG6-1, as it no longer requires the network to configure the UE with a wideband BWP if the network wants to allocate the UE to only use Resource Blocks far from the RBs of the CD-SSB. In addition, as agreed for RedCap UEs (see below), we propose that a normal UE may be configured with multiple NCD-SSBs provided that for each BWP the UE is configured with only one SSB (CD-SSB or NCD-SSB).

|  |
| --- |
| RAN2 #117e1. A RedCap UE may be configured with multiple NCD-SSBs provided that each BWP is configured with at most one SSB |

We propose the following: **Proposal 1: Specify both of the following as Rel-18 TEI as optional features:** * **Extension of NCD-SSB applicability to “normal” (non-RedCap) UEs, a.k.a Option C. The work on the details should be led by RAN1.**
* **Complementary to the above, support Option B-1-1 without early implementability. The work on the details should be led by RAN2.**

**Proposal 2: For Option C, a normal UE may be configured with multiple NCD-SSBs provided that for each BWP the UE is configured with only one SSB (CD-SSB or NCD-SSB).** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #13**

* **Specify both of the following as Rel-18 TEI as optional features:**
	+ **Extension of NCD-SSB applicability to “normal” (non-RedCap) UEs, a.k.a Option C. The work on the details should be led by RAN1.**
	+ **Complementary to the above, support Option B-1-1 without early implementability. The work on the details should be led by RAN2.**
* **For Option C, a normal UE may be configured with multiple NCD-SSBs provided that for each BWP the UE is configured with only one SSB (CD-SSB or NCD-SSB)**

This proposal is already supported by MediaTek.

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| Qualcomm | N | We are supportive to specify both Option B-1-1 and Option C together. However, we are not OK to specify only Option C. The proposal implies that only Option C can be specified, as a sub-bullet describes Option B-1-1 should be led by RAN2, which means Option B-1-1 cannot be part of RAN1 TEI. We are OK if it is possible to decide supporting both in RAN1. Otherwise, we think making the decision at RAN plenary would be a straightforward approach. |
| FUTUREWEI | Y | Can accept Opt C |
| DOCOMO |  | In our understanding, whether Option B-1-1 and/or Option C is/are supported or not will be discussed in RAN#99 according to the following conclusion made at RAN#98-e.---conclusion: RAN4 shall not discuss this further and RAN will come back at RAN #99---Therefore, we think WGs should not discuss this topic until RAN#99. In addition, it seems the proposal includes one step forward only for Option C while leaving Option B-1-1 to RAN2. It is not preferable to proceed one of the options without having RAN guidance as which option(s) to be supported has been controversial.If RAN1 can agree on supporting both Option B-1-1 and Option C, it can be informed to RAN to facilitate upcoming discussion at RAN#99. But anything more than that should be discussed after RAN confirmation/guidance. |
| ZTE | Y | Overall, we are supportive to agree this TEI proposal. This issue has been discussed for several meetings, it would be better if we can address it as early as possible. Based on our understanding, Option C will have limited RAN1 impact and Option B-1-1 is mainly to introduce a UE capability.  |
| Nokia, NSB |  | While we indicated being able to accept B-1-1 & C combination as an acceptable compromise in RAN#98, we share Qualcomm’s concern on how the proposal is formulated, and agree with DOCOMO that the topic is something for RAN#99 to continue with, rather than debate the topic in this WG round. |
| vivo |  | It would be good if RAN1 can reach some consensus on this topic, eventhough it is supposed to be handled in the coming RAN plenary. Our first preference is option C, but can accept if both Option C and Option B-1-1 can be specified in Rel-18.  |
| MediaTek | Y | We support this TEI proposal. In our opinion, both Option B-1-1 and Option C could be completed in R18 TEI since they don’t fit in to any ongoing WIs. Regarding QC's comment, we are happy to agree both together in RAN1. |
| Moderator |  | According to the above comments, this proposal is supported by MediaTek, FUTUREWEI, ZTE, and hence does not meet the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies. |

* 1. Enhancement for HARQ multiplexing on PUSCH

Following proposal is made in the contribution.

|  |  |
| --- | --- |
| [9] |  In Rel-15 and Rel-16, to maintain the single carrier metric of uplink transmission, UCI (except SR) from PUCCH is multiplexed on a PUSCH within the same PUCCH group, when they are overlapped in time and have same priority level. To guarantee UE and gNB have the same understanding of HARQ bits number on the PUSCH, total DAI mechanism is applied and a restriction on PDSCH scheduling is introduced, which is described in the TS 38.213 Clause 9 and the restriction is copied as below:*“A UE does not expect to detect a DCI format scheduling a PDSCH reception or having associated HARQ-ACK information report without scheduling a PDSCH reception, and indicating a resource for a PUCCH transmission with corresponding HARQ-ACK information in a slot if the UE previously detects a DCI format scheduling a PUSCH transmission in the slot and if the UE multiplexes HARQ-ACK information in the PUSCH transmission.”*In Rel-17 TEI stage, whether/how to relax the restriction is discussed but did not reach agreement or conclusion in the end, however, the majority companies consider such restriction is not very necessary especially for the case of PUSCH repetition and dynamic scheduling PDSCH. In this contribution, the impact of this scheduling restriction is further analyzed based on the PUSCH repetition case and solution to calculate the number of HARQ information bits on the PUSCH are also discussed.**Scheduling restriction on PDSCH**In contribution [R1-2110856], the scheduling restriction on PDSCH is explained and can be interpreted as two ways:* Interpretation 1: After UL DCI, gNB cannot schedule a PUCCH transmission to carry HARQ information in the slot of PUSCH transmission scheduled by the UL DCI, unless the PUSCH and PUCCH transmissions are not overlapped in time.
* Interpretation 2: After UL DCI, gNB may not schedule PDSCH until all the PUSCH transmissions scheduled by the UL DCI are finished.

Following Interpretation 1, to avoid overlapping between PUCCH and PUSCH, when gNB schedules a DL data transmission after the UL grant, gNB has to indicate a PUCCH reporting corresponding HARQ information transmitted after PUSCH transmission, which results in quite large HARQ latency. Considering the case of PUSCH with repetition in TDD system, the latency could become huge and beyond the largest k1 value (i.e. 15) configured for eMBB service. Take Figure 1 as an example, a DL domain frame is configured as DDDSU. In slot 0 of frame N, UL DCI triggers PUSCH transmitted 4 times repeatedly and each repetition occupies 14 symbols. Although PDSCH is scheduled in slot 1 of frame N, the corresponding HARQ only can be reported until slot 4 of frame N+2, 22 slots between the PDSCH reception and PUCCH transmission. It should be noted, number of repetitions can be configured as 8 and for the coverage extension scenario, the number could be configured as large as 32. ***Observation 1: If PUSCH repetition is configured, the timing restriction on scheduling PDSCH after UL grant introduces large delay for HARQ feedback.***C:\Users\y00415751\AppData\Local\Microsoft\Windows\INetCache\Content.MSO\7E9E5B9.tmp**Figure 1. PDSCH scheduling restriction results in large HARQ feedback delay**As interpreted in the second way, to have a short HARQ latency and smaller value of k1, gNB may postpone PDSCH scheduling after PUSCH repetitions finishing. This will cause no PDSCH can be scheduled during the period of PUSCH repetition which will decrease the spectrum efficiency dramatically. Use the same UL\_DL configuration and repetition times as above example, once gNB triggers a PUSCH transmission with repetition in slot 0, Frame N, it may wait until slot 0, Frame N+2 to schedule a new PDSCH expecting a quick HARQ feedback. Details are illustrated in Figure 2. C:\Users\y00415751\AppData\Local\Microsoft\Windows\INetCache\Content.MSO\896AA6CE.tmp**Figure 2. PDSCH scheduling restriction results in PDSCH blockage*****Observation 2: If PUSCH repetition is configured, the timing restriction on scheduling PDSCH after UL grant causes PDSCH blockage for small k1 values.***During the discussion in Rel-17, several possible solutions are proposed by companies, including configuring TDMed PUCCH resource with PUSCH in a slot, enabling parallel PUCCH and PUSCH transmissions and always enabling PUSCH repetition type B. However, these solutions cannot always fix the issue completely, on the contrary, may introduce more restrictions on gNB scheduling. Specifically, when UE is required to repeatedly transmit a TB, it means UE may locate at edge of a cell and UL coverage is possibly constraint. Hence, gNB intends to allocate more resources, typically 14 symbols, for UE to have better UL transmission performance. Less number of PUSCH transmission might lead to more PUSCH repetitions. On the other hand, gNB cannot predict whether there will be any new PDSCH scheduling after a UL grant. If gNB always spare some symbols in UL slots for potential PUCCH transmission, a large quantity UL resource could be wasted.Transmit PUCCH and PUSCH simultaneously within a PUCCH group is supported in Rel-17, however, such kind of transmission are only applicable PUCCH and PUSCH are in different bands and with distinguished priority index. Therefore, it cannot be feasible for typical eMBB case in same band.PUSCH repetition type B is applicable for a small packet and repetitions can be finished as soon as possible, which is enhanced for URLLC transmission purpose. Despite type A PUSCH repetition are supported widely and latency is also a critical metric for eMBB service, so using Type B repetition might not be always suitable.Based on the analysis in section 2.1 and considering the possible solution discussed above, relaxing the scheduling restriction on PDSCH and associated HARQ seems a more feasible way which brings more flexibility for gNB scheduling. ***Proposal 1: The restriction on scheduling PDSCH after UL grant should be removed for the case of PUSCH with repetitions.***Considering from the gNB configuration perspective, an RRC parameter to configure the function of scheduling PDSCH after a UL DCI format and multiplexing associated HARQ on the PUSCH scheduled by the DCI format, can be introduced in Rel-18. When gNB configures the function, it will schedule such HARQ-ACK information multiplexed on the PUSCH scheduled previously. Otherwise, the scheduling restriction is maintained and there is no change to current specifications. ***Proposal 2: An RRC parameter to configure the function of scheduling PDSCH after a UL DCI format and multiplexing associated HARQ on the PUSCH scheduled by the DCI format can be introduced in Rel-18.*** **DAI enhancements**The optimization of restriction in section 2 relaxes the scheduling of PDSCH later than UL DCI and makes it possible to piggyback the associated HARQ information on the scheduled PUSCH. However, in this case total DAI in a UL grant cannot reflect the number of scheduled PDSCH(s) after the UL grant. Therefore, some enhancements are needed here. Serval solutions are discussed in previous contribution [2]. As shown in Figure 3, if the scheduling restriction is relaxed, one simple way to indicate the number of HARQ bits on PUSCH is reusing the DAI mechanism of the HARQ feedback piggybacked on CG PUSCH or a PUSCH scheduled by DCI format 0\_0, which is using the DAI in the last DL DCI for calculating HARQ bits on CG PUSCH. Relative description in TS38.213 to multiplex HARQ on CG PUSCH can be found in the Appendix.**Figure 3. Update total DAI in UL DCI by the DAI in DL DCI**Further enhancements on total DAI mechanism taking the DL scheduling after the UL grant into account should be investigated. It should allow total DAI covers both the number of PDCCHs sent before the UL DCI and the ones will be delivered after the UL grant. Although in the PHY layer, it may be difficult for gNB to anticipate how many PDSCHs will be scheduled in the future, gNB could simply 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 4. The challenge of this solution is the uncertainty for the future scheduling from gNB side. If the upper bound is set too large, additional resources are wasted. If the bound is set too small, it will also limit the potential PDSCH receptions so that to degrade the downlink data rate.**Figure 4. Total DAI in UL DCI cover all past and future DL grants**Updating total DAI by a new signaling could be discussed. For example, a new DCI is sent to UE to update the total DAI value just before the PUSCH transmission subject to the timeline conditions, similar operation as DCI format 2\_4 used to cancel the PUSCH transmission scheduled previously. As shown in Figure 5, UL DCI\_2 is transmitted to UE to update the total DAI value which has been 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. **Figure 5. New UL DCI delivered to update DAI value**As summarized in [R1-2112148], morecompanies prefer to keep total DAI usage and avoid potential misalignment due to last DCI missing. Thus, the second option can be a way for moving forward. Additionally, in Rel-17, one company also mentioned the scheduling relax is not applied to the first PUSCH repetition, however, this can be discussed further and a generic rule is proposed for all PUSCH repetitions.***Proposal 3: When the restriction on scheduling PDSCH after UL grant is released for PUSCH with repetition case, a large total DAI value can be configured to count all HARQ bits corresponding to the PDSCHs scheduled before and after the UL grant.*** |

Based on the above contribution, following TEI proposal can be discussed in RAN1#112 meeting.

### **TEI proposal #14**

* **The restriction on scheduling PDSCH after UL grant should be removed for the case of PUSCH with repetitions**
	+ **An RRC parameter to configure the function of scheduling PDSCH after a UL DCI format and multiplexing associated HARQ on the PUSCH scheduled by the DCI format can be introduced in Rel-18.**
	+ **When the restriction on scheduling PDSCH after UL grant is released for PUSCH with repetition case, a large total DAI value can be configured to count all HARQ bits corresponding to the PDSCHs scheduled before and after the UL grant**

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

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

|  |  |  |
| --- | --- | --- |
| Company | Suppport (Y/N) | Comment |
| QC | Partially No | We are open to discuss this. But before we decide support or not support it, we have a question on this part: “**a large total DAI value can be configured to count all HARQ bits corresponding to the PDSCHs scheduled before and after the UL grant**”. What is the spec impact regarding this? In our view, gNB can do this in a transparent way to spec/UE, i.e., just issue a larger total DAI than it currently needs to overbook some HARQ-ACK bits for future potential PDSCHs. We are not sure why RRC is needed to configure a large totalDAI.  |
| FUTUREWEI | Y |  |
| DOCOMO | Y (w/ update) | We support to remove the scheduling restriction since especially when PUSCH repetition is used, the issue of delaying PUCCH timing is critical for DL data latency. Regardig the proposal details, the first sub-bullet is OK, but the second sub-bullet seems not spec-wise description, i.e., not text from UE perspective. Whether each DAI value is larger than the actual number of scheduled PDSCHs or not is not considered at UE side. Rather, from UE side, what should be clarified is whether still UL DAI is used or DAI in the last DL assignment is used, to generate HARQ-ACK CB. We think that the intention is still to use the UL DAI value for HARQ-ACK CB generation, so the second sub-bullet should be updated as follows.**For HARQ-ACK CB generation, UE uses UL DAI value for total DAI value as in the existing specification. No spec change is assumed** |
| CATT | N | These are implantation issue, which gNB should schedule PDSCH at a proper occasion.  |
| ZTE |  | As discussed in the tdoc, there could be other solutions to solve the concerned issue. For instance, using PUSCH repetition type B and invalid symbol pattern indication to restrict transmission of PUSCH repetition in some of the slots, which can be used for HARQ-ACK transmission in PUCCH. We are wondering why this is not suitable here. Regarding the proposal, we are not sure whether it is for type 2 HARQ-ACK codebook or both type 1 and type 2 HARQ-ACK codebook. In addition, does the proposal impact the fallback mode of HARQ-ACK transmission. More specifically, what would be the UE behavior if UL\_DAI=0 for type-1 HARQ-ACK codebook and UL\_DAI=4 for type-2 HARQ-ACK codebook.  |
| vivo |  | We understand the scheduling restriction issue and would be open to discuss proper solution with less specification/implementation impacts.  |
| Moderator |  | According to the above comments, this proposal is supported by Huawei, HiSilicon, Ericsson, China Unicom, FUTUREWEI, DOCOMO and hence meets the condition of support by at least 1 operator, 1 infra vendor and 1 UE vendor yet.Proponent is encouraged to address the concern from companies.Proposal is updated based on the comment as follows:* **The restriction on scheduling PDSCH after UL grant should be removed for the case of PUSCH with repetitions**
	+ **An RRC parameter to configure the function of scheduling PDSCH after a UL DCI format and multiplexing associated HARQ on the PUSCH scheduled by the DCI format can be introduced in Rel-18.**
	+ **~~When the restriction on scheduling PDSCH after UL grant is released for PUSCH with repetition case, a large total DAI value can be configured to count all HARQ bits corresponding to the PDSCHs scheduled before and after the UL grant~~**
	+ **For HARQ-ACK CB generation, UE uses UL DAI value for total DAI value as in the existing specification. No spec change is assumed**
 |

* 1. Changing Table 5.2.2.1-2 name to 4-bit CQI Table 1

Following CR is made in the contribution.

|  |  |
| --- | --- |
| [3] | **Reason for change:**In TS 38.214, Section 5.2.2.1: Table 5.2.2.1-2 name is mentioned as 4-bit CQI Table instead of 4-bit CQI Table 1. In TS 38.331 (RRC specification) section 6.3.2 for IE CQI Table, it is mentioned as below. cqi-Table ENUMERATED {table1, table2, table3, table4-r17}It can be noted that, in TS 38.214, Section 5.2.2.1: Table 5.2.2.1-3 is named as 4-bit CQI Table 2 and Table 5.2.2.1-4 is named as 4-bit CQI Table 3 which are corresponding to table2 and table3 in TS 38.331: IE cqi-Table respectively**Summary of change:**Changing Table 5.2.2.1-2 name from “4-bit CQI Table” to “4-bit CQI Table 1”**Consequences if not approved:**Minor confusion about reference of CQI table 1 in TS 38.214 |

Since the content is editorial modification, it seems better to be discussed under AI 7.1. As announced by the chair over RAN1 reflector, this contribution will be treated under AI 7.1.

1. Conclusion

To be updated

Reference

[1] R1-2300155 Proposal for Rel-18 TEI Ericsson

[2] R1-2300257 TEI on the introduction of a UE capability with up to 6-layer DL MIMO OPPO

[3] R1-2300306 Changing Table 5.2.2.1-2 name to 4-bit CQI Table 1 RadiSys

[4] R1-2300484 Rel-18 TEI proposals vivo

[5] R1-2300811 TEI proposals for Rel-18 ZTE

[6] R1-2301061 [TEI18] Extensions to FR1 TRS configurations Nokia, Nokia Shanghai Bell

[7] R1-2301446 Rel-18 RAN1 TEI proposals Qualcomm Incorporated

[8] R1-2301620 R18 TEI on BWP without CD-SSB for normal UE MediaTek Inc.

[9] R1-2301718 Rel-18 TEI proposal on HARQ multiplexing on PUSCH Huawei, HiSilicon, Ericsson, China Unicom

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

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

Appendix: TEI guidance in [11]

**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.