**3GPP TSG RAN WG1 #110bis-e R1-2209714**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary on Rel-18 CSI enhancements

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-18 NR Evolved MIMO WID pertaining to CSI enhancement is as follows:

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| --- |
| 1. Study, and if justified, specify CSI reporting enhancement for high/medium UE velocities by exploiting time-domain correlation/Doppler-domain information to assist DL precoding, targeting FR1, as follows:
	* Rel-16/17 Type-II codebook refinement, without modification to the spatial and frequency domain basis
	* UE reporting of time-domain channel properties measured via CSI-RS for tracking
2. Study, and if justified, specify enhancements of CSI acquisition for Coherent-JT targeting FR1 and up to 4 TRPs, assuming ideal backhaul and synchronization as well as the same number of antenna ports across TRPs, as follows:
	1. Rel-16/17 Type-II codebook refinement for CJT mTRP targeting FDD and its associated CSI reporting, taking into account throughput-overhead trade-off
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## Summary of companies’ views

### Issue 1: Type-II codebook refinement for CJT

Table 1A Summary: issue 1

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| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 1.1 | [110] **Agreement**On the Type-II codebook refinement for CJT mTRP, down-select from the following TRP selection/determination schemes (where N is the number of cooperating TRPs assumed in PMI reporting) by RAN1#110bis-e:* Alt1. N is gNB-configured via higher-layer (RRC) signalling
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signalling
	+ Note: only one transmission hypothesis is reported
* Alt2. N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating TRPs, while NTRP is the maximum number of cooperating TRPs configured by gNB
	+ In this case, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme)
	+ FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

FFS: Whether S-TRP transmission hypothesis is also reported[Reformulation]* Alt1. N is gNB-configured via higher-layer (RRC) signalling
	+ The N configured CSI-RS resources are gNB-configured via higher-layer (RRC) signalling
	+ Note: Selection of a subset from the configured N CSI-RS resources can be performed by UE via NZC selection (indicated by bitmap(s))
	+ Note: only one transmission hypothesis is reported
* Alt2. The selection of N CSI-RS resources is performed by UE and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating CSI-RS resources, while NTRP is the maximum number of cooperating CSI-RS resources configured by gNB
	+ In this case, the selection of N out of NTRP CSI-RS resources is also reported (FFS: exact reporting scheme, selection restriction)
	+ FFS: Configuration of NTRP CSI-RS resources and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

FFS: Whether S-TRP transmission hypothesis is also reported**FL Note**: Companies have correctly pointed out that ***Alt2 (dynamic TRP selection by UE) can already be implemented in Alt1 using NZC selection (bitmap)* – hence there is no W2 overhead reduction from Alt2 compared to Alt1.**  | **Alt1**: Huawei/HiSi, Google, CMCC, MediaTek, Samsung, AT&T, DOCOMO, Nokia/NSB, Fraunhofer IIS/HHI**Alt2**: IDC, ZTE, Spreadtrum, vivo, Lenovo, OPPO, LG, CATT, Sony, NEC, Xiaomi, Apple, Ericsson, Qualcomm, CEWiT, Intel  |
| 1.2 | [110] **Agreement**On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, down-select one from the following alternatives by RAN1#110bis-e:* Alt1. One group comprises one polarization across all TRPs/TRP-groups (*C*group,phase=1, *C*group,amp=2), one (common) SCI across all TRPs/TRP groups
* Alt2. One group comprises one polarization for one TRP/TRP-group (*C*group,phase=N, *C*group,amp=2N), per-TRP/TRP-group SCI
	+ FFS: Quantization of N strongest coefficients
* Alt3. One group comprises one polarization for one TRP/TRP-group with a common phase reference across TRPs/TRP-groups (*C*group,phase=1, *C*group,amp=2N)
	+ FFS: SCI, per-TRP/TRP-group vs. one (common) SCI across all TRPs/TRP groups
	+ FFS: Quantization of N strongest coefficients
* Alt4. For a selected TRP/TRP-group, one group comprises one polarization, and for remaining N-1 TRPs/TRP-groups, one group comprises one polarization across remaining N-1 TRPs/TRP-groups (*C*group,amp=2+2=4), with a common phase reference across all of N TRPs/TRP-groups (*C*group,phase=1)
	+ FFS: The selected TRP/TRP-group

FFS: The need for “strongest” TRP/TRP-group indicator in addition to SCI(s)**Proposal 1.B**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer: * One (common) SCI applies across all N CSI-RS resources
* Further down-select one from the following alternatives by RAN1#110bis-e:
	+ Alt1. One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)
	+ Alt3. One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (*C*group,phase=1, *C*group,amp=2N)
		- For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude and its location are reported

FFS: The need for “strongest” TRP/TRP-group indicator in addition to the SCI**FL Note**: Out of the 4 candidates, 2 candidates are supported by most companies. It is proposed to better focus our difficult discussion by comparing the 2 most supported candidates. The need for strongest TRP indicator (issue 1.3) will be decided after this is finalized. | **Alt1:** IDC, vivo, MediaTek, Fraunhofer IIS/HHI, Apple, Samsung (2nd pref), DOCOMO (2nd pref), Intel (2nd pref)**Alt2:** ZTE, LG, CATT**Alt3:** * **1 SCI**: Huawei/HiSi, Ericsson, Lenovo, Intel, Xiaomi, NEC, CMCC, AT&T, Qualcomm, Nokia/NSB, ZTE, DOCOMO, CATT
* **N SCIs**: Spreadtrum, LG

**Alt4:** Samsung, AT&T**Proposal 1.B:*** **Support/fine:** IDC, vivo, MediaTek, Fraunhofer IIS/HHI, Apple, Samsung, DOCOMO, Huawei/HiSi, Ericsson, Lenovo, Intel, Xiaomi, NEC, CMCC, AT&T, Qualcomm, Nokia/NSB, OPPO, Google, ZTE, CATT
* **Not support:**
 |
| 1.3 | **Question**: Is “strongest CSI-RS resource indicator” needed given your preference on issue 1.2 (please also state your preference on issue 1.2)?   | **The need for “strongest CSI-RS resource indicator (along with preference on issue 1.2):*** **Yes:** ZTE, LG, CATT, Samsung, NEC, DOCOMO, Spreadtrum
* **No:** Huawei/HiSi, Ericsson, Nokia/NSB, vivo, MediaTek, Intel, Apple, IDC, OPPO, Google, CMCC, Xiaomi
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| 1.4 | **Proposal 1.D**: On the Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), for a given CSI-RS resource:* SD basis selection is layer-common and polarization-common, with *N*1, *N*2, *O*1, *O*2 defined per Rel-16 specification for refinement based on Rel-16 regular eType-II, and per Rel-17 specification for refinement based on Rel-17 PS FeType-II
* FD basis selection is
	+ For refinement based on Rel-16 regular eType-II: per-layer with *M*v, *p*v, *N*3, and *R* defined per Rel-16 specification
	+ For refinement based on Rel-17 PS FeType-II: layer-common with *M*, *N*3, and *R* defined per Rel-17 specification
	+ FFS: Details on FD basis selection window

Note: The supported value(s) for each of the defined parameters are to be discussed separately (e.g. possibilities of adding new or removing existing value(s) in addition to those supported by legacy specification).**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 1.1 | **Support/fine:** ZTE, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, Apple, Google, LG, OPPO, Xiaomi, Intel, Spreadtrum, NEC, Fraunhofer IIS/HHI, Lenovo, Sharp, Samsung, IDC, Sony, CMCC, AT&T, Nokia/NSB, Huawei/HiSi, CATT**Not support:** |
| 1.5 | **Proposal 1.E**: On the SD basis selection for Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), SD basis selection is per CSI-RS-resource. * Down select from the following alternatives (RAN1#110bis-e) on the *L* parameter:
	+ Alt1. Per-CSI-RS-resource *Ln* parameter
		- TBD: Whether {*Ln*, *n*=1, ..., *N*} are higher-layer configured by gNB, or the total $\sum\_{n=1}^{N}L\_{n}$ is higher-layer configured by gNB while {*Ln*, *n*=1, ..., *N*} are reported by the UE
	+ Alt2. gNB configures a common *L* parameter for all *N* CSI-RS resources via higher-layer signaling

FFS: Study on additional optimization for collocated multi-panel scenario**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 1.2* Alt1: Samsung, ZTE, Ericsson, MediaTek (concern with UE reporting Ln), vivo, Qualcomm, DOCOMO, LG, OPPO, Huawei/HiSi, Intel, AT&T, NEC
* Alt2: vivo, Google, Xiaomi, Intel
 | **Support/fine:** ZTE, Ericsson, Samsung, MediaTek, vivo, DOCOMO, LG, OPPO, Huawei/HiSi, Intel, Spreadtrum, Apple, NEC, Fraunhofer IIS/HHI, Lenovo, Sharp, Xiaomi, IDC, Sony, vivo, Google, Intel, NEC, Apple, CMCC, AT&T, Nokia/NSB, Qualcomm, CATT **Not support:** |
| 1.6 | **Proposal 1.F**: On the Type-II codebook refinement for CJT mTRP, following legacy (Rel-16 regular eType-II and Rel-17 PS FeType-II), regarding the location of non-zero coefficients (NZCs) indicated by bitmap (following legacy mechanism), for each layer, support separate bitmap per each CSI-RS resource * Total size = $\sum\_{n=1}^{N}B\_{n}$ where $B\_{n}$ is the bitmap size for CSI-RS resource *n*
	+ TBD: Whether $B\_{n}=2L\_{n}M\_{v,n}$ ($M\_{v,n}=M\_{v}$ for mode 2) analogous to legacy, or further reduction of bitmap size is supported.
	+ FFS: Depending on the outcome of other issues, whether $M\_{v,n}=M\_{v}$ or $L\_{n}=L$
* FFS: Per-CSI-RS-resource NNZC (number of NZCs) constraint vs. joint NNZC constraint across *N* CSI-RS-resources

**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 1.3 | **Support/fine:** ZTE, Ericsson, MediaTek, Samsung, vivo, Qualcomm, DOCOMO, Apple, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Intel, Spreadtrum, NEC, CATT, Fraunhofer IIS/HHI, IDC, Lenovo, Sharp, IDC, Sony, CMCC, AT&T, Nokia/NSB**Not support:** |
| 1.7 | Constraint on the (maximum) number of NZCs (K0) **for each layer**:* Alt1. K0 is defined per-CSI-RS-resource
* Alt2. K0 is defined jointly across all N CSI-RS resources

**Proposal 1.G**: For the Rel-18 Type-II codebook refinement for CJT mTRP, the constraint on the maximum number of non-zero coefficients (NZCs) per-layer (K0) is defined jointly across all N CSI-RS resources* TBD: the constraint on the total number of NZCs across all layers
 | **Alt1 (per resource):** **Alt2 (joint) – proposal 1.G:** vivo, Intel, Samsung, MediaTek, Fraunhofer IIS/HHI, Qualcomm, Nokia/NSB, AT&T, Apple, vivo, OPPO, Google, DOCOMO, Ericsson, CMCC, Huawei/HiSi, Xiaomi, CATT, NEC, CMCC, Spreadtrum |
| 1.8 | **Proposal 1.H**: For the Rel-18 Type-II codebook refinement for CJT mTRP, * Only CSI reporting over PUSCH is supported
	+ FFS: Whether AP only, or both AP and SP (following legacy), is supported
* An associated Resource Setting includes a CMR comprising *K*≥1 NZP CSI-RS resources from one CSI-RS resource set
	+ Periodic, semi-persistent, and aperiodic NZP CSI-RS are supported
	+ The supported CSI-RS resource parameter settings follow the legacy specification (without additional enhancement)
	+ FFS: Whether or not the K NZP CSI-RS resources are constrained to be in the same slot

**FL Note**: This fully reuses the legacy CSI-RS.The use of K>1 NZP CSI-RS resources has been agreed in RAN1#110 | **Support/fine:** Google, LG, MediaTek, Qualcomm, Samsung, Apple, vivo, OPPO, ZTE, DOCOMO, CMCC, Ericsson, ZTE, CATT, Fraunhofer IIS/HHI, NEC, Nokia/NSB, Spreadtrum**Not support:**  |
| 1.9 | [110] **Agreement**For the Rel-18 Type-II codebook for CJT mTRP, support the following two modes:* Mode 1: Per-TRP/TRP-group SD/FD basis selection which allows independent FD basis selection across N TRPs / TRP groups. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f,1}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f,N}^{H}\end{matrix}\right]$$* Mode 2: Per-TRP/TRP group (port-group or resource) SD basis selection and joint/common (across *N* TRPs) FD basis selection. Example formulation (*N* = number of TRPs or TRP groups):

$$\left[\begin{matrix}W\_{1,1}\tilde{W}\_{2,1}W\_{f}^{H}\\\vdots \\W\_{1,N}\tilde{W}\_{2,N}W\_{f}^{H}\end{matrix}\right]$$* Striving for the two modes to share commonality in detailed designs such as parameter combinations, basis selection, TRP (group) selection, reference amplitude, W2 quantization schemes.
* FFS: Depending on the decision on SCI design, whether additional per-TRP/TRP-group amplitude scaling and/or co-phase is needed or not, and whether they are a part of W2s

[109-e] **Agreement**For the Type-II codebook refinement for CJT mTRP, further study the following issues:* The need for the following additional parameters:
	+ …
	+ Indication of relative offset of reference FD basis per TRP with respect to a reference TRP
	+ …

**Proposal 1.I**: For the Rel-18 Type-II codebook for CJT mTRP, the switching between mode-1 and mode-2 is gNB-initiated via RRC signallingSome companies suggest to use per-CSI-RS-resource FD basis offset (relative to a reference CSI-RS resource) for “per-TRP/TRP-group” FD basis selection in mode 1. | **Per-CSI-RS-resource FD basis offset (relative to a reference CSI-RS resource) for “per-TRP/TRP-group” FD basis selection (on a TRP-common FD basis selection) in mode-1:*** **Support/fine**: Huawei/HiSi, ZTE, Xiaomi, Samsung, Fraunhofer IIS/HHI, Qualcomm, Nokia/NSB, Intel, AT&T, DOCOMO,
* **Not support**: Apple, vivo

**For mode-1, the number of FD basis vectors (Mv relared to pv for Rel-16, M for Rel-17) is:*** **TRP-common**: Huawei/HiSi, Samsung, Qualcomm, Nokia/NSB, Intel, AT&T, Ericsson
* **TRP-specific**: ZTE, DOCOMO

**Switching between mode-1 and mode-2 is gNB-configured via higher-layer signalling:*** **Support/fine (proposal 1.I)**: Xiaomi, Samsung, MediaTek, Qualcomm, Nokia/NSB (RRC only), Intel (RRC), AT&T, Ericsson, vivo, OPPO, ZTE(RRC), DOCOMO (RRC), CMCC (RRC), Huawei/HiSi, Google, Fraunhofer IIS/HHI, NEC, Spreadtrum
* **Not support**: CATT
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| 1.10 | The need for new UCI/PMI-related parameters:[109-e] **Agreement**For the Type-II codebook refinement for CJT mTRP, further study the following issues:* The need for the following additional parameters:
	+ Receiver side information by per RX reporting or per layer, e.g. information related to the left singular matrix U of the channel
	+ …
	+ Information related to the windows for FD basis
	+ Delay/frequency difference(s) across TRPs

… | **RX side info:** Huawei/HiSi, ZTE, Sony**FD basis window info:** ZTE, Xiaomi, LG, Samsung, Lenovo, Fraunhofer IIS/HHI**Per-TRP delay/frequency offset:** Fraunhofer IIS/HHI (N-1 relative delay offsets), Ericsson (in a phase form) |
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Table 1B Type II CJT: summary of observation from SLS

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| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 1.5 | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | TRP-specific $L\_{n}$ has a better performance compared to the TRP-common case, with 5~9% gain for mean UPT and 4~10% for 5% UPT. |
| 1.10 (RX side info) | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | The full channel feedback for CJT codebook by per-RX reporting can provide 5~10% gain for mean UPT and 18~35% gain for 5% UPT respectively. |
| 1.4 (on R) | Mean UPT gain vs overhead, 5%-tile UPT gain vs overhead | Performance gain can be achieved when the PMI granularity changes from 4RB to 2RB with R=4, with 5% gain for mean UPT and at 8~11% gain for 5% UPT. |
| ZTE | 1.10 (RX side info) | Avg UPT,50% UPT | Through additionally reporting Rxx information, the reporting of receiving side information can bring a significant performance gain. (9~10% avg UPT gain) |
| vivo | 1.1 | Cell mean SE gain (full-buffer)Overhead reduction ratio  | TRP recommendation (by UE) causes marginal performance loss (1~7% cell-mean SE loss), but it can bring maximum reduction in overhead of about 40% because more than 50% of UEs do not need to measure CSI of all TRPs based on simple TRP selection rules and do not need to report CSI for all TRPs in the measurement set. |
| 1.2 | Cell mean SE gain (full-buffer) | Alt2/Alt3/Alt4 bring negligible performance improvement (1~2%) and Alt1 has minimal payload. |
| 1.7 | Cell mean SE gain (full-buffer) | The TRP-specific beta (TRP-specific NNZC constraint) may reduce the feedback of the coefficients corresponding to the strongest TRP, which leads to a decrease in performance (up to 12% cell-mean SE loss).  |
| 1.4(on R) | Cell-mean, 5%-UE, 95%-UE SE gain (full-buffer) | A limited performance gain (up to 2% cell-mean SE gain) is obtained for a larger R for Indoor Hotspot and Intra-site CoMP(Outdoor2). |
| MediaTek | 1.4 (On M) | Avg UPT gain, statistics of dominant FD bases | Mode 1 and Mode 2 codebook structures achieve nearly same performance in intra-cell mTRP scenarios.For Mode 1 codebook structure, the dominant FD bases computed from FD compression of precoder coefficients are the same for all TRPs. |
| 1.2 | Avg UPT gain | Alt 2 quantization has $N$ SCIs, due to which phase coherence cannot be maintained among different TRP precoders and therefore it yields a poor performance.Alt 3 quantization scheme can give a much better performance than Alt 2 by virtue of having a single-phase reference (single SCI whose amplitude and phase is not reported).Alt 1 and Alt 4 quantization schemes achieve nearly same performance. |
| Samsung | 1.1 | Avg UPT gain vs overhead | 1) UE-based dynamic TRP selection degrades the performance of UPT vs overhead (4% avg. UPT loss) especially in the intra-cell scenario due to unpredictable interference fluctuation, and 2) the gNB-based dynamic TRP selection method outperforms (2~4% avg. UPT gain) the other two methods in both of the intra-/inter-cell scenarios. |
| 1.2 | Avg UPT gain vs overhead | Alt4 (#. Ref Groups for amp = 4) yields the best UPT vs overhead trade-off and 2~4% avg. UPT gain over the other methods, Alt1, 2, and 3. |
| 1.5 | Avg UPT gain vs overhead | Multiple (or different) L values (Alt1) can be beneficial as showing ~5% avg. UPT gain over the same L value case (Alt2). TRP-common SD beam selection (Alt3) yields the worst UPT vs overhead trade-off performance. |
| 1.6 | Avg UPT gain vs overhead | TRP-common bitmap incurs large avg. UPT loss that cannot be compensated for the overhead saving (it turns out 2~3% avg. UPT loss).  |
| 1.4(on new ParaComb) | Avg UPT gain vs overhead | A sufficient performance gain (70% - 100%) can be obtained in a low-overhead regime that is comparable to the overhead of sTRP case, when $L=1$ and/or low values of $p\_{v}$ (e.g., 1/8) are allowed. |
| Qualcomm | 1.4  | Throughput gain, Percentage of # TRPs selected  | Throughput gain of UE-determined Ln over configured Ln are show in Table 2. (average throughput gain 5~24% over configured Ln)It is noted that for smaller value of $L\_{tot}$ (e.g. $L\_{tot}=$3 or 4 with 3-TRP), allowing UE to determine $L\_{n}$ basically means allowing $L\_{n}=0$ reported, thus naturally allow TRP selection. |
| **Summary**:  |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 1A especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **More moderator proposals may be added in the next revision**
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| vivo | **Issue 1.1**Based on our evaluation in R1-2208628, the overhead saving from Alt 2 can be up to 40% due to the reduction of reporting SD basis, FD basis, coefficients and bitmap associated with the reduced CMR. Further, UE complexity can also be reduced due to UE does not have to further store the temporary CSI values in their buffer. Hence we support Alt 2.We think Alt 1 and Alt 2 can be configured by gNB, which is same as NCJT CSI in Rel-17. gNB can configure a minimum N value to be selected by UE to achieve this.[Mod: It has been pointed out that there is no saving in W2 compared to Alt1 since Alt1 can utilize NZC selection and achieve the same function. To have a more accurate and objective comparison, let’s focus on the correct potential/hypothetical saving, e.g. bitmap size, basis selection indication? If this can be quantified it will help.]**Proposal 1.B**We support Alt 1.* We do not observed clear gain from other Alts in our evaluation in R1-2208628.
* Alt 1 has the smallest overhead.

**Issue 1.3**No need for strongest CSI-RS resource indicator. |
| Mod V2 | **No revision** |
| MediaTek | Regarding Proposal **1.B**, as shown in our contribution R1-2209494 and pointed out by Vivo Alt 1 has better performance compared without increased overhead compared to other down selected Alts. Hence, we support Alt 1.On Proposal **1.E**, we support Alt 1. However, we like to raise our concern regarding UE complexity of selecting and reporting the number of SD beams Ln. Further, from a spatial beam perspective, we think it can create a similar effect of interference fluctuation as TRP selection (i.e., UE selecting a very low value of Ln is equivalent to less spatial interference and vice-versa). We would rather prefer the gNB to configure Ln for each TRP n. Such a gNB configuration extends from the Rel-16 configuration of L.Regarding Proposal **1.H**, we would like to point out based on 38.214 SP CSI is also supported for R16 Type II and R17 FeType II:“Semi-persistent CSI reporting on the PUSCH supports Type I, Type II with wideband, and sub-band frequency granularities, Enhanced Type II and Further Enhanced Type II Port Selection CSI. The PUSCH resources and MCS shall be allocated semi-persistently by an uplink DCI.”However, we are supportive of only supporting AP CSI for CJT enhancements. [Mod: Thanks for pointing this out. I removed the text in brackets] |
| Qualcomm | Re 1.1We don’t think Alt2 definitely means smaller overhead than Alt1 – it depends on further design. For example, it is possible that even with less TRPs selected, a same {Ltot, M, K0} can be maintained.But still, we support Alt2 due to evaluation based on nearly same overhead for both Alt1 and Alt2 (same {Ltot, M, K0} ), considerable TPUT gain is observed for Alt2 over Alt1 as in our contribution and FL’s summary listed above (thanks for the concise and accurate capture).Besides, some wording suggestion for Alt2. Since N may be explicit or implicit (depending on further designs on the exact reporting of TRP selection), we suggest to modify the wording of Alt2 as:

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| --- |
| * Alt2. N is UE-determined ~~selected and reported~~ as a part of CSI report where N$\in ${1,..., NTRP}
 |

[Mod: Good point. I reworded Alt2 to capture what you said above]Re 1.2Regarding the new proposal 1.B, we want to point out Alt1 may also be a special case of Alt3, i.e. by grouping all TRPs together (thus N=1).Besides, the grouping config can be according to static deployment, which is known by gNBRe 1.5For standard progress, we support current Proposal 1.E (Alt1). Two additional comments: 1. It is noted that under Alt1, the TBD option “{*Ln*, *n*=1, ..., *N*} are reported by the UE” is also relevant to TRP selection (issue 1.1) – depending on whether a certain *Ln*=0 is allowed to report or not.[Mod: Correct. This is quite obvious, no need to state it ☺]2. Can we leave a note in the agreement like “**tailoring work** specifically for multi-panel deployment can be considered for revisit after PMI reporting mechanisms are stabilized, within Rel-18”?[Mod: Done]Re 1.8: AgreeFor the FFS (time-constraint of K CSI-RS resources), reuse Rel-17 NCJT can work (i.e. 1 or 2 consecutive slot without DL/UL switch in between the K CSI-RS resources)Besides, also add our preference in some other issues with tracked change. |
| Samsung | Re **Issue** **1.1*** We do not support dynamic TRP selection by UE due to several reasons: 1) the existing feature of NZC selection via bitmap already provides the operation of dynamic TRP selection by UE with a finer granularity, so Alt2 is possible is included in Alt1. 2) In our SLS results, we can’t see any performance gain for dynamic TRP selection by UE even considering the overhead (compared to semi-static gNB-based TRP selection), as we expected due to the unpredictable interference fluctuation. In the worst case, there is no overhead saving with Alt2 over Alt1. 3) The UE complexity with Alt2 is more than Alt1 since the UE has to consier multiple TRP selection hypotheses. 4) Alt2 also adds to gNB complexity due to more involved scheduling across TRPs for different UEs. 5) For MU-MIMO (main use case of Type II), it is desired to group multiple UEs (across TRPs) for MU scheduling. Alt2 makes MU scheduling more challenging.

Re **Proposal 1.B*** Although we still think Alt4 is a superior scheme among Alt1-4, but we can be OK for progress and support Alt 1. In our SLS results, it is shown that Alt3 performs worse than Alt1 from both the overhead and UPT performance perspectives. Also, Alt1 is legacy and the simplest scheme.

[Mod: Thanks for the compromise – also noted only 3 companies (Samsung, MediaTek, vivo) provide results on this issue and all 3 demonstrate Alt1/4 are more competitive than Alt3]Re **Proposal** **1.E*** We support Alt1 with Ln configured by gNB. To simplify parameter combinations on Ln, we prefer that one L is configured, and Ln is determined based on the configured L value.

[Mod: We can discuss this if/when Alt1 is agreed]Issue 1.7: in legacy, we have two constraints: per layer constraint, and constraint on the total number of NZCs across layers. We prefer to clarify this by adding a note.* Note: the constraint on the total number of NZC shall be discussed separately.

[Mod: Done] **Proposal 1.H**: Support.Issue 1.10: we are supportive of studying the FD basis window for mTRPs, since the FD basis window is there in legacy, and can be beneficial for efficient FD basis/SCI reporting.  |
| Nokia/NSB | **Issue 1.1**We support Alt 1 because it allows network flexibility to configure a subset of the CJT scheduling set for CSI reporting, based on RSRP measurements.We have some concern with Alt 2 for the negative impact on the gNB scheduler as the combination of reported TRPs is not controlled by the network, which may result in higher interference and/or reduced throughput. Another drawback of Alt 2 is the need to introduce extra signalling, including in Part 1 CSI.**P1.B**Support. Our preference is for Alt 3 because of the power imbalance between TRPs, which may exist due to different distances and RSRPs.**Issue 1.3**No need for the strongest TRP indicator, as the strongest TRP can be obtained from the SCI in a similar way as the stronger polarisation in obtained from the SCI in Rel16 without an additional indicator**Issue 1.7**Support Alt 2 (K0 across TRPs). Because layers are formed across TRPs, performance is optimised when NZC are chosen freely across TRPs. Restricting K0 per TRP may degrade the precoder accuracy.**P1.H**As pointed out by Mediatek, semi-persistent on PUSCH reporting is also supported in legacy single-TRP Type-II reporting. We don’t see strong reasons to exclude SP reporting if complexity and number of active ports/resources allow.[Mod: Added FFS] **Issue 1.9**We support unified reporting of a single FD basis set for both Mode 1 (with TRP-common $M\_{ν}$) and Mode 2 and both Rel-16 and Rel-17 extension. TRP-specific $W\_{f,n}$ for Mode 1 are obtained by reporting an FD offset per TRP with respect to a reference TRP.We also note that FD offset reporting is useful in Mode 1 for Rel-17-based extension when $W\_{f}$ is not reported, i.e., when M=1 or M=N=2, as a UE is free to select a different FD basis vector or pair of adjacent FD basis vectors, for each TRP.**Issue 1.10**Regarding the FD basis window for Rel16-based extension, when $N\_{3}>19$ (for R=2), if R=2 is supported for CJT, the legacy parameter $M\_{initial}$ seems enough because only one FD window is needed with the unified Mode1/Mode2 solution described in Issue 1.9Regarding the delay/frequency differences between TRPs, for clarification, is this parameter the same as the FD offset proposed in Issue 1.9?[Mod: That’s correct] |
| Mod V9 | **Minor revision on proposals 1.E and 1.H.** **Added proposal 1.G** **Need more inputs before I can compose proposals 1.A** |
| Lenovo | **Issue 1.1:**In our understanding the proposal should clearly address two points 1. The entity determining the value “N”, e.g., via log(NTRP) bits2. The entity determining N out of NTRP TRPs, e.g., via log (NTRP-choose-N) bitsAlt1 clearly identifies gNB as the entity determining both value N and the N indices, whereas the same clarity is not available for Alt2. In our understanding, since the network would allocate UCI resources for CSI report prior to CSI calculation at UE, the gNB should determine the value “N” in both alternatives. If so, it is preferable to give the UE the privilege to select the N out of NTRP TRPs based on measured CSI. We therefore prefer Alt-2 with the following note:**- Note: The value “N”, where N**$\in $**{1,..., NTRP}, is gNB configured**[Mod: This is not Alt2, actually closer to Alt1. But there is virtually no difference in payload variation between Alt1 and Alt2 since dynamic TRP selection can be performed in Alt1 via NZC selection – please see above comments and responses] **Issue 1.2 (Proposal 1.B):**Prefer Alt-3 with one SCI, agree with Nokia’s comment**Issue 1.3:**This depends on SCI determination in Issue 1.2. But even if one SCI is supported, which can implicitly infer the strongest TRP, CRI may be needed since it is mapped to CSI report Part 1 and can be more helpful for CSI mapping priority, whereas SCI appears in CSI Part 2 as per legacy Type-II CB design**Issue 1.8 (Proposal 1.H):**Agree with MediaTek, Nokia’s comments. OK to discuss support for SP reporting on PUSCH. Can the FL note also be updated since it still states that “This basically follows the legacy spec re Type-II codebook (only A-CSI is supported)”[Mod: Good catch ☺]**Issue 1.10:**OK to discuss FD basis offset window info on legacy FD basis window design.  |
| Intel | **Issue 1.1.**Support the reformulation, especially clarification that 0 coefficients can be reported for Alt1.We have slight preference for Alt 2 due to lower maximum overhead.**Issue 1.2.** For SCI design we can accept both Alt1 and Alt3 since the performance/overhead is at the similar level. [Mod: Indeed, this is the most accurate characterization of Alt1 and Alt2]**Issue 1.3.** Agree with Nokia**Issue 1.7.** In our view additional constraints on actual number of NZC per TRP are not needed. Discussion is required on the NNZC reporting design. **Issue 1.8.**We are open to support both: aperiodic and semi-persistent.[Mod: Added FFS, hope it is now acceptable] |
| AT&T | **Issue1.1: Support Alt1** **Proposal 1.B: Support Alt3**Alt3 can accommodate the PL differences between UE & the cooperating TRPs**Proposal 1.E**: **Support Alt1**Because the SD basis encountered by the UE is not uniformly distributed across the TRPs (see the example below). In addition, we would like to make the following proposal: due to the non-uniform distribution SD basis across TRPs, the gNB can configure the maximum number of SD basis rather than the total number of SD basis ($\sum\_{n=1}^{N}L\_{n}\leq L\_{max}$). Proposal: “For the type-II codebook refinement for CJT mTRP, the maximum number of SD basis across all N CSI-RS-resources is $L\_{max}$ and it is higher-layer configured by gNB. The total SD basis reported by UE should not exceed $L\_{max}$ $\left(\sum\_{n=1}^{N}L\_{n}\leq L\_{max}\right)$”[Mod: I will include this when we start discussing the next level details (later rounds) after Alt1 is agreed]**Issue 1.7: Support Alt2**Support Alt 2 (K0 across TRPs). The NZC is not uniformly distributed and an upper bound across the TRPs can provide further optimization.**Proposal 1.G Support****Issue 1.9: Support** |
| LG | Issue 1.1:According to FL’s reformulation, Alt 1 also supports UE selection of transmission hypothesis via NZC selection. However, it is still unclear whether Alt 1 can save feedback overhead as much as Alt 2 since, in Alt 1, it is not clear whether codebook parameters such as bitmap and basis selection indicator for non-selected TRP is still reported with dummy value such as zero padding or omitted from UCI. We would like to make it clear before comparing overhead saving between Alt 1 and Alt 2. In addition, based on the reformulation in Alt2, it is not clear whether UE reports the value of N as well as selection of N CSIRS. In our understanding Alt 2 reports value of N as well so we suggest to make it clear.[Mod: For Alt2, if the selection of N out of NTRPs is reported, explicitly reporting the value of N is unnecessary since the value of N can be implicitly inferred. This has been mentioned by a number of companies.Your understanding of overhead saving for Alt2 is correct IMO – check my response to vivo.] Proposal 1.B:Support original Alt 3 including 1 SCI and N SCIs. Given the fact that 13 companies support the original Alt 3 including 1 SCI and N SCIs, we don’t need to split Alt 3 further depending on the number of SCI at this moment. If original Alt 3 is agreed, we can further discuss the number of SCI. Even though our 1st preference is Alt 2, we are fine with the original Alt 3 at this moment.[Mod: Since the issue with W2 quantization + SCI, Alt3 with 1 SCI and Alt3 with N SCIs are two different schemes. Since using N SCIs is supported by only 3 companies I will have to remove it, just as I remove Alt2 with 4 companies, and Alt4 with 2 companies. To progress, I hope all companies can be considerate and focus on what I proposed in 1.B (two most supported alternatives). Note that only 3 companies care enough to provide simulation results (vivo, Samsung, MediaTek) and none suggest that Alt3 with N SCIs is superior.]Regarding Alt 1, we have the same view with Nokia, AT&T and Lenovo. Specifically, current quantization table for differential amplitude does not consider distributed MTRP scenario so that differential range in legacy table which is up to 10.5dB is not sufficient to cover both transmission power difference among inter TRP and power difference among SD/FD basis for intra TRP. [Mod: Only 3 companies care enough to provide simulation results (vivo, Samsung, MediaTek) and none suggest that Alt3 with N SCIs is superior. Your speculation is not unsound but there is no tangible simulation evidence to support your claim re Alt3 superiority, unfortunately ☹ I just want to be fair to the 3 companies who provided SLS results ☺] |
| Mod V15 | **Minor revision on proposal 1.B to align terminology of CSI-RS resource instead of TRP/group** |
| Apple | **Issue 1.1**In our view, we should first agree that UE can select a subset of configured TRP/TRP groups. In terms of how UE can indicate the TRP selection, it is up for the next step discussion. **Issue 1.2**We are fine with Proposal 1.B, we slightly prefer Alt1**Issue 1.3**We do not think it is needed. Even if it is needed, it is secondary optimization **Issue 1.4**We support proposal 1.D**Issue 1.5**We are fine with proposal 1.E. We slightly prefer Alt 2**Issue 1.6**We are fine with proposal 1.F**Issue 1.7**We are fine with proposal 1.G**Issue 1.8**We are fine with proposal 1.H. It might be better to “At least a~~A~~periodic CSI reporting is supported”**Issue 1.9**We do not think FD offset is flexible enough. We should allow indepdent FD basis selection per TRP/TRP group for mode 1**Issue 1.10**Discussion of those issues should be delayed until we have codebook design details ready  |
| Qualcomm | Re 1.1 & 1.5According to the discussion above, seems this SD/TRP selection is the most controversial topic for CJT in this meeting. And it seems to be mixed with too many variables and difficult to get **into** technical discussion (I believe no companies want to sadly see political vote).Therefore, to be possibly more tech-constructive to the upcoming discussion (I guess probably round 1), and to be more clearly with the issue we are dealing with, we suggest to merge these two issues with all option combinations we can think of as below:

|  |
| --- |
| * Alt1. N and Ln (n=1,…,N) are gNB-configured via higher-layer (RRC) signalling
	+ …
	+ Alt1A and Alt1B, for common Ln value, or TRP-specific Ln value, respectively
* Alt1’. N is gNB-configured via higher-layer (RRC) signalling, and Ln (n=1,…,N) are performed by SD basis selection (by UE)
	+ …
* Alt2. The selection of N CSI-RS resources and Ln (n=1,…,N, e.g. according to SD basis selection) are performed by UE and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ …
* Alt2’. The selection of N CSI-RS resources is performed by UE and reported as a part of CSI report where N$\in ${1,..., NTRP}, and Ln (n=1,…,NTRP) are gNB-configured via higher-layer (RRC) signalling
	+ …
	+ Alt2’A and Alt2’B, for common Ln value, or TRP-specific Ln value, respectively
* Alt3. (??? Possibly some option combination we miss-considered)
 |

Some considerations for the above 4 Alts:Since N represents the cooperated TRPs within a TRP-cluster, it may be configured to UE based on certain **large-scale fading** properties (e.g. RSRP) of UE channel; Similarly, SD basis selection represents certain **small-scale fading** properties (finer in spatial domain than RSRP)Therefore, in our intuitive and not 100%-strict understanding,* Alt1 means gNB has some certain knowledge about both large-&small-scale channel properties
* Alt1’ means gNB has some certain knowledge about large-scale channel properties, while small-scale needs UE report by CSI
* Alt2 means both large-&small-scale channel properties need UE report/assist
* Alt2’ means gNB has some certain knowledge about small-scale channel properties, while large-scale needs UE assist

[Mod: Thanks for the inputs. I can consider this for later rounds after proposal 1.E (also supported by Qualcomm) is agreed and issue 1.1 progresses more]Re 1.2Fine with V15 proposal 1.B revision – then there is no ambiguous understanding regarding TRP-group |
| Qualcomm2 | Some small updates to the above input |
| InterDigital | **Proposal 1.B**We support Alt 1.**Issue 1.3**Added our view in the table. With Alt 1., we don’t see the need for a strongest CSI-RS resource indicator since the SCI already indicates it as one reference across TRPs. |
| Mod V23 | **Minor revision on proposal 1.G per Apple’s input**  |
| vivo2 | **Issue 1.1**We agree with QC that the evaluation of overhead vs performance should either assume same configuration to compare the overhead, or should assume the same overhead to compare the performance. In our evaluation, we assume same configuration and compare the overhead between Alt 1 and Alt 2, which shows Alt 2 can save overhead. We also agree with QC that if a same number of coefficients is maintained for Alt 1 and Alt 2, Alt 2 can provide performance gain as shown by QC results. Both sides reveal the benefit of Alt 2.We don’t think Alt 2 has higher UE complexity than Alt 1. It is clear that UE does not need to compute full CSI for Alt 2 to do TRP selection. Hence Alt 2 actually saves UE complexity compared with Alt 1. We don’t think Alt 2 makes scheduling in gNB side more challenging or complex. This goal of this CJT CSI is to perform scheduling and MU precoding over maximum N\_TRP TRPs, so no extra complexity for gNB is brought by Alt 2.[Mod: Thanks for revising the assessment (more accurate this time ☺). From FL perspective, * Alt1 vs Alt2 is about potential opportunistic saving in bitmap overhead, and perhaps basis selection indicator. In this aspect Alt2 can reduce such overhead over Alt1.
* In terms of UE complexity, interference fluctuation, W2 overhead (Alt1 can use NZC selection), NW scheduling, what gNB needs to know, I don’t think there is any notable difference between Alt1 and Alt2.
* Alt1 “looks” simpler than Alt2 but this is perhaps superficial.

So the deciding factor is whether the opportunistic overhead saving from bitmap and perhaps basis selection from Alt2 can convince Alt1 proponents to accept Alt2]**Proposal 1.G**Support**Proposal 1.H**Support**Issue 1.9**We don’t support to use an offset and a common set of TRPs to report FD basis for Mode 1. Mode 1 clearly says independent FD basis selection. Hence this proposal violates this definition.We agree that the switch between Mode 1 and Mode 2 is to use RRC signaling. |
| OPPO | **Issue 1.1**We are fine with the refinement. We think Alt.1 is difficult to work in practical network without information of DL channel.[Mod: Please see my comment to vivo. There is no difference here]**Issue 1.2**Proposal 1B is fine and Alt.1 is preferred.**Issue 1.3**We think strongest CSI-RS resource indicator is not needed.**Issue 1.4-1.8**Support the current proposal.**Issue 1.9**We think RRC signaling can be used for switching between mode-1 and mode-2. |
| Mod V26 | **Editorial revision on proposal 1.B (same content)** **Added proposal 1.I (RRC mode switching)** |
| Google | Our view is added aboveFor issue 1.9, we are ok with current proposal. |
| ZTE | Issue 1.1: Technical speaking, Alt2 can be assumed as a superset of Alt1 due to supporting further TRP selection from UE side (but under a given N). From gNB perspective, it may support the several candidates for co-ordination TRP groups and then the UE is to further select one of them. As a fall back mode, if N = NTRP, Alt2 is equivalent to Alt1. Then, in our views, some further restriction on UE selection of N out of NTRP TRPs should be further studied. For instance, candidate(s) of N co-operating TRP(s) combination are pre-configured by gNB according to corresponding deployment (e.g., only combination corresponding to intra-site as shown in the following a)) * Alt2. The selection of N CSI-RS resources is performed by UE and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating CSI-RS resources, while NTRP is the maximum number of cooperating CSI-RS resources configured by gNB
	+ In this case, the selection of N out of NTRP CSI-RS resources is also reported (FFS: exact reporting scheme, selection restriction, e.g., from pre-configured combinations)
	+ FFS: Configuration of NTRP CSI-RS resources and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

[Mod: OK]Issue 1.2: We support Alt3. But further reformulating Alt3 by adding ‘one (common) SCI across N CSI-RS resources’ is a little bit confusing (for original agreement, we do not have such description for Alt-3). Since we have 2N groups for amplitude, anyway, we need to indicate the individual reference for each group. One (common) SCI across all N CSI-RS resources? That seems only relevant to a single phase-group. Therefore, the following should be added for clarification. * Alt3. One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (*C*group,phase=1, *C*group,amp=2N)
	+ Strongest/reference amplitude for each of 2N amplitude groups is individually indicated

[Mod: Your understanding is correct. Added]Issue 1.3: Support. Technically speaking, it is relevant to how to define/specify the above ‘one (common) SCI’ in Alt3. If our understanding is correct, it should be a global ID across all candidate coefficients of all N CSI-RSs. Like strongest CSI-RS resource indicator + a local coefficient ID. Then, for mode-1 TRP-specific FD indication, it seems to be another usage for ‘strongest CSI-RS resource indicator’Issue 1.8: In our views, both AP and SP-CSI on PUSCH should be supported.[Mod: OK, changed the time-domain property to FFS]Issues 1.10: Support receiver side information report. In our contribution, we provide some results and clarify the potential benefits having the information.  |
| Xiaomi | **Issue 1.2 &1.3**We support Alt 3 since the amplitude gap among inter-site TRP may be large and amplitude group per TRP can improve the accuracy by reporting relative amplitude to the strongest one from the same TRP. And with Alt 3, the strongest TRP/TRP-group can be implicitly indicated by the one SCI. Thus additional strongest CSI-RS resource indicator is not necessary. **Issue 1.5**We slightly prefer Alt 2 in which the overhead of W2 can also be reduced by NZC selection. If majorities support Alt 1, we can accept it only when *Ln* is configured by gNB to reduce UE complexity for *Ln* determination for each TRP.**Issue 1.7**We are OK with proposal 1.G.**Issue 1.8**One clarify question to the second sub-bullet, what is the definition of “one CSI-RS resource set” here? Does it mean that the set will contain N NZP CSI-RS resource and each resource corresponds to different TRP/TRP group?[Mod: This follows legacy behavior when K>=1 resources are configured for CSI reporting (Type-I), they come from a same CSI-RS resource set. Of ocurse each resource corresponds to one TRP/group, that’s agreed in the last meeting already] |
| DOCOMO | **Issue 1.1:** Current reformulation of Alt1 with the new note is not clear to us. Does it mean that the SD basis of N TRPs are reported but there may be no NZC reported for a certain TRP? [Mod: Yes.]It seems that Alt1 and Alt2 become two different ways of UE down-selection/reporting of N. We think it is not the original intension of Alt1. [Mod: It has been that way for Alt1, no revision – it’s just many companies forget that Alt1 does that.]In addition, we have similar feeling as QC that it seems to be mixed with too many variables.In our understanding, gNB configuration of N (without UE down-selection) should be supported. Because NW knows much more information than UE, and NW may want to get CSI from those configured TRPs for a UE, to perform dynamic scheduling, including MU pairing. The UE recommended TRPs may not be used by NW after considering all UEs’ information. We’re open to support both gNB configuration and UE determination of N.[Mod: Please check my comment to vivo above and Ericsson’s input. Yes, both Alt1 and Alt2 support UE selection of TRPs, but with different mechanisms. Alt1 is implicit via NZC selection while Alt2 is explicit. The only difference is that Alt2 allows reduced overhead of NZC bitmaps, i.e. some overhead reduction]**Issue 1.2 (Proposal 1.B):**Ok with Proposal 1.B. Okay to support both Alt1 and Alt3, for different codebook modes. If down-selection is required, we slightly prefer Alt3.**Issue 1.3:**Needed for Alt3 of Proposal 1.B.**Proposal 1.G/1.H/1.I**Support |
| CATT | **Issue 1.1**We agree with ZTE’s views. Because we are also confused with the difference between Alt 1 and Alt 2 if the TRP selection in Alt 1 can also be achieved by NZC bitmap implicitly. In our opinion, the maximum number N of cooperating TRPs can be configured by gNB in Alt2, which is equivalent to gNB pre-selection/pre-configuration. In addition, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme, explicitly or implicitly) in the current agreement. Therefore, the Alt 1 with NZC bitmap seems to be one sub-alternative of Alt 2 by implicit reporting. Hence, we support Alt 2 and our suggestion is to extend the detail on FFS in Alt 2 as shown below.* Alt1. N is gNB-configured via higher-layer (RRC) signalling
	+ The N configured CSI-RS resources are gNB-configured via higher-layer (RRC) signalling
	+ Note: Selection of a subset from the configured N CSI-RS resources can be performed by UE via NZC selection (indicated by bitmap)
	+ Note: only one transmission hypothesis is reported
* Alt2. The selection of N CSI-RS resources is performed by UE and reported as a part of CSI report where N$\in ${1,..., NTRP}
	+ N is the number of cooperating CSI-RS resources, while NTRP is the maximum number of cooperating CSI-RS resources configured by gNB
	+ In this case, the selection of N out of NTRP CSI-RS resources is also reported (FFS: exact reporting scheme)
		- Alt 2-1: explicit reporting (i.e. CRI)
		- Alt 2-2: implicit reporting.(i.e. NZCs bitmap, co-phasing, the number of SD selection and so on)
	+ FFS: Configuration of NTRP CSI-RS resources and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported. UE is not mandated to calculate CSI for multiple transmission hypotheses.

FFS: Whether S-TRP transmission hypothesis is also reported[Mod: Thanks, we can discuss that in later rounds if Alt2 is selected]**Issue 1.2 and issue 1.3**We support either Alt 2 or Alt 3 at least *C*group,amp=2N. In addition, if the indicator of the strongest TRP is introduced, the two-level amplitude quantization can be considered with for more precise quantization. That’s because if one TRP is relatively weak among the TRPs, the weak coefficients of this TRP can also be accurately quantized.**Issue 1.4 ,1.5 and 1.6:** Support**Issue 1.7:** Support Alt 2.**Issue 1.8 :** Support**Issue 1.9:** For the per-CSI-RS-resource FD basis offset**,** we are open to discuss it when the indicator of the strongest TRP is introduced; For the switching between mode-1 and mode-2, we list possible alternatives in our contribution (R1-2208947), the following alternatives can be discussed not only based RRC-signalling.* Alt 1: semi-static switching one codebook mode by RRC signaling
* Alt 2: One codebook mode selection by UE
* Alt 3: One or two codebook modes selection by UE

Alt 1 is the simplest solution for the configuration of 2 modes and the reporting format and bitwidth for each mode is clear. However, forcing the single modes is not suitable for both scenarios discussed above; For Alt 2, flexibility can be improved because UE can select the codebook modes according to the different channel state. In this case, the selection result is also needed to be reported. For example, the selection between mode 1 with mode 2 can be reported in CSI Part I, then some specific parameters (e.g. co-phasing in mode 1) or bitwidth can be defined separately; For Alt 3, if there are coexistence of two deployments in the current coherent-JT TRPs, a part TRPs can be reporting in mode 1 due to the big difference with delay paths or FD basis such as distributed TRPs, and a part TRPs might be reporting in mode 2 due to the similar FD basis such as co-located TRPs for these TRPs. In this case, UE can report for mode 1 in principle, and if the measurement shows that the delay paths of different TRPs are relatively close, the UE can also report the same FD basis to reduce the computational complexity. In addition, UE might need to report the grouping of TRPs in CSI Part I/II. Therefore, to sum up three alternatives, Alt 3 is more compatible solution for the unified feedback framework, and it can also reduce the overhead of FD basis according to the channel measurement states by UE. |
| Fraunhofer IIS/Fraunhofer HHI | **Issue 1.1**: In our view, Alt2 increases complexity of the scheduler at the gNB as TRP selection cannot be controlled by the network. We therefore prefer Alt1.**Issue 1.2**: We prefer Alt 1. In our view, if the precoders for all TRPs are calculated jointly, the strength of the channels between each TRP and UE is reflected in the power of the precoder coefficients. By selecting K strongest coefficients across all TRP precoders jointly, weaker precoder coefficients are anyway discarded. So, our question is how much gain can be seen by improving the resolution of the few weaker coefficients among the K selected coefficients?**Issue 1.8**: Support P1.H.**Issue 1.9-1.10**: We support studying FD basis window and FD offset reporting more in detail. |
| Ericsson | **On Issue 1.1**Regarding the reformulated Alt 1, we may need one more clarification. Since we are discussing the support of separate bitmaps for different CSI-RS resources and for each layer in issue 1.6, may be there are multiple bitmaps involved. So we suggest to either change ‘indicated by bitmap’ to ‘indicated by bitmap**(s)**’ or remove ‘indicated by bitmap’ altogether. Also, whether UE feeds back bitmaps corresponding to non-selected CSI-RS resources can be discussed separately. We think the UE does not need to feedback the bitmaps of non-selected TRPs which should be possible with either Alt 1 or Alt 2.But reading some of the comments above, we wonder if there is some different understandings about Alt 1. For instance, regarding Nokia’s comment:*Nokia comment on Issue 1.1: We support Alt 1 because it allows network flexibility to configure a subset of the CJT scheduling set for CSI reporting, based on RSRP measurements.* According to the above comment, we have a few of questions:1. What is CJT scheduling set for CSI reporting in reformulated Alt 1? 2. What is meant by “configuring a subset of the CJT scheduling set”?Isn’t it that in Alt 1, the gNB configures *N* CSI-RS resources and the UE can select a subset from *N* CSI-RS resources? At least that is how we read Alt 1 (i.e., based on the note, the UE selects the subset as part of NZC selection.Could Nokia clarify their understanding on Alt 1? Is there is a need for the gNB to configure both the CJT scheduling set for CSI reporting and N? We think it is enough the gNB just configures *N* CSI-RS resources. Also, there are some comments about Alt 2 increasing the complexity of the scheduler at the gNB as TRP selection cannot be controlled by the network. Even with reformulated Alt 1, UE does the sub-selection from the configured *N* CSI-RS resources via NZC selection. So we see that in both alternatives, TRP selection is done by UE. So we don’t think this ‘complexity of the scheduler’ argument is valid.**On Issue 1.2**Some companies mention Alt 3 with N SCIs. N SCIs does not make sense to us. There needs to be a single strongest coefficient so that the phase of the other combining coefficients can be reported relative to the single SCI. In our view, Alt 3 only makes sense with a single SCI. We are ok with revised proposal 1.B. **On Issue 1.4**Regarding Proposal 1.D, we note that the number of SD basis *L* is being discussed in a separate proposal (i.e., Proposal 1.E) where we are discussing per CSI-RS resource *Ln*, total number of Ln etc. So, the definition of number of SD basis will any way change from those defined in Rel-16 and Rel-17. So, we suggest removing *L* as follows:* SD basis selection is layer-common and polarization-common, with *~~L~~*~~,~~ *N*1, *N*2, *O*1, *O*2 defined per Rel-16 specification for refinement based on Rel-16 regular eType-II, and per Rel-17 specification for refinement based on Rel-17 PS FeType-II

[Mod: Good catch, thanks]**On Issue 1.5**Regarding Proposal 1.E, it is a bit unclear what the gNB configures in some places. While for Alt1 there are two possible which are TBD, may be we should clarify the case for Alt2. Suggest the following revision: * Alt 2: gNB higher layer configures a common *L* parameter for all *N* CSI-RS resources

[Mod: Correct, done]**On Issue 1.6**Regarding Proposal 1.F, we have a minor clarification:* for each layer, support separate bitmap per each CSI-RS resource

[Mod: another good editorial catch]**On Issue 1.7**We can support Proposal 1.G and Ericsson is added to Support list.**On Issue 1.8**In our view both AP CSI on PUSCH and SP CSI on PUSCH should both be supported as they are both supported in legacy. So far, only one company says they don’t support SP CSI on PUSCH although they don’t provide proper reasoning. As mentioned by Nokia, there is no reason to exclude SP CSI if complexity and number of active ports/resources are allowed. Making support for SP CSI on PUSCH FFS basically has the risk that SP CSI on PUSCH will not be agreed in the end. From our perspective, we will be ok if ‘Support of SP CSI on PUSCH’ is made a working assumption. The other possibility is we could make ‘Support of SP CSI on PUSCH’ a UE capability which will very likely be the case in the end. Overall, we prefer to take the decision on AP CSI and SP CSI together.We can support the 2nd sub-bullet of Proposal 1H for now.[Mod: Modified 1st bullet to keep time-domain behavior open. Added Ericsson on support list]**On Issue 1.9**For mode-1, we support the number of FD basis vectors (*Mv* related to *pv* for Rel-16 and M for Rel-17) to be TRP common.Regarding per-CSI-RS-resource FD basis offset relative to a reference CSI-RS resource, we don’t support it at the moment. We think this is related to issue 1.10 (see bullet on ‘information related to the windows for FD basis’). So it should be studied further along with other issues mentioned in issue 1.10. As pointed out in our paper, what we prefer is to report delay difference between TRPs in form of phase difference per PRB in the Type II CJT report. We think FD basis shifting approach may not work when large delay differences exist among TRPs. Anyway, we need more simulation work to verify the merits of these additional proposals in issue 1.10. |
| NEC | **Issue 1.1:** We can be fine with the reformulation. While we share similar view with some companies that current reformulation seems UE selection TRP for both alternatives. If so, the main difference for the two alternatives may come to be how to design the CSI payload? Maybe we can directly go to the details on CSI design.[Mod: That would be great, but we progress step-by-step ☺]**Issue 1.2:** Support the proposal 1.B, and we support Alt 3.**Issue 1.3:** We support to have strongest TRP indication.**Issue 1.4:** Support proposal 1.D.**Issue 1.5:** Support proposal 1.E, and prefer Alt 1.**Issue 1.6:** We can be fine with the reformulation. While we share similar view with some companies that current reformulation seems UE selection TRP for both alternatives. If so, the main difference for the two alternatives may come to be how to design the CSI payload? Maybe we can directly go to the details on CSI design.**Proposal 1. F/G/H/I:** Support |
| CMCC | **Issue 1.1**We prefer Alt1. NZC selection can already achieve TRP selection.**Issue 1.2**We support Proposal 1.B and prefer Alt3. **Issue 1.3**If the one SCI applied across all N CSI-RS in Proposal 1.B is a global ID in the W2 matrix, we think the strongest CSI-RS is not needed anymore.**Issue 1.4**We support Proposal 1.D.**Issue 1.5**We support Proposal 1.E. If Alt1 in issue 1.1 is supported, we think Ln can be reported by UE to further reduce overhead of coefficients. **Issue 1.6**We support Proposal 1.F.**Issue 1.7**We support Proposal 1.G. It is helpful to reduce W2 overhead.**Issue 1.8**We are OK with Proposal 1.H. SP reporting on PUSCH can also be supported if the reporting overhead and UE complexity is acceptable.**Issue 1.9**We support Proposal 1.I. RRC signaling is enough. |
| Huawei, HiSilicon | **Issue 1.1**We support the reformulation, and prefer Alt1. By NZC selection via bitmaps, Alt 1 can accomplish the same functionality and flexibility of Alt 2 while all configured TRPs are measured, and can maintain the same feedback overhead as preconfigured to avoid waste of resources for UCI.For Alt2, there is also possibility that UE under-estimates some TRPs with instantaneous measurement, thus the performance is degraded. Moreover, UE is not aware of the cell-level information such as scheduling information, load and overall MU interference at gNB side, which will limit the UE selection and make it hard for MU pairing. We also agree that Alt 2 can increase scheduler complexity/challenge in scheduling. With Alt 1, UE will feedback the SD for the configured TRPs if the beam is strong enough, then gNB could have the information of interference so that MU interference can be avoided, by e.g., using the beams orthogonal fedback SD to other UEs under the TRP.**Issue 1.2**Support Proposal 1.B and prefer Alt3. Since the signal strength from different TRPs may vary significantly, with per-TRP reference amplitude and per-TRP per-polarization amplitude group, the range of amplitude within each group is smaller and can be quantified more accurately with a limited quantization alphabet. **Issue 1.3**For the indication of strongest TRP, we failed to see the necessity as the SCI can already provide the reference to phase or amplitude.**Issue 1.4**We are fine with Proposal 1.D. For the per TRP FD basis selection of Rel-16 based codebook with mode1, we prefer a combination of layer-specific and layer-common FD basis to reduce the indication overhead. For the X strongest TRPs, FD basis is layer-specific; while for the other N-X TRPs, FD basis is layer-common (where 1≤X≤N-1).**Issue 1.5**Support Proposal 1.E and prefer Alt1. Regarding Alt1, A total number of basis can be configured by gNB to control the overhead and Ln per TRP can be reported for the strong enough beams measured by the UE.**Issue 1.6**Support Proposal 1.F and agree with Ericsson’s minor clarification.**Issue 1.7**Support Proposal 1.G. **Issue 1.8**Support the first bullet of Proposal 1.H. For the second bullet, we prefer to support the flexibility of re- to change between single-TRP and multi-TRP, so we propose to change as “*An associated Resource Setting includes a CMR comprising K=>1 NZP CSI-RS resources from one CSI-RS resource set*”. This is also aligned with following agreement:AgreementThe work scope of Type-II codebook refinement for CJT mTRP includes the support of NTRP={1, 2, 3, 4} cooperating TRPs for CJT CSI report* FFS: Signaling of NTRP, e.g. higher-layer (RRC) vs. dynamic
* FFS: Determination of NTRP, e.g. NW-configured vs UE-selected
* FFS: Whether to prioritize or only support NTRP={1, 2}

[Mod: Good catch. It should have been K>=1 regardless, thanks]**Issue 1.9**Regarding per-CSI-RS-resource FD basis offset, we share similar view with Nokia/NSB that a unified solution is preferred for both mode1 and mode 2 and both Rel-16 and Rel-17 extension. But for mode1, even though with the reported FD basis offset, the FD basis selection should be TRP-specific rather than a single FD basis set. In addition, the reporting of FD basis offset is strongly related to the FD windows information that they can be discussed together.Regarding the number of FD basis vectors for mode1, we prefer TRP-common to avoid the varying NZC bitmap size. Then the total size of bitmap can be $\sum\_{n=1}^{N}2L\_{n}M\_{v,n}=2L\_{tot}M\_{v}$ for TRP-common $M\_{v,n}=M\_{v}$.And we are fine with the mode switching by gNB configured via higher-layer signaling.**Issue 1.10**We support receiver side information feedback for CJT by per-RX reporting obtain the full channel, where the full channel is $H=\left[h\_{1} h\_{2}…h\_{t}\right]=W\_{1}W\_{2}W\_{f}$ and $h\_{t}$ is the channel measured at antenna port *t* by UE. Regarding the FD basis window, it can be discussed together with the FD basis offset. It seems the basis offset can be achieved by reporting of the FD basis window, e.g., reporting of Minit for both Rel-16 and Rel-17 based refinement.We support to discuss the issue of large delay spread between TRPs, which leads to more frequency selectivity. From companies’ contributions, there are following proposals to resolve. We are open to discuss all potential ways to resolve it* Finer frequency granularity in CSI reporting, by larger R (e.g. R=4).
* RB-level phase shift or RB-level FD basis offset
* Reporting of delay difference between TRPs.

. |
| Mod V39/43 | **Minor editorial revisions for proposals 1.B, 1.E, 1.F****For 1.H, now I keep the time-domain property open per Ericsson, Lenovo Nokia, and ZTE input**  |
| NEC | **Issue 1.2:** Regarding the updated part for proposal 1.B* + - Reference amplitude (and its location) for each of the 2N amplitude groups is reported

We’d like to clarify the part “(and its location)”, is this something like SCI? and the parentheses mean this part may not be needed? If so, we think whether SCI is needed for each of 2N amplitude groups needs further discussion. One possible way is that, only one SCI is needed for one of the 2N amplitude groups, and the corresponding amplitude coefficient is 1 (no need of report), while for other amplitude coefficients, reported may always be needed. To make is more clear, we suggest:* + - Reference amplitude (and/or its location) for each of the 2N amplitude groups is reported

[Mod: Thanks for the good comment. You are correct that 1 of the 2N amplitudes corresponds to SCI and the location isn’t needed. Revised] |
| Spreadtrum | **Issue 1.1**We don’t think Alt2 can be implemented in Alt1 using NZC selection. The reason is that if W2 grouping is per TRP per polarization with a single SCI across all TRPs, there should be a reference amplitude in each group. According to legacy rule, the reference amplitude in each group other than the one indicated by the SCI should be reported and the corresponding bit within the bitmap should be 1. As a result, TRP selection cannot be achieved.We share similar view as some companies that UE based TRP selection can save UE complexity by avoid calculating CSI parameters for weaker TRP(s). On the other hand, gNB can set the CSI parameters corresponding to weaker TRP(s) to default values (e.g., amplitude = 0), if needed.**Issue 1.2**For Alt3, regarding 1 SCI vs N SCI, we have a clarification question: For 1 SCI, does it mean the SCI indicates the location of strongest amplitude among 2N groups (only one strongest amplitude), or the location of strongest amplitude in each TRP (total N strongest amplitudes)?[Mod: among all 2N groups]If it means only one strongest amplitude, the location of reference amplitudes corresponds to other TRPs should be indicated as well. [Mod: Yes, that’s already clarified in the latest version]If the indicator for the location of reference amplitudes cannot be called SCI, additional parameter needs to be introduced.[Mod: Correct] **Issue 1.3**Yes. N strongest coefficients can be differential quantized relative to the strongest coefficient of strongest TRP.**Issue 1.4**Support proposal 1.D.**Issue 1.5**Support proposal 1.E. Alt1 is preferred for better flexibility.**Issue 1.6**Support proposal 1.F.**Issue 1.7**Support proposal 1.G**Issue 1.8**Support proposal 1.H. AP CSI report should be enough.**Issue 1.9**Support proposal 1.I.We also support to introduce per-CSI-RS-resource FD basis offset in mode-1. |

### Issue 2: Type-II codebook refinement for high/medium UE velocities (with time/Doppler-domain compression)

Table 3A Summary: issue 2

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 2.1 | [109-e] **Agreement**The work scope of Type-II codebook refinement for high/medium velocities includes refinement of the following codebooks, based on a common design framework:* Rel-16 eType-II regular codebook
* Rel-17 FeType-II port selection (PS) codebook

FFS: Whether to prioritize/down-select from the two**Proposal 2.A**: The Rel-18 Type-II codebook refinement for high/medium velocities comprises refinement of the following codebooks:* Refinement of the Rel-16 eType-II regular codebook
* Refinement of the Rel-17 FeType-II port selection (PS) codebook, based on the same design details as the Refinement of the Rel-16 eType-II regular codebook, except for the supported set of parameter combinations
	+ Time-/Doppler-domain reciprocity is not assumed

**FL Note**: This proposal has been discussed in RAN1#110  | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi, ZTE (Rel-16 first), Fraunhofer IIS/HHI* **Concern:** vivo, Lenovo, LG, Apple, DOCOMO, Spreadtrum

**Down-select to only Rel-16 eType-II:** Apple, DOCOMO, MediaTek, NEC, Xiaomi, Samsung, Lenovo, Intel (if Rel-17, no DD reciprocity), Xiaomi. Qualcomm, Apple, DOCOMO, Ericsson, Nokia/NSB, LG, Spreadtrum, CMCC, vivo, OPPO, Google **Proposal 2.A:*** **Support/fine:** IDC, ZTE, Huawei/HiSi
* **Not support (Rel-16 only):**
 |
| 2.2 | Supported RI values**Proposal 2.B**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support RI={1,2,3,4}. | **Support/fine:** Xiaomi, Fraunhofer IIS/HHI, Apple, Samsung, Qualcomm, Nokia/NSB, IDC, vivo, OPPO, Google, ZTE, Ericsson, Huawei/HiSi, CMCC, MediaTek, Spreadtrum**Not support (1,2 first – 3,4 FFS):** Lenovo, Intel  |
| 2.3 | **Proposal 2.C**: For the Rel-18 Type-II codebook refinement for high/medium velocities, down-select at least one from the following codebooks structures (by RAN1#110bis-e):* Alt1: Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
* Alt3. Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f}⨂I)^{H}$

In addition:* Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specification
* FFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.
* FFS: Whether Doppler-/time-domain (DD/TD) basis vector length (N4) is RRC-configured or reported by the UE
* FFS: Whether the number of selected DD/TD basis vectors (for Alt1) is RRC-configured or reported by the UE

**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 2.1 | **Support/fine:** Samsung, ZTE, MediaTek, vivo, Qualcomm, Apple, LG, OPPO, Huawei/HiSi, Xiaomi, Intel, Spreadtrum, DOCOMO, NEC, Fraunhofer IIS/HHI, Lenovo, Sharp, Ericsson, Google, MediaTek, vivo, CATT, IDC, Sony, CMCC, Nokia/NSB, CEWiT , CMCC**Not support:** |
| 2.4 | **Proposal 2.D**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:* For N4=1, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f})^{H}$
* For N4>1, Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ Only Q (denoting the number of selected DD basis vectors) >1 is allowed
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
	+ FFS: Whether *Q* is RRC-configured or reported by the UE

Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specificationFFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 2.2 | **Proposal 1.D:*** **Support/fine:** Samsung, ZTE, Qualcomm, Apple, Google, OPPO, Huawei/HiSi, Intel, Spreadtrum, CATT, DOCOMO, NEC, Fraunhofer IIS/HHI, Sharp, IDC, Sony, MediaTek, CEWiT, LG, ZTE, CMCC
* **Support if switching at N4=2:** Nokia/NSB, Ericsson, vivo
* **Not support:**

**Rotation factor for DFT basis:*** **No:** Huawei/HiSi, Xiaomi, Ericsson, Qualcomm, MediaTek, Intel, OPPO, Google
* **Yes (details FFS):** Fraunhofer IIS/HHI, ZTE (can be flexible), Samsung
 |
| 2.5 | **Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where *δ* ≥ 0
* FFS: Possible value(s) of *δ* and possible value(s) of WCSI

Note: Per legacy behavior, the legacy CSI reference resource, i.e., (*n* – *nCSI,ref* ), is reused for locating the last CSI-RS occasion used for a CSI report**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 2.3 | **Support/fine:** Samsung, vivo, Qualcomm (questionable regarding CQI prediction), DOCOMO, Lenovo, IDC, ZTE, Spreadtrum, vivo, [LG], CATT, Intel, NEC, Xiaomi, CMCC, MediaTek, Ericsson, [Nokia/NSB], OPPO, Huawei, HiSi, Fraunhofer IIS/HHI**Not support:** Google (remove n-nref) |
| 2.6 | **Question**: In addition to the already agreed assumption of UE-side prediction, can the Rel-18 Type-II codebook refinement for high/medium velocities be used with the following assumption?1. Legacy UE procedure for CSI measurement/calculation (the only spec impact would be to enable this as an option for CSI measurement/calculation. If proposal 2.E is agreed and W\_CSI=1 is supported for the legacy reference resource, the answer to this question is “yes”)
2. gNB-side prediction (to be incorporated in the spec, assumed by the UE in CSI measurement/calculation)

**FL Note**: This proposal has been discussed in RAN1#110.  | **Legacy:*** **Yes:** Qualcomm, Lenovo, LG, Apple, Google, ZTE, Xiaomi
* **No:** MediaTek, Nokia/NSB, Ericsson (ok for CSI-RS measurement but not for CSI calculation)

**gNB-side prediction (to be specified, assumed by the UE in CSI measurement/calculation):** * **Yes**: Google, CATT, Xiaomi, Spreadtrum
* **No**: Samsung, vivo, MediaTek, LG, Nokia/NSB, Ericsson, CMCC, Huawei/HiSi,
 |
| 2.7 | CSI-RS resource types/structures **supported** for measurement (discussion on whether/how the legacy Resource setting needs enhancement will take place in later rounds)**Proposal 2.G**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the following CSI-RS resource types/structures for CMR:* Time-domain behaviour for NZP CSI-RS resource: periodic, semi-persistent, aperiodic
	+ FFS: Whether to introduce constraints on allowed configuration
* The use of K≥1 NZP CSI-RS resources:
	+ FFS: details

[109-e] **Agreement**On potential refinement of Resource setting configuration associated with Type-II codebook refinement for high/medium velocities, study the following options to assess whether/how the legacy Resource setting configuration needs to be enhanced for “burst” measurement:* Periodic (P) CSI-RS: periodicity and offset
* Semi-persistent (SP) CSI-RS: activation/deactivation, periodicity, and offset
* Aperiodic (AP) CSI-RS: triggering, offset of a group of AP CSI-RS resources

FFS: Support for K>1 NZP CSI-RS resources association with Type-II codebook refinement for high/medium velocitiesFFS: Whether specification support for jointly utilizing two types of CSI-RS time-domain behaviors is needed**FL Note**: This proposal has been discussed in RAN1#110 | **Proposal 2.G:*** **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC, Sharp, Apple, Huawei/HiSi, Fraunhofer IIS/HHI, IDC, Ericsson
* **Not support:** vivo (concern on AP), Intel (concern on AP)
 |
| 2.8 | **Proposal 2.H**: For the Type-II codebook refinement for high/medium velocities, only CSI reporting over PUSCH is supported * FFS: Whether AP only, or both AP and SP (following legacy), is supported

**FL Note**: This basically follows the legacy Rel-16/17 spec re Type-II codebook and reuses the legacy CSI-RS | **Support/fine:** Qualcomm, Samsung, vivo, OPPO, Google, ZTE, Xiaomi, DOCOMO, Lenovo, ZTE, CATT, Fraunhofer IIS/HHI, Ericsson, Nokia/NSB, CMCC, Huawei/HiSi, , Spreadtrum**Not support:**  |
| 2.9 | **Proposal 2.I:** For the Type-II codebook refinement for high/medium velocities, down-select from the following alternatives: * Alt1. *Q* different 2-dimentional bitmaps are introduced for indicating the location of the NZCs, where the qth (q=1,…., *Q*) 2-dimentional bitmap corresponds to qth selected DD basis vector
	+ The number of selected DD basis vectors is denoted as *Q*
	+ This implies that for each layer, the location of NZCs in SD-FD can be different for different selected DD basis vectors.
* Alt2. A DD-basis-common per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is used
	+ This implies that for each layer, the location of NZCs in SD-FD is common across all the Q selected DD basis vectors

FFS: Further overhead reduction on bitmap(s)FFS: Whether the number of NZCs is upper bounded across all DD basis vectors or per DD basis vector | **Support/fine:** Qualcomm, Samsung (Alt2), Intel (Alt1), IDC (Alt2), vivo, OPPO, ZTE(Alt1)**,** Xiaomi(Alt1), DOCOMO, CATT, Ericsson (Alt1), CMCC (Alt1), Huawei/HiSi**Not support:** |
| 2.10 | DD basis selection:* Alt1. Per layer,
	+ The number of selected DD basis vector (denoted as *Q*) is layer-common
* Alt2. Layer-common

**FL Note**: The above alternatives are analogous to legacy principle for SD/FD compression.  | **Alt1:** Intel, Qualcomm, Samsung, Apple, Google, ZTE, CMCC, Huawei/HiSi**Alt2:** |
| 2.11 | For one CSI reporting instance associated with the Type-II codebook refinement for high/medium velocities, for a given CQI sub-band (in frequency domain, per Rel-15 specification) and a given layer, how many CQIs (sampled across time-/Doppler-domain) are included?  | **Only 1:** Google, Qualcomm, vivo, CATT, MediaTek, Spreadtrum**≥1 (configurable):** ZTE, NEC, Samsung, Ericsson, Nokia/NSB, Huawei/HiSi, Xiaomi, DOCOMO |
| 2.12 | [110] **Agreement**For the Rel-18 Type-II codebook refinement for high/medium velocities, support DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook) as a codebook parameter.* FFS: whether this parameter is defined as a function of another parameter
* FFS: whether this is used for PMI only, or PMI/CQI
 | **PMI only:** Huawei/HiSi, ZTE, MediaTek, Qualcomm, vivo, Google, CATT**PMI and CQI (common vs independent FFS):** Samsung, Xiaomi, Ericsson |
|  |  |  |

Table 3B Type II Doppler: summary of observation from SLS

|  |  |
| --- | --- |
| **Company** | **SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 2.3, 2.4 | SLS: UPT | Observation 7: For R17 FeType II and R16 eTypeII codebook enhancement, Alt2B has no obvious performance gain compared with Alt2A.Observation 8: For R17 FeTypeII and R16 eTypeII codebook enhancement, compared with Alt2A, Alt3 which reports double W2 is worse than Alt 2A with double CSI overhead.Observation 9: For R17 FeType II and R16 eTypeII codebook enhancement, there’s no obvious performance gain between orthogonal DFT without rotation factor, orthogonal DFT with rotation factor and oversampled DFT. |
| ZTE | 2.5, 2.12 | SLS: UPT | Based on the SLS results for high/medium UE velocities in UMa in Figure 5, the distinct average UPT and cell-edge UPT gain can be obtained between CSI prediction scheme (Alt1.B or Alt2.B) and legacy CSI scheme. However, it is not observed that there is a big difference between Alt1.B and Alt2.B. Moreover, we also observe that the variation of CQI is quite slow, which means that the parameter for supporting DD/TD compression unit, described in Agreement#5, can be used for PMI only as a starting point |
| 2.7 | Cross-correlation  | * For periodic CSI-RS configuration, it can be observed in Figure 1 that the periodicity of CSI-RS transmission marked in green is 5 slots. Under 5 measurement samples, cross-correlation from slot n+6 to n+10 between predicted channel (Wiener and extrapolation) and real-time channel can be greater than 0.97, as shown in Figure 3.
* In addition, for aperiodic CSI-RS configuration as shown in Figure 2, it is observed that the cross-correlation from slot n+6 to n+10 between predicted channel and real-time channel is still greater than 0.93, shown in Figure 4.
 |
| Vivo | 2.3, 2.4, 2.5 | SLS: UPT | For UE based CSI prediction performance * + UE based prediction assuming Alt 2B and N4=1 achieves significant performance gain
	+ Smaller N4 brings higher performance gain than larger N4 values
	+ Measurement with 16 CSI-RS occasions has higher performance gain than 8 CSI-RS occasions, especially for medium or large N4 values

We evaluate the performance of DD compression ratio 0.2 and 1 (No compression) for N4=6. The results are given in Table 2. It can be observed that clear performance loss exists. This loss will basically eliminate the gain of CSI prediction for N4=6 as the gain for no compression compared with no prediction is only 4.15% as show in Table 1. |
| OPPO | 2.3, 2.13 | UPT vs overhead | DFT basis outperform identity basis at low overhead, the gain is about 10% for N2=2We show the performance of N4 >= 1 in figure 3. The measurement window is set to {16, 24, 32} ms respectively. There are {4, 6, 8} CSI-RS occasions for time unit 4 slots and {8, 12, 16} CSI-RS occasions for time unit 2 slots. We assumed time unit equals CSI-RS spacing. Frequency-time domain LMMSE is used for channel prediction where covariance is measured from Wmeas. Reporting window size is prediction horizon (from the latest CSI-RS occasion). The overhead for each setting of W\_CSI is about 300 bits, R16 PC6 is the reference. Although the prediction is less reliable as W\_CSI increase, the performance gain is still obvious. Moreover, supporting N4 > 1 could reduce the normalized overhead. At medium velocity, precoder may only hold on in duration of 1~2 ms, supporting N4=1 only may be quite wasteful in terms of CSI-RS and CSI overhead |
| Google | 2.3, 2.4 | Square cosine similarity | When the UE velocity is high and the interval between the CMR instances is large, the performance loss due to the DD/TD domain compression could be big. Figure 2 illustrates the square cosine similarity (SCS) distribution for the CSI with DD/TD domain compression with different number of DD/TD basis, where N4 is assumed as 10, the interval between each CMR instance is 1 ms and the UE velocity is 120 km/h. The SCS is calculated based on the ideal channel eigenvector and the decompressed channel eigenvector for each CMR instance. Figure 3 illustrates the SCS distribution when the UE velocity is 60 km/h. Figure 4 illustrates the SCS distribution when the UE velocity is 10 km/h.It can be observed that the best number of DD/TD basis should be different for different UE velocity. When the UE velocity is too high, the identity matrix can be used. When the UE velocity reduces, DD/TD compression can be used. |
| Intel | 2.3, 2.4 | UPT vs overhead | Observation 1: * PMI codebooks with DFT-based DD compression (Alt. 2A, Alt. 2B) has significantly lower overhead comparing to Alt. 3

Alt. 2A outperforms Alt 2B for most of codebook configurations |
| MediaTek | 2.3, 2.4, 2.5, 2.7 | UPT | * Extrapolation performance degrades as the size of CSI reporting window increases.
* Assuming CSI interpolation, joint CSI calculation for the entire TD unit is more robust than individual CSI calculation for each slot.

Next, we compare the case of using the latest CSI-RS transmission occasion as reference and the case of using the predicted CSI as reference. Specifically, the reference is used to calculate single $W\_{1}, W\_{f}$, RI, and CQI for the entire CSI reporting window. Both cases assume Scheme 3 and the results are shown in Table 2. It can be seen that for the UMa scenario with UE speed 30 km/h, using the predicted CSI as reference provides a better performance. To summarize, from the perspectives of performance and UE complexity, it is worth the specification effort to support that the CSI reporting window starts no earlier than the CSI reporting slot $n$* To enhance the throughput for the case of UMa 60 km/h, reducing CSI-RS periodicity to 2, 3 ms is beneficial.
* Linear prediction does not perform well under CSI-RS burst measurement.
 |
| Fraunhofer IIS/HHI | 2.3, 2.4, 2.13 | UPT | * The performance gain increases with increasing oversampling factor.
* Rotation factor reporting per SD component further reduces the feedback overhead in reporting the selected TD/DD components.
* An oversampling factor of four suffices to provide a significant better performance compared to the baseline.
* Enhanced Type II CB with Doppler domain information outperforms Rel. 16 eType-II CB in terms of both performance and feedback overhead by a large margin
 |
| Samsung | 2.3, 2.4, 2.5, 2.7, 2.11, 2.12 | UPT vs overhead | Observation 13: Alt1 and Alt2 achieve similar performance vs overhead trade-offObservation 14:* Alt1B outperforms Alt2B
* There is an ‘optimal’ $W\_{CSI}$ (predicting beyond this window does not help)
	+ Alt1B with CSI window $[n\_{ref},n+X]$ is the best among the considered CSI windows
	+ In general, the value of $X$ depends on UE speed (cf. Appendix C)

Observation 15: * 2 CQIs can achieve better UPT vs overhead trade-off than one CQI (up to 2% gain in avg. UPT gain)
* The order of the overall UPT vs overhead trend is 2 CQIs > 4 CQIs ~ per slot CQI > 1 CQI

Observation 16: CSI-RS burst separation = 1 slot achieves better UPT vs overhead trade-off than CSI-RS burst separation = 5 slots. |
| Ericsson | 2.3, 2.4, 2.12 | UPT vg overhead | 1. For type II Doppler codebook with a 16Tx2Rx and 60 km/hr scenario, Alt 2 results in a larger overhead compared to Alt1, and Alt 2 only provides some small gains over Alt 1.
2. Alt3 is beneficial for the case where reporting a single predicted PMI results in significant performance improvement
3. For type II Doppler codebook with a 16Tx2Rx and 60 km/hr scenario, when AR prediction is considered, Alt3 with a single predicted PMI provides similar gains as Alt1 and Alt2 but at a much reduced overhead.
4. Performance of Alt1 compared to Alt3 depends on the accuracy of the UE side channel predictor.
5. We find no performance gain in considering DFT TD-bases with a rotation factor

As shown in Figure 14, there are some reductions of the gains compared to Rel-16 when only a single CQI is used instead of $N\_{CQI}$=$N\_{4}$, especially for the cell-edge users and for longer CSI feedback periodicity $T\_{F}$. However, we have also found simulation cases, e.g., 4 RX, with limited gain of using $N\_{CQI}$=$N\_{4}$ compared to $N\_{CQI}$ =1, and thus selecting a good $N\_{CQI}$ value may be scenario dependent |
| Qualcomm | 2.3, 2.4, 2.5 | UPT, overhead | Observation 1: Beam-specific TD basis selection has about 1% TPUT gain over beam-common, at a cost of 7.7% increased overhead.Observation 3: For different CSI window location (starting slot *l*), similar performance is obtained based on a same CSI window length N4. |
| Nokia/NSB | 2.5 | UPT, cosine similarity | In Figure 4, Figure 5, Figure 6, the cosine similarity is compared for each of the two layers, for UE speed of 10, 30 and 60km/h, whilst in Figure 7 and Figure 8, mean and cell-edge throughput are compared, respectively. We observe that the prediction gain of Type-II-Doppler is generally consistent with speed. However, the relatively significant gain observed in cosine similarity does not appear as large in throughput. Also note that the feedback overhead is larger for Type-II-Doppler than for the baseline because two CSIs are sent per report rather than one, although they share the same $W\_{1}$ and $W\_{f}$. |
| **Summary**:  |

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 3A, especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **More moderator proposals may be added in the next revision**
 |
| vivo | **Proposal 2.A**We don’t agree to further span the scope of 9.1.2 after we have already done so in last meeting. We support to only enhance Rel-16 eType II CSI. We have serious concern to include the work on Rel-17 FeType II CSI due to the workload.**Proposal 2.D**We think the intention of this proposal is to support Alt 3 and Alt 1 based on the configured N4 value. For N4 < the switching point, at least N4 =1 is supported. The detailed value of the switch point can be further studied, for which we propose N4=4. Hence we think a more accurate formulation of the current status is the following.**Proposal 2.D**: For the Rel-18 Type-II codebook refinement for high/medium velocities, support the following codebook structure where N4 is gNB-configured via higher-layer signaling:* For N4<= N0, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.* $W\_{1}\tilde{W}\_{2}(W\_{f}⨂I)^{H}$
	+ At least N4=1 is supported
* For N4> N0, Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases reusing the legacy$W\_{1}$and$W\_{f}$*,* e.g.$W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$
	+ TBD (by RAN1#110bis): whether rotation is used or not
	+ FFS: identical or different rotation factors for different SD components
	+ FFS: Whether the number of selected DD/TD basis vectors (denoted as *Q* at least for discussion purposes)) is RRC-configured or reported by the UE
* For the switch point N0, support one of the following
	+ Opt 1: N0 = 4
	+ …

Note: Detailed designs for SD/FD bases including the associated UCI parameters follow the legacy specificationFFS: Whether one CSI reporting instance includes multiple $W\_{2}$ and a single $W\_{1}$ and $W\_{f}$ report.[Mod: There are at least 2 companies, e.g. Fraunhofer IIS/HHI, who have serious concern on Alt3 and can only compromise with N4=1 as the switching point. Else, I’d have no choice but to propose the original offline proposal 2.2 which seems to have represented super-majority. Regardless I put “1” in brackets. SO there is no need to revise the formulation per your suggestion since this needs to be discussed anyway,]**Proposal 2.E**Regarding the reference of CSI reporting window in case UE-side prediction is assumed, **it has been agreed in RAN1#109e that it is a length-WCSI window starting from slot l, i.e., it is a window of [*l*, *l*+*W*CSI –1]**. Two alternatives are suggested down selecting in RAN1#110, i.e.,* Alt 1B: **l ≥ n\_ref**, where n\_ref is a CSI reference resource slot as boundary
* Alt 2B: **l ≥ n**, where n is the CSI reporting slot as boundary

It is clear that from the previous agreements, the start of the CSI reporting window is l, and l >= n is defined for Alt 2B. Hence it is clear that Alt 2B includes the case that the start of the CSI reporting window is after slot n. Further, to support the case with N4=1, it only makes sense for UE prediction to have l>n, as gNB needs to know the CSI after the CSI report reception. Hence we suggest the following change.**Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after the slot with a reference resource (*l* ≥ *n*ref) where the location of CSI reference resource is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of CSI reference resource location include the legacy slot location (*n* – *nCSI,ref* ) and slot *n+ndelta,* where *ndelta* is configured from thenumbers {0, 2, 4}
* FFS: Possible value(s) of WCSI

[Mod: OK, putting the values 2, 4 in brackets for now]**Issue 2.6**We don’t support gNB side prediction. **Proposal 2.G**We still have concern on the supporting AP CSI-RS, due to the following reasons* It introduces large latency for CSI reporting due to triggering a number of CSI-RS occasions after sending the CSI triggering DCI.
* The large CSI latency requires gNB to schedule PUSCH with long duration between DCI and PUSCH. It will forbid gNB to schedule any other PUSCH for this UE due to out of order (OOO) issue during this long duration, which will reduce UL throughput.
* Last but not least, to support AP CSI-RS, RS enhancement is needed as the current specification does not support to use one DCI to trigger AP CSI-RS spanning more than 1 slot. However, RS enhancement is not included in the WID.

Hence we support to have only P/SP CSI-RS with one resource in this proposal.[Mod: Thanks, we can check if other UE vendors share your concern as well]**Issue 2.11**We support only one CQI, which means W\_CSI is 1 or N4 TD units in this case. |
| Mod V2 | **Revised proposals 2.E per vivo input, please check** |
| MediaTek | **Issue 2.4**: We can be fine with Proposal 2.D with brackets. We prefer the identity basis is supported for $N\_{4}=1$, 2.With the same feedback overhead as the agreed baseline in EVM, $N\_{4}=1$ can provide a competitive throughput gain compared with larger $N\_{4}$ values. In addition, NR is designed to be flexible, so the case of $N\_{4}=1$ should be supported. Identity basis should also be supported for $N\_{4}=2$. If Doppler-domain orthogonal DFT basis is commonly selected for all SD/FD bases, then time-domain compression implies gNB only acquires one Doppler component. Recovery from a single Doppler component involves merely phase rotation. As common phase rotation does not change the performance of precoders, gNB might as well double the size of TD unit and set $N\_{4}=1$.As proved by Qualcomm, rotation is not needed to be specified when Doppler-domain orthogonal DFT basis is commonly selected for all SD/FD bases. We remark that rotation can be useful for compression, but it can be absorbed into $W\_{2}$ and thus transparent to gNB.**Issue 2.5**: We support Proposal 2.E in general. We share the same view as vivo that the starting position of CSI reporting window can be configurable, depending on gNB’s processing capability and scheduling. The supported set of values for $δ$ can be FFS.Although we do not prefer to include the legacy slot location ($n-n\_{CSI\\_ref}$), we can make a compromise for making progress. In our understanding, the legacy CSI reference resource, i.e., slot $n-n\_{CSI\\_ref}$, should be reused for locating the last CSI-RS occasion used for a CSI report. In other words, the legacy CSI reference resource is reused for CSI measurement. We prefer to add a note to Proposal 2.E:**Note: The legacy CSI reference resource, i.e., slot** $n-n\_{CSI\\_ref}$**, is reused for locating the last CSI-RS occasion used for a CSI report.**[Mod: Good point, done]**Issue 2.6**: Legacy UE procedure for CSI measurement/calculation can be assumed up to UE implementation, so the answer to the question should have no specification impact. We think the configuration of $l=n-n\_{CSI\\_ref}$ and $W\_{CSI}=1$ is redundant and should be avoided.As for gNB-side prediction, no promising gains are reported by companies, so we prefer not to incorporate gNB-side prediction into specification. If any company would require more time, we are fine to defer the final decision until the next RAN1 meeting.Regarding Proposal **2.H**, we would like to point out based on 38.214 SP CSI is also supported for R16 Type II and R17 FeType II:“Semi-persistent CSI reporting on the PUSCH supports Type I, Type II with wideband, and sub-band frequency granularities, Enhanced Type II and Further Enhanced Type II Port Selection CSI. The PUSCH resources and MCS shall be allocated semi-persistently by an uplink DCI.”However, we are supportive of only supporting AP CSI for Type-II codebook refinement for high/medium velocities[Mod: Thanks for pointing this out. Done] |
| Fraunhofer IIS/HHI | We have serious concerns with Vivo’s proposal. We have extensively discussed this issue offline and as a compromise we have accepted N4 = 1 with out compression. Any other value other than 1 will not be acceptable to us. We do not agree with the point that compression cannot be achieved with N4 =2. Compression can still be achieved with N4 = 2 as pointed out by many companies (please look to our response in the previous offline discussion). [Mod: Understood, removed the brackets around 1]  |
| Qualcomm | Re 2.5We are OK with the proposal for standard progress.We have question/concern on the feasibility of CQI prediction – regarding “the location of CSI reference resource is configured (from multiple candidate values) by gNB” in proposal 2.E, although we are open to study.Anyhow, in our view, CQI prediction should be conditional on UE capability.[Mod: Correct, in all likelihood this will have to be UE capability – which will be discussed when UE feature for Rel-18 starts (usually 2 meetings before the WI ends, i.e. Aug/Oct 2023)]Re 2.7We are OK with the proposal for standard progress. Still, we want to point out:AP CSI-RS burst would be more friendly to UE implementation due to it being “causal” (i.e. all CSI-RS occasions occur after PDCCH): (1) No need to pre-buffer CSI-RS occasion(s); (2) More importantly, it can be notified to UE to receive with phase continuity, before receiving a burst of CSI-RS occasions. (Since most companies’ assumption is H-based extrapolation, receiving phase continuity is essential.)For AP/SP CSI-RS, some restriction should be satisfied for “causal”-like usage.[Mod: Added FFS for this]Therefore, for vivo’s concern on long latency b/w PDCCH and PUSCH, still, we haven’t changed our view as provided in the last meeting: We don’t see a difference b/w AP CSI-RS and P/SP.Re 2.9We’d like to add a sub-bullet for some clarification regarding the size of the 3-D bitmap:

|  |
| --- |
| * FFS: The size of this 3-dimensional bitmap (2LMQ or smaller)
 |

[Mod: Done]Besides, also add our preference in some other issues with tracked change. |
| Samsung | **Proposal 2.D:** support the FL proposal. We have similar concerns (large overhead) with identity DD basis (Alt3) for N4>1. Re N4=2 commented by e.g. MediaTek.* With identity basis, the overhead is large (2x) due to 2 W2
* With DFT basis, Q can be either 1 or 2. The issue brought up on Q=1 (that it only performs phase rotation and has no impact on PMI selection along DD) applies to any N4 value, not only to N4=2. With Q=2, for a given (SD,FD) basis pair, the UE can select 0, 1, or 2 DD basis vectors (using NZC selection), so there is still some compression gain (which isn’t possible for identity basis).

Therefore, we tend to agree with, e.g. Fraunhofer, that DFT basis is still prevalent for N4=2.**Proposal 2.G:** * we support AP and SP, and can be OK with P for progress, although we don’t see any need for P CSI-RS if SP CSI-RS is supported.
* Based on our SLS results, we do see a need for supporting faster CSI-RS measurement (E.g. per slot), which can’t be supported with current spec on P/SP CSI-RS (the min period can be 4).
* Besides, Type II CSI report is AP, and AP CSI-RS resource is a natural choice for AP CSI report. P/SP CSI-RS measurement for Type II CSI can be an over-burden for a UE.

**Proposal 2.I*** The overhead of a 3D bitmap can be $2LMQ$ per layer, which can be large if legacy $(L,M$) are supported, and even if $Q$ is small (e.g. 2,3). There are two options to control the overhead:
	+ Option 1: 3D bitmap size ($2LMQ$) is at most or similar to legacy (Rel16), i.e., Rel. 16 bitmap overhead is an upper bound
	+ Option 2: 2D bitmap (e.g. legacy bitmap applied to all DD/TD units).

We prefer to study these options.**Proposal 2.I:** For the Type-II codebook refinement for high/medium velocities, study* Option 1: the per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is extended to a per-layer 3-dimensional bitmap
	+ The third dimension is associated with the number of selected DD basis vectors (denoted as *Q* at least for discussion purposes)
* Option 2: the per-layer 2-dimensional bitmap for indicating the location of NZCs used in Rel-16/17 Type-II is reused for all DD/TD units

[Mod: Added Alt2 with different wording]Issue 2.12* Based on our SLS results, we do see up to 2% avg. UPT gain with 2 CQIs (over 1 CQI). So, at least 2 DD/TD units for CQI reporting should be supported. More than 2 can be studied further.
 |
| MediaTek | **@Samsung:** On **Issue 2.4**, in our understanding, NZC selection can also be applied to identity basis. It can be FFS whether the selection is across TD units or per TD unit. Thus, we do not agree that the overhead is necessarily large.Indeed $Q=1$ can apply to all $N\_{4}$ values, but it is not the only option for $N\_{4}=2$ if Doppler-domain compression is assumed.If $Q=N\_{4}$ can be configured at least for small $N\_{4}$ values, then we are fine with DFT basis for all $N\_{4}$ values.[Mod: Thanks for your understanding. It seems the issue is Q=1 not affecting SINR (hence PMI selection). Added constraint only Q>1 is supported when DFT is used (N4>1) which should achieve the same thing as your suggestion. Re N4=1 with identity, although you are fine not to have it ☺ a small # companies still strongly want it]**Issue 2.11**: In our understanding, CQI depends on interference, which is difficult to predict. Thus, the CQI would be calculated by assuming interference is unchanged. In other words, interference prediction follows “sample and hold”. If it happens that the interference has a stable influence on CQI, then calculating CQI using predicted channel may be beneficial. However, we think one CQI should be enough because it is very likely that interference can change a lot after some period, especially when the precoders are updated frequently.  |
| Mod V9 | **Revised some proposals per companies’ inputs** |
| Lenovo | **Issue 2.1 (Proposal 2.A):**We share the same concerns as vivo regarding support of Rel-7 FeType-II CB as an additional basis of Rel-18 Type-II codebook refinement. We do not see the gain of introducing such basis unless the CSI-RS beamforming exploits DD reciprocity, which would require extensive study. Preference is to keep Rel-16 eType-II regular codebook as baseline**Issue 2.2 (Proposal 2.B):**Our preference is to prioritize Rank 1,2. At high speed, due to CSI prediction, the CSI quality is expected to deteriorate throughout WCSI window (the larger the Doppler, the less the precision of the predicted CSI over WCSI due to shorter channel coherence time). Rank 3,4 are nominally supported for good channel conditions with precise CSI, which may not be the case at high speed. Prefer to start off with Rank 1,2 design**Issue 2.4 (Proposal 2.D):**In our understanding, for DFT-based Wd, Wd dimension is N4xD, where N4≥D. Therefore at N4=1, Wd boils down to a scalar value of 1 and both Alt-1A and Alt-3 would be the same. We prefer to set the N4 threshold to N4=2 rather than N4=1[Mod: Please review comments from companies especially Fraunhofer and MediaTek. Also LG’s good summary below]**Issue 2.5 (Proposal 2.E):**Agree with FL updated proposal as a compromise**Issue 2.6:**We support including legacy UE procedure for CSI measurement/calculation as a fallback approach in case the UE cannot generate CSI with required CQI BLER target. Regarding the comments not to support “gNB prediction”, in our understanding nothing prohibits the network from updating the precoder based on the received CSI, even under UE-side prediction[Mod: As noted since last meeting, this is about gNB side prediction that results in spec impact. gNB is always free to do whatever it wants as a part of its implementation]**Issue 2.7 (Proposal 2.G):**Agree with FL updated proposal. Support AP and SP CSI-RS resource types**Issue 2.9 (Proposal 2.I):**OK to study both alternatives. Prefer to discuss after proposal 2.C, 2.D discussions are concluded, since bitmap depends on codebook structure**Issue 2.10:**OK to study both alternatives. Prefer to discuss after proposal 2.C, 2.D discussions are concluded, since bitmap depends on codebook structure**Issue 2.11:**We believe this is an important question that needs to be addressed. Below we propose four solutions which span different alternatives and can be a good starting pointProposal 2.K: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, the following alternatives are studied for CQI reporting* Alt1: A single CQI value corresponding to the entire WCSI window
* Alt2: Two CQI values corresponding to the first and last time slots of the WCSI
* Alt3: *N*4 CQI values corresponding to the *N*4 time units
* Alt4: *K* CQI values corresponding to a selected *K* slots within WCSI, where *K* < *N*4
* FFS: whether the *K* value and/or slot indices are RRC-configured or reported by the UE

[Mod: This is a good list. Thanks. I will include this in later rounds] |
| Intel | **Issue 2.2.**We are fine to support rank 1-4 at this meeting and start work on the design for rank 3-4 at the next meeting. **Issue 2.4.** We don’t see strong need to support rotation factor. **Issue 2.7.** We have a concern on aperiodic CSI-RS since it may complicate UE implementation for prediction. If implementation is not optimized for uneven periodicity (i.e.) aperiodic channel measurements then performance loss is expected. **Issue 2.9.**Alt 1 should be supported. |
| LG | Issue 2.1: We have the same view with vivo and Lenovo.Issue 2.4: Support FL’s Proposal 2.D without bracket. We have similar understanding with Fraunhofer and Samsung regarding overhead saving with compression for N4>1. Even though our preference is independent DD basis selection per SD/FD basis, we can live with the current Proposal 2.D for the progress. Proposal 2.E: Even though our preference is to keep the legacy reference resource only, we can live with the current Proposal 2.E for the progress. In addition, we also support to make a note suggested by MediaTek since measurement should be done several symbols/slots before reporting slot n. [Mod: Thanks for your understanding]Issue 2.6:Q1: Yes, if CSI reference resource location is “n-n\_ref” and window size is one slot which is a special fallback case.Q2: Yes, but don’t need to have specification impact. gNB can compensate the reported CSI always if needed.[Mod: Correct, the question is only related to spec impact]Issue 2.11:It depends on how many CSI reference resources is introduced for a CSI because a CQI is calculated based on a CSI reference resource.[Mod: Tend to agree] |
| Mod V15 | **No revision** |
| Apple | **Issue 2.1**We prefer to focus on Rel-16. PS codebook has not been deployed and performance is the baseline is questionable **Issue 2.2**We support proposal 2.B**Issue 2.3**We are fine with Proposal 2.B, we support Alt1. We do not think Alt 3 is good solution. For CSI prediction, we need to have CSI correlation in time domain if we can perform predication, identity matrix is good for the situation in which CSI prediction is not even feasible. **Issue 2.4**We object proposal 2.D. When N4 = 1, there is no difference between identity and DFT basis. **Issue 2.5**Before we agree on Proposal 2.E, we first need to agree on the CSI reference resource definition. In the current specification, it is defined in Clause 5.2.2.5 in 38.214, differently for P/SP/AP-CSI. However there is lingering Rel-15 issue that it is ambiguous for AP-CSI when P/SP resource is used. In more details, for AP-CSI, the CSI reference resource is defined based on Z’ defined in Clause 5.4. However, in Clause 5.4, the SCS is only taken over the AP CSI-RS. When P/SP CSI-RS is used for AP-CSI, the definition of CSI reference resource is unclear. [Mod: please check the revised version per Nokia’s comment. Basically the reference resource definition remains the same as legacy]**Issue 2.6**We can consider legacy UE procedure, for example, only CSI compression without prediction **Issue 2.7**We are fine with proposal 2.G**Issue 2.8**We do not see strong urgency to discussion this. This can be discussed at later time. **Issue 2.9**Before we discussion this, we think we first need to agree how the basis is selection, i.e., whether it is joint FD/DD basis selection, or separate FD/DD basis selection [Mod: We can discuss this in parallel or after proposal 2.C/2.D. Basis selection (joint vs separate) is a UE implementation since Alt1 in 2.C allows both algorithms] **Issue 2.10**We prefer per layer**Issue 2.11**What is the definition of CQI sub-band. We have CQI frequency domain sub-band in the current specification. Is this the sub-band time/doppler domain subband? [Mod: Added clarification that this is FD per Rel-15 spec]**Issue 2.12**CQI can be discussed later after PMI has more progress |
| Apple2 | **Issue 2.4**We can compromise to the switching point being N4 =1 between identity and DFT, since mathematically, there is no difference between identity and DFT basis. We do not support the switching point to be N4 other than 1. [Mod: OK] |
| InterDigital | **Support**: Proposal 2.A, 2.B, 2.G, and 2.I (prefer Alt2). |
| Nokia/NSB | **Proposal 2.D**For $N\_{4}=2$, the only possibility is $Q=2$, and the TD basis vectors are [1, 1] and [1, -1]. It is not clear what gain is achieved by TD compression in this case. The bitmap size is the same as without compression, $2LMN\_{4}$, and in case of TD-basis-common bitmap (Alt 2 of Proposal 2.I), there is no difference from reporting 2 $W\_{2}$’s with the same bitmap.[Mod: the compression gain is small indeed. Some W2 coeffs can be made 0]**Proposal 2.E**Our preference is for the CSI reporting window to start from the report slot $n$, because all applicable slots to use the reported CSI for PDSCH precoding are after $n$.The intention of the current proposal is to make the start of the CSI reporting window, $l$, configurable between the values {$n\_{ref}$, $n$, [$n+2$, $n+4$]}. However, to do so we should avoid redefining the legacy reference resource as defined in sec 5.2.2.5 of 38.214, because of the implication for DRX, etc. The existing note may not be sufficient to clarify the ambiguity because this configurable reference resource and the legacy reference resource. We suggest calling the start of the CSI reporting window with a different name, e.g., slot $l$:**Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after slot $l$ where the location of slot $l$ is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot $l$ location include the CSI reference resource $n\_{ref}$ and slot (*n*+*δ*) where *δ* is [gNB-configured via higher-layer signalling from] {0, [2, 4]}
* FFS: Possible value(s) of WCSI

[Mod: Thanks for this better formulation. Done. I still keep the note since this is basically the legacy behaviour. But strictly speaking the note may not be needed with your rewording since reference resource location is per legacy. But it doesn’t harm either ☺]**Issue 2.6**Question 1. We don’t think legacy procedure for CSI calculation is needed because even in the case $W\_{CSI}=1$, the UE is supposed to predict the channel/CSI at slot $l$, whereas in legacy CSI calculation there is no prediction assumed.Question 2. We do not support specification for gNB-side prediction. For gNB-side predictor to be effective, phase continuity of reported PMIs is needed, which depends on UE implementation. Besides, there does not seem to be any advantage in gNB-side prediction in either throughput, feedback overhead or UE complexity (multiple Type-II CSIs still need to be calculated)**Proposal 2.H**SP on PUSCH reporting is also supported in legacy Type-II. We don’t see strong reasons to exclude SP reporting if complexity and number of active ports/resources allow. In fact, with SP reporting, the time prediction filters for the channel/CSI, calculated from the initial CSI-RS burst could be reused until reporting is deactivated[Mod: added FFS similar to 1.H] |
| Mod V23 | **Minor revision on 2.E and 2.H per inputs** |
| vivo2 | **Proposal 2.B**OK**Proposal 2.D**We support MTK’s proposal to make N4=2 as the switch point, i.e., N4=1 and 2 use Alt 3. This is same as the current proposal but simpler in our view. As if only Q>1 is allowed for compression, it is equivalent to use Alt 3 for N4 = 2.[Mod: Please check the comments from MTK (latest), Apple, Fraunhofer, LG, etc. N4=2 as switching point is not acceptable to them ☹ Since Alt1 is super majority, this is the best we can do ] **Proposal 2.E**1. We support the note added by MTK, i.e., the slot with legacy reference resource is used to located the latest CSI-RS occasion used for measurement.
2. As N4=1 is supported, we think it is clear at least one delta value larger than 0 is needed. Hence we think we should remove the brackets for “gNB-configured via higher-layer signalling from”. Further, it is better to list options for delta values. Hence we suggest the following change.

**Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*), where *δ* is ~~[~~gNB-configured via higher-layer signalling from~~]~~ {0, [2, 4]}
* FFS: Possible value(s) of WCSI

Note: The legacy CSI reference resource, i.e., slot $n-n\_{CSI\\_ref}$, is reused for locating the last CSI-RS occasion used for a CSI report[Mod: OK]**Proposal 2.H**OK**Proposal 2.I**OK**Issue 2.12**We support for PMI only. |
| OPPO | **Issue 2.1**, we prefer to prioritize R16 codebook.**Proposal 2.B**: support.**Proposal 2.D**: support. We prefer DFT basis for N4=2 based on our evaluation. Rotation is not needed.**Proposal 2.E/2.G**: support **Proposal 2.H/2.I**: OK |
| Mod V26 | **Minor revision on 2.E per vivo input (one bracket removal – which makes sense)**  |
| Google | For issue 2.5, we think n – n\_ref should be removed, which seems to require gNB prediction in addition to UE prediction. [Mod: This is a compromise proposal betwwen Alt1.B and Alt2.B proponents which can be accepted by (almost) all. Please be considerate. Re n-nref, it doesn’t require gNB prediction (it is up to gNB whether to do so or not)]Our views on other issues were provided above. |
| ZTE | Issue 2.4: Although it is not our first preference, we can be compromise for that if only N4=1 is applied to the scheme of identity-basis, i.e. a legacy eTypeII CSI but with a predicted W. Then, we have the following modification for clarification. Then, from spec perspective, we do NOT need to clarify the applicable range of this $W\_{1}\tilde{W}\_{2}W\_{f}^{H}$ that is up to gNB implementation as usual.* For N4=1, Doppler-domain basis is the identity (no Doppler-domain compression) reusing the legacy$W\_{1}$*,* $\tilde{W}\_{2}$*,* and$W\_{f}$*, e.g.*$ W\_{1}\tilde{W}\_{2}W\_{f}^{H}$

[Mod: Done]Then, based on our observation, a rotation factor is definitely beneficial for improving accuracy of CSI compression especially for that case that N\_DD is limited. But, we also identify that this parameter may be implicitly achieved by a fixed frequency offset for all DD-bases (up to implementation and not to be reported explicitly). Therefore, we can be flexible a little bit. Issue 2.5: Based on the latest version, we are wondering whether CQI is included in the ‘UE predicting channel/CSI’ or not. If our understanding is correct, the previous version tends to clarify that the time instance of determining CQI, i.e., candidate reference resource, can be *n* – *nCSI,ref* or slot (*n*+*δ*). Therefore, we have the following suggestion：**Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI (involving PMI/CQI) after slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where *δ* is gNB-configured via higher-layer signalling from {0, [2, 4]}
* FFS: Possible value(s) of WCSI

Note: Per legacy behavior, the legacy CSI reference resource, i.e., slot $n-n\_{CSI\\_ref}$, is reused for locating the last CSI-RS occasion used for a CSI report[Mod: Since CSI includes PMI, CQI, and RI, prediction algorithm (up to UE implementation) includes all aspects. Hence your comment is implied (no need to mention explicitly to avoid confusion whether, e.g. RI is included or not).]Issue 2.7: Support AP-CSI-RS resource burst. Based on our observation, we can have a quite stable channel prediction for subsequent time instance(s), e.g., for predicting the subsequent ~10 slot based on 5 CSI-RS resource occasion with consecutive slots.Issue 2.8: Due to the same reason as in issue 1.8, both AP and SP-CSI on PUSCH should be supported.[Mod: Keeping time-domain FFS] Issue 2.11: At least CQI for the slot *l* should be reported in the CSI, in our views. Then, if greater than one, we need to consider whether we need to have different time-domain resolution compared with DD-basis.  |
| Xiaomi | **Issue2.3&2.4**According to our and some other companies’ observation, when N4=1 or 2, there are no difference between Alt1 ($W\_{1}\tilde{W}\_{2}\left(W\_{f}⨂W\_{d}\right)^{H}$) and Alt3 ($W\_{1}\tilde{W}\_{2}(W\_{f}⨂I)^{H}$) if N4=Q. When N4=2, if only one DD basis is selected, the first DD basis (the element is all one) will be selected due to phase shift just likes as the selected FD basis always including the first FD basis. Then, the performance of N4=2 and selecting one DD basis is same to that of N4=1. Thus, we think Alt1 has included Alt3. It is not necessary to introduce switching point, i.e., N4=1.[Mod: The revision should address your concern. But your understanding that Alt1 includes N4=1 is not correct since Q>1 is now introduced for N4>1]**Issue2.9**Support the proposal, Alt1 is straightforward. The location of NZC may be different for different DD basis. Hence, Alt2 is too restrictive. In addition, the indication of NZCs is associated with the selection of DD, i.e., DD basis is jointly or separately selected with FD basis. We prefer this proposal can be discuss latterly. **Issue2.11&2.12**Since downlink channel and predicted PMI are variable, the CQI is also changed at different TD compression unit. Hence, multiple CQIs across DD/TD should be included. |
| DOCOMO | **Proposal 2.A**We share vivo’s concern. **Proposal 2.H and 2.I**Support them. Our position has been added above. **Issue 2.11**Our position has been added.  |
| CATT | **Issue 2.8 (Proposal 2.H):** Support.**Issue 2.9 (Proposal 2.I), Issue 2.10:**We are fine to study both alternatives. **Issue 2.11:**We support only one CQI.**Issue 2.12:**We think that the DD/TD unit should be used for PMI only. |
| Fraunhofer IIS/Fraunhofer HHI | **Issue 2.4**: Regarding the rotation factor, it is evident that using a single/common rotation factor for all SD components is equivalent to multiplying the precoder with a common phase value. Our intention is to use different rotation factor for different SD components. Even for Q=1, the resulting precoder using a common rotation factor for all SD components is not the same as the precoder using a different rotation factor for each SD/subset of SD components.  Our simulations results showed that using a rotation factor/oversampling significantly improved the performance of the Rel.18 Codebook compared to the baseline. So, we would like to further study this issue.[Mod: OK]**Issue 2.5**: Support**Issue 2.8**: Support.**Issue 2.9**: Although, using a bitmap of size 2LMQ is a straightforward way of reporting the non-zero coefficients, it will result in high feedback overhead. Therefore, we think feedback reduction schemes need to be studied. Therefore, we ask FL to add the following note to Proposal 2.I.Note: Other schemes based on legacy bitmap are not precluded.[Mod: Added FFS on potential overhead reduction] |
| Lenovo | **Re Issue 2.8 (Proposal 2.H)**We are not convinced the FL note captures legacy behavior. In legacy Type-II codebooks, AP/SP on PUSCH CSI reporting are supported, and also P/SP on PUCCH reporting for i1 parameters only are also supported. We appreciate the FL’s intent to narrow down the reporting alternatives to achieve some progress, we therefore suggest the following updated proposal:***Proposal 2.H’: For the Type-II codebook refinement for high/medium velocities, only CSI reporting over PUSCH is supported*** * ***FFS: whether only aperiodic CSI reporting is supported***

[Mod: Done] |
| Ericsson | **On Issue 2.2**We can support proposal 2B.**On Issue 2.3**Given that we are discussing proposal 2.D, do we still need proposal 2.C? Or is it the FL’s intension to a first step down-selection in Proposal 2.C and then discuss Proposal 2.D further?[Mod: Not really. 2.C is my backup in case 2.D completely falls apart (remember I did the same last meeting for CMR CJT issue]**On Issue 2.4**First, we should clarify the definition of Q (i.e., the number of selected DD/TD orthogonal basis vectors) in the first sub-sub-bullet itself.With Q>1 and N4=2, there is no compression gain. Note that with N4=2, there are only two DD/TD orthogonal DFT basis vectors. And by selecting both of these DFT basis vectors (i.e., only valid case is Q=2 when Q>1 ) does not give any compression gain.Similar some other companies’ preference, we think brackets should be kept around 1. The switching point can be decided after further evaluations/study.[Mod: Noted]**On Issue 2.5**In Proposal 2.E, is it correct understanding that *l* is that starting location of the CSI window? [Mod: Yes]Then, for predicted CSI, we should allow a window that starts slot *N* that means non-zero values of *δ* should be supported. So we can support the proposal if brackets around [2, 4] are removed. Alternatively, rather than listing [2,4] under brackets and 0 outside the brackets, we can simply say the values of *δ* are FFS.Furthermore, according to the current formulation, *l* will have multiple candidate values and the gNB will configure one value among the candidates. Then do we really need *δ* to be separately configured? For instance, we can have *l* to be RRC configured with the following candidate values:(*n* – *nCSI,ref* ) (*n*) => *δ=0*(*n* + 2) => *δ=2*(*n* + 4) => *δ =4* Hence, configuring *l* with the above four candidate values is enough. We don’t need to separately configure *δ*. We suggest the following revision:[Mod: Correct, sorry for the redundancy] **Suggested Revision to Proposal 2.E**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, support UE “predicting” channel/CSI after slot *l* where the location of slot *l* is configured (from multiple candidate values) by gNB via higher-layer signalling* Candidates of slot *l* location include the legacy CSI reference resource location (*n* – *nCSI,ref* ) and slot (*n*+*δ*) where the values of *δ ≥ 0* are FFS ~~is gNB-configured via higher-layer signalling from {0, [2, 4]}~~
* FFS: Possible value(s) of WCSI

Note: Per legacy behavior, the legacy CSI reference resource, i.e., slot $n-n\_{CSI\\_ref}$, is reused for locating the last CSI-RS occasion used for a CSI report[Mod: Another good editorial catch (redundant gNB configuration statement on my part), thanks]**On Issue 2.6**Regarding the 1st Question, we think legacy UE procedure for CSI-RS measurement should be fine as the UE can measure CSI-RS in the legacy way. But CSI calculation cannot be assumed to be in legacy way as the UE has to calculate a predicted CSI for a future slot.Regarding the 2nd Question, we do not support gNB-side prediction with spec impact. gNB-side prediction is up to gNB implementation.**On Issue 2.7**We support the proposal. We support AP CSI-RS to be included in the proposal.**On Issue 2.8**Similar to Nokia comment, we don’t think SP CSI on PUSCH should be excluded since it is supported in legacy. [Mod: Done]**On Issue 2.9**On proposal 2.I, we are not sure if there is a need to introduce a 3-D bitmap. It may be simpler to report *Q* different bitmaps instead. Note that this is analogous to what we are discussing for Type II CJT (i.e., separate bitmap per TRP). Hence, we suggest to add another alternative with *Q* different bitmaps:* Alt 3. *Q* different 2-dimentional bitmaps are introduced for indicating the location of the NZCs, where the qth (q=1,…., Q) 2-dimentional bitmap corresponds to qth selected DD basis vectors
	+ number of selected DD basis vectors is denoted as Q
	+ this implies that for each layer, the location of NZCs in SD-FD can be different for different selected DD basis vectors.

[Mod: Actually this is my intention for Alt1 ☺ the 3D term can be misunderstood (sorry). Replaced Alt1 with the above better description]**On Issue 2.11**We support >= 1 configurable number of CQIs. We have seen some gains with supporting more than 1 CQI in our evaluation results.**On Issue 2.12**In our view, one CQI could correspond to X different DD/TD compression units. Hence, the configurable number of CQIs depend on the total number of DD/TD compression units configured. Thus, the number of CQIs can be a function of the number of DD/TD compression units in our view. |
| NEC | Our views added in above table.**Issue 2.11.** We support multiple CQIs. |
| CMCC | **Issue 2.1**We prefer prioritize R16 regular codebook.**Issue 2.2**We support proposal 2.B**Issue 2.3/2.4**We support proposal 2.C/2.D. Only when N4=1 with identity basis is enough. For N4>1, it should be DFT basis.**Issue 2.5**We support proposal 2.E.**Issue 2.6**Question 1: When$ W\_{CSI}=1$, legacy procedure can be reused, which means no prediction, only compression.[Mod: Not for l=n+delta (there is prediction here). For l-(n-n\_CSI,ref) you are correct] Question 2: gNB-side prediction with spec impact is not needed.**Issue 2.7**We support proposal 2.G. Both P, SP, AP CSI-RS can be supported.**Issue 2.8**We support proposal 2.H. And SP CSI report on PUSCH can be supported.**Issue 2.9**We support proposal 2.I and prefer Alt1.**Issue 2.10**We prefer Alt1. Maybe some simulation results can be instructive for the decision. |
| Huawei, HiSilicon | **Proposal 2.A**We support the proposal. Even without considering DD reciprocity, Rel-17 FeType-II CB has better performance compared with Rel-16 eType-II CB as a result of exploiting SD/FD reciprocity. Moreover, most of the refinement for Rel-16/17 codebooks are the same, including codebook structure, Doppler basis design and indication, and W2 reporting, except for parameter combinations. Therefore, support Rel-17 FeType-II CB require minimal spec workload.**Proposal 2.B**: Support.**Proposal 2.D:**Although we prefer Doppler-domain orthogonal DFT basis commonly selected for all SD/FD bases, we can accept the proposal only if N4=1 for identity Doppler-domain basis for progress.**Proposal 2.E:**Although our first preference is *l>n*, we are fine for this proposal if the reference resource definition remains the same as legacy.[Mod: Correct. No change in reference resource definition]**Issue 2.6**In our understanding, legacy UE procedure for CSI measurement/calculation can be assumed up to UE implementation, no need spec impact.We don’t support gNB-side prediction.**Proposal 2.G, Proposal 2.H:** Support**Proposal 2.I and Issue 2.10:** Support in general. But we think this issue can be discussed after codebook structure is concluded.**Issue 2.11 and Issue 2.12:** We prefer reporting the abruptly changed CQIs (if there is) and the corresponding slots than reporting multiple CQIs for each unit. |
| Mod V39/43 | **Minor editorial (wording, no content change) revision on 2.D, 2.E, and 2.I****For 2.H, I keep the time-domain property FFS for now.** |
| MediaTek | **Proposal 2.I:** Support in principle. However, we propose to add the following FFS sub-bullet to Alt 1.:FFS: Whether number of NZCs are upper bounded across DD basis or per DD basis[Mod: OK] |
| Spreadtrum | **Issue 2.1**We prefer only Rel-16 eType-II. Multiple codebook types and codebook structure modes have been introduced in this AI, we need to limit the work scope.**Issue 2.2, 2.3, 2.4, 2.5**Support proposal 2.B/C/D/E.**Issue 2.6**gNB side prediction can be additionally supported in case UE reported CSI can be further extrapolated for the following DL scheduling. **Issue 2.7, 2.8**Support proposal 2.G/H.**Issue 2.11**We prefer to report only one CQI. |

### Issue 3: TRS-based reporting of time-domain channel properties (TDCP)

Table 5A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | [110] **Agreement**For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA. Based on Doppler profile
	+ E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc
* AltB. Based on time-domain correlation profile
	+ E.g. Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts
* AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network
	+ E.g. gNB configures UE with multiple choices on what to assist (e.g. two or more CSI-RS/report periodicities, or precoding schemes depending mainly on UE velocity), then UE report according to configuration; parameters correspond to CSI reporting periodicity, codebook type, etc.

Note: Different alternatives may or may not apply to different use cases**Proposal 3.A**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA1. Quantized Doppler profile (amplitude vs. Doppler shift)
* AltA2. Doppler spread
	+ E.g. Doppler spread derived from the 2nd moment of Doppler power spectrum, difference between lowest- and highest-value Doppler shifts in Doppler profile
* AltA3. Doppler shift(s)
	+ E.g., average Doppler shifts, Doppler shift per TRS resource, Doppler shift corresponding to the peak in Doppler profile,
* AltB. *Quantized amplitude of* time-domain correlation profile (amplitude vs. delay)
	+ FFS: Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts

Note: Different alternatives may or may not apply to different use casesFFS: The need for a measure of confidence level in the TDCP report, and/or UE behaviour when the quality of TDCP measurement is not sufficiently high**FL Note**: This issue/proposal has been discussed OFFLINE [1] as offline proposal 3.1This is the current situation. * AltA: ZTE, vivo, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Fraunhofer IIS/HHI, Mavenir, Apple (1st pref), CATT, IDC, Spreadtrum, NEC (2nd pref), Nokia/NSB
* AltB: Samsung, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, OPPO, Sharp, Lenovo, Apple (2nd pref), IDC, NEC (1st pref), CEWiT
 | **Proposal 3.A:*** **Support/fine**: Samsung, ZTE, vivo, Google, LG, OPPO, Huawei/HiSi, Xiaomi, Fraunhofer IIS/HHI, Mavenir, Apple, CATT, Ericsson, MediaTek, vivo, Qualcomm, DOCOMO, OPPO, Sharp, Lenovo, Sony, Nokia/NSB, CMCC, Spreadtrum
* **Not support**:
 |
| 3.2 | Whether the following time-domain behaviour of TDCP reporting is supported:* Periodic
* Semi-persistent
* Event-triggered (UE-initiated)

Note: Aperiodic TDCP reporting has been agreed in RAN1#110**Conclusion 3.B**: For the Rel-18 TRS-based TDCP reporting, there is no consensus in supporting periodic, semi-persistent, and event-triggered/UE-initiated TDCP reporting. | **Periodic:*** **Yes:** Qualcomm, Nokia/NSB, ZTE
* **No:** Spreadtrum, Samsung, MediaTek, vivo, LG, OPPO

**Semi-persistent:*** **Yes:** Lenovo, Nokia/NSB, ZTE
* **No:** Spreadtrum, Samsung, MediaTek, vivo, LG, OPPO

**Event-triggered/UE-initiated via UL MAC CE:*** **Yes:** Samsung, MediaTek, Google
* **No:** LG, Nokia/NSB, OPPO

**Conclusion 3.B:** Xiaomi, Huawei, HiSi, Spreadtrum |
| 3.3 | Whether using >1 TRS resources for TDCP measurement is supported in addition to only 1 TRS resource**FL Note**: This can be decided after 3.1 is finalized. | **Yes:** Samsung, Google (for mTRP and multi-beam), ZTE**No:** Qualcomm, LG, MediaTek, Spreadtrum |
|  |  |  |

Table 5B TDCP: summary of observation from LLS/SLS

|  |  |
| --- | --- |
| **Company** | **LLS/SLS results** |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 3.1 | Doppler profile | Observation 10: SRS could not provide accurate Doppler shift information.Observation 11: Due to the common feature of Doppler profile among gNB antennas, TRS could provide sufficient Doppler shift information even if it is single port.Observation 12:A “common Doppler profile” of multiple delay paths is a satisfying depict of the Doppler profile. |
| vivo | 3.1 | Auto-correlation vs lags | The Figure 4 shows the relationship between temporal correlation at different lags and maximum doppler shift in term of Bessel function.…Since maximum lags between four TRS resources in two consecutive slots is 14 symbols (or say 1 slot) and the values of correlation are [1, 0.97, 0.90] respectively corresponding to [3km, 30km, 60km], UE would not identify the minor difference taking noise and interference into account in practical algorithm unless AP TRS is triggered to compensate lacked occasions of P TRS. Hence it means to make the TDCP use case work, gNB has to trigger AP TRS to assist P TRS for this TDCP reporting. How this works for periodic or semi-persistent CSI reporting requires further study as P or SP CSI report cannot be associated with aperiodic RS |
| Google | 3.1 | Square cosine similarityAuto-correlation | Figure 5 illustrates SCS for the first layer at each Doppler spread. Figure 6 illustrates the Doppler spread at different UE velocity. It can be observed that with the help of Doppler spread, it is possible to predict the UE velocity. However, the SCS span can still be large. At some UE velocities, it is hard to determine whether the CSI could change quickly or not based on the Doppler spread.Figure 7 illustrates the SCS distribution at different channel auto-correlation, where different color indicates different SCS. Figure 8 illustrates the UE velocity distribution at different channel auto-correlation, where different color indicates different UE velocity. It can be observed that with channel auto-correlation only cannot help to distinguish the UE velocity and it is hard to identify the proper CSI report periodicity. |
| CATT | 3.1 | LLS: normalized TP | * + Observation-3:

Compared with no gNB-side CSI prediction, the single Doppler reporting has slight performance gain, and obvious performance gain can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm |
| Mavenir | 3.1 | Correlation vs lag | Observation 3. For given Doppler shift, different lags result in different time correlations |
| Samsung | 3.1 | Correlation vs lag | Observation 15:* The perceived Doppler spread increases as the number of reported correlation lags decreases due to windowing before FFT operation.
* For a given UE speed, there is a minimum number of reported correlation lags that can represent the Doppler spread accurately.
 |
| Ericsson | 3.1 | Correlation vs lag | However, we don’t think it’s crucial to capture the sign changes of the autocorrelation. It’s the behaviour of the autocorrelation for low lags corresponding to an autocorrelation above zero that is of most interest (see Figure 3). Also, the measure $A\_{alt}\left(t,τ\right)$ would not be robust towards phase jumps. Thus, if UE manufacturers prefer the measure $A\left(t,τ\right)$ to avoid problems with phase jumps, that is perfectly fine with us.1. Maximum doppler shift would be the same for channels with vastly different channel variabilities, and it does not reflect how fast channel varies with time.

Thus, the second moment of the Doppler power spectrum is a much better measure of channel variability than the maximum Doppler shift. However, it can’t predict the rather abrupt break-off point where the autocorrelation of the CDL channels takes off steeply downwards as can be seen in Figure 5. Compared to the autocorrelation it gives less information about the channel variations. The second moment of the Doppler power spectrum is therefore not our preferred TDCP measure.To measure the relative Doppler shift of a number of channel peaks is also a very complex measurement which in the end gives worse performance than the autocorrelation as shown in Figure 6. In Figure 6, we show the result, showing that the Autocorrelation based estimate totally outperforms the channel peak based estimate. It has both lower bias and lower standard deviation than the peak based estimate. This should be viewed as an illustration of the general fact that the measurement of relative Doppler shifts per peak is a complex and inaccurate measurement while the Autocorrelation is a simple and comparably accurate one.1. Estimates based on intra-TRS autocorrelation lags doesn’t give decent accuracy below 50km/h.
2. Estimates based on inter-TRS : autocorrelation lags of 20 or 40 slots perform best at 3km/h; autocorrelation lags of 10 and 5 slots performs best at 6km/h and 10km/h respectively.
3. Different autocorrelation lags are suitable for different UE velocities.
4. Based on the evaluated use cases, reporting of the Autocorrelation for the four lags, 4 symbols, 1 slot, ~5 slots and ~10 slots look reasonable.
 |
| **Summary**:  |

Table 6 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | 1. **Check and update your view in Table 5A, especially on the moderator proposals**
2. **Share additional inputs here if needed**
3. **More moderator proposals may be added in the next revision**
 |
| vivo | **Issue 3.2**We would like to check companies’ view on the following issue for P/SP reporting.Since maximum lags between four TRS resources in two consecutive slots is 14 symbols (or say 1 slot) and the values of correlation are [1, 0.97, 0.90] respectively corresponding to [3km, 30km, 60km], UE would not identify the minor difference taking noise and interference into account in practical algorithm unless AP TRS is triggered to compensate lacked occasions of P TRS. Hence it means to make the TDCP use case work, gNB has to trigger AP TRS to assist P TRS for this TDCP reporting. We are wondering how this works for periodic or semi-persistent CSI reporting as P or SP CSI report cannot be associated with aperiodic RS.Correlation vs maximum doppler shift |
| Mod V2 | **No revision** |
| Qualcomm | Re 3.2We are fine with periodic report.Periodic report would have smaller issue even than the agreed aperiodic, since everything is pre-determined and no need to buffer TRS, especially for cross-burst measurementRe 3.3We have questions regarding multi-TRS (or cross-burst) measurement.We can understand its motivation for longer lag measurement (e.g. 5msec, 10msec), but it may not need to be tied with multi-TRS based on existing TRS definition, i.e. each with 4 symbols within 2 consecutive slots – large overhead.To save the overhead, a simpler way is to define a set of single-port CSI-RSs with different time spacing (e.g. 5msec, 10msec for longer lag) than existing TRS – this can also be seen as enhancements of TRS(I guess this is also relevant to vivo’s question regarding longer lag) |
| Samsung | Proposal 3.A: since Doppler profile can be obtained if sufficient number of auto-correlation values for multiple lags are reported, Doppler profile is also possible via AltB. So, we prefer AltB over AltA.Issue 3.3* We support > 1 TRS resources for TDCP reporting
 |
| Mod V9 | **No revision** |
| Lenovo | **Re 3.1**Both Alt-A and Alt-B are equivalent, since one is a transformed version of the other. One disadvantage of either alternatives is that reporting absolute autocorrelation/Doppler spread values may not be efficient unless an autocorrelation/Doppler function is specified (companies proposed different normalization factors for autocorrelation fn in RAN1#110bis-e tdocs). One advantage of Alt-B is that it can indicate the autocorrelation in terms of a lag value, i.e., instead of reporting an autocorrelation value for a fixed lag, a lag value is indicated for a pre-determined autocorrelation**Re 3.2**Since aperiodic TDCP reporting (likely on PUSCH) is to be supported, we prefer to support an additional format with reporting over PUCCH, mainly SP. TDCP reporting should only be activated/deactivated when needed, e.g., when network detects a larger Doppler shift from SRS measurements**Re 3.3**Agree with FL assessment, better to discuss after Issue 3.1 is finalized. Motivation needs to be clarified; for P TRS, autocorrelation can also be measured across different TRS occasions |
| LG | Issue 3.1: we prefer AltA since AltB has overhead issue to report correlation value for sufficient multiple lags.Issue 3.2: On demand reporting trigger at gNB is sufficient and motivation to support additional reporting mode is not clear to us. |
| Mod V15 | **No revision** |
| Ericsson | **Issue 3.1 and Breakdown of Alt A**We think alternative A covers several very different things which makes it hard to understand what different companies really want and it also makes it very hard to discuss what could work and not. We therefore think that alternative A should be broken down into at least three sub-alternatives, and companies should explain which sub-alternative they are after. As we understand it, different companies wantA1: Doppler spread which may be further broken down into A1a Maximum Dopplershift A1b Second moment of the Doppler power spectrumA2: Relative Dopplershift for multiple TRPsA3: Doppler profile, which it seems no one has really defined, but could mean A3a Relative Dopplershift per identified channel peak A3b Relative Dopplershift and delay per identified channel peak A3c Relative Dopplershift, delay and power per identified channel peak A3d Relative Dopplershift and power per delay-sampleWe note that A1 clearly addresses the same use-cases as Alt B, i.e. selection of the best precoding scheme, CSI-feedback mode and CSI-RS/feedback periodicity.Alt A2 on the other hand address a completely different use-case (Doppler shift pre-compensation for high speed train scenarios) compared to Alt A1 and B. It should really be broken out as a separate issue.Alt A3 could in principle be used to address the same use cases as Alt A1 and Alt B, but it’s clearly an overly complicated way to solve that problem. The real use-case of Alt 3 is instead NW side channel prediction which is also what the proponents of this alternative are arguing for.Thus, we really have two alternatives, A1 and B for selection of the best precoding scheme, CSI-feedback mode and CSI-RS/feedback periodicity. Here, we support Alt B.In addition we have two methods addressing two other use-cases:A2: Doppler shift pre-compensation for high speed train scenariosA3: NW side channel predictionBy breaking down Alt A into it’s three sub-alternatives and acknowledging what use cases each alternative address we think the discussion could become more constructive.[Mod: I may consider this in later rounds if necessary]**Issue 3.2**we are supportive of Periodic as well as semi-persistent TDCP reporting. We are also open to further study event-triggered TDCP reporting.**Issue 3.3**We agree with the FL that this issue can be discussed after finalizing 3.1. |
| Apple | **Issue 3.1**We are fine with Proposal 3.A**Issue 3.2**We are supportive of all three, periodic, semi-persistent, and UE-initiated **Issue 3.3**Maybe we can clarify the TRS resource. I guess it means CSI-RS resource set for TRS, in which case, it contains 2 CSI-RS resource for single slot, or, 4 CSI-RS resource for two slot. The baseline should be based on one CSI-RS resource set for tracking[Mod: I will ask proponents to clarify] |
| InterDigital | Per definition the purpose of TDCP is “to enable refinement of CSI reporting configuration, and/or codebook configuration parameters”. Therefore, from our perspective, Alts A and B could work properly only if we define a UE behavior for when the accuracy of TDCP measurement is not sufficiently high. For example, some additional indication can be considered to help gNB assess the quality TDCP report for CSI configuration and UE/gNB prediction. For instance, a UE can determine a confidence level (CL) of prediction or quality of prediction and report it as part of a TDCP report. Now that Alt C is removed, we could support AltA or AltB, if a reliability aspect of the measurement is considered, and a corresponding UE behavior for TDCP reporting is studied. Otherwise, we find AltC would be a better way-forward. Our proposed change is,**Proposal 3.A**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA. Based on Doppler profile
	+ E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum, average Doppler shifts, Doppler shift per resource, maximum Doppler shift, relative Doppler shift, etc
* AltB. Based on *quantized amplitude of* time-domain correlation profile
	+ E.g. Correlation within one TRS resource, correlation across multiple TRS resources
	+ Note: The correlation over one or more lags of TRS resource may be considered. The lags may be within one TRS burst or different TRS bursts
* Study inclusion of a measure of confidence level in the TDCP report, and/or UE behaviour when the quality of TDCP measurement is not sufficiently high.

Note: Different alternatives may or may not apply to different use cases[Mod: OK] |
| Nokia/NSB | **Issue 3.2**In our view, the gNB needs to collect multiple reports over time for an accurate estimate of Doppler spread, hence we think periodic and SP reporting of TDCP is important for accuracy. They are also important for the network to determine when to change CSI reporting/resource setting configurations.We don’t think event-triggered reporting is needed for the use cases under consideration, because the network can monitor UE’s speed by periodic/SP TDCP reporting or trigger a report based, for example, on the number of retransmissions or other link adaptation monitoring parameters.**Issue 3.3**It may be worth clarifying if multiple TRS resources refer to the legacy aperiodic TRS configuration over two slots or the introduction of new TRS configurations, such as multiple periodic TRS resources or aperiodic resources with more than 4 resources, etc.[Mod: I will ask proponents to clarify] |
| OPPO | Issue 3.2:We think aperiodic CSI reporting is sufficient. Issue 3.3:We think aperiodic TRS can be used in addition to periodic TRS by current mechanism. In this case, multiple TRS resources don’t seem so necessary.  |
| Mod V26 | **Added FFS in proposal 3.A per IDC input.****Added conclusion 3.B** |
| Google | For issue 3.2, we are open for MAC CE based UE initialed TDCP report, which similar to legacy BFR framework to reduce our effort for further study. |
| ZTE | Issue 3.1:Support the FL’s proposal. Then we have the following analysis for AltA and AltB* Regarding AltA, the corresponding channel property is reported directly (either way, for data demodulation, Doppler profile parameter should be estimated by UE). Then, for sTRP, we may consider to report Doppler spread (i.e., maximum Doppler shift (difference)), but for mTRP, relative Doppler shift information across different TRS may be quite useful. Then, channel coherent time is determined according to the Doppler spread.
* Regarding AltB, instead of directly reporting channel property, it tends to report the middle-ground parameter for determining Doppler spread. As a cost, a list of auto-correlation(s) due to the presence of multiple lags in time correlation calculations should be reported in the CSI reporting, and then the report overhead is too big. Otherwise, if just being based on auto-correlation for determining the periodicity of CSI-RS resource and/or CSI reporting setting configuration, as an instantaneous variable, it is difficult for gNB to have a stable performance as mentioned by several other companies.

Issue 3.2: We support periodic and semi-persistent CSI report. Then we can be open for event-triggered if the above P/SP report has been supported. Issue 3.3: Based on the current WID, it is clear that TRS is used for TDCP measurement, and so we think that we need to fully follow this guidance. Since using >1 TRS can be sufficient for TDCP measurement (e.g., report relative Doppler shift), we do not identify the necessity of further using several CSI-RS sets for this measurement. RS overhead should be serious considered. If going with AltA, we think that Doppler shift/spread can be well estimated per TRS transmission occasion, and then we may consider whether more than one Doppler shift(s) for several TRS(s) or relative Doppler shift can be reported for saving report overhead.  |
| Xiaomi | **Issue 3.2**Support the conclusion |
| CATT | **Issue 3.1**We prefer Alt A because we think the Doppler profiles in Alt A can cover all the use cases for TDCP. In addition, we still suggest that different use cases should be discussed separately. **Issue 3.2**We are open to discuss all the periodic, semi-persistent, and UE-initiated CSI reporting.**Issue 3.3**We agree with the FL’s suggestion.  |
| CMCC | **Issue 3.1**We are fine with Proposal 3.A.**Issue 3.2**We are supportive to study P and SP TDCP reporting. And We are also to study UE-initialed reporting.**Issue 3.3**We agree with FL’s assessment, it is related to the outcome of issue 3.1. |
| Huawei, HiSilicon | **Issue 3.1**We support Alt A which is more useful for more use cases.**Issue 3.2:** We are fine with it.**Issue 3.3:** Agree with the FL’s assessment. |
| Mod V39/43 | **Given the situation (tend to agree with Ericsson that AltA comprises several different solutions), I reformulated the alternatives in proposal 3.A** |
| Spreadtrum | **Issue 3.1**Support proposal 3.A.**Issue 3.2**We are fine with conclusion 3.B. **Issue 3.3**TDCP can be measured through one TRS resource, no need to support multiple TRS resources. |

# References

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