**3GPP TSG RAN WG1 #110 R1-2207876**

**Toulouse, France, August 22nd – 26th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#2 on Rel-18 CSI enhancements: Round 1

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-19 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

Proposals planned for presentation and potential endorsement on 1st online session for AI 9.1.2:

* Issue 1:

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* Issue 2:

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* Issue 3: Proposal 3.C

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.3 | [109-e] **Agreement**The work scope of Type-II codebook refinement for CJT mTRP includes refinement of the following codebooks:* Rel-16 eType-II regular codebook
* Rel-17 FeType-II port selection (PS) codebook

FFS: Whether to prioritize/down-select from the two**Proposal 1.C**: The Rel-18 Type-II codebook for CJT mTRP 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
 | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi, Sharp**Down-select to only (prioritize) Rel-16 eType-II:** Apple, AT&T, Google, DOCOMO, MediaTek, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, Intel, Xiaomi, Fraunhofer IIS/HHI, Qualcomm, Ericsson, Sony, LG, ZTE (involving R16 port-selection CSI), Sony (at least Rel-16), CEWiT**Down-select to only (prioritize)Rel-17 FeType-II:**  |
| 1.6 | [109-e] **Agreement** On the spatial-domain (SD) and frequency-domain (FD) basis design for the Rel-16 Type-II codebook refinement for CJT mTRP, down-select from the following alternatives:* Alt1 (separate, legacy DFT): SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design
* Alt2 (joint, DFT): joint SD-FD DFT-based basis
	+ FFS: Details on DFT parameters, e.g. length, oversampling (if any), rotation (if any)
* Alt3 (joint, eigenvector): joint SD-FD eigenvector-based basis
	+ FFS: eigenvector codebook design, parametrization
* Alt4 (separate, eigenvector): SD basis and FD basis are separate, using eigenvector-based basis
	+ FFS: eigenvector codebook design, parameterization

**Proposal 1.F**: For the Rel-18 Type-II codebook for CJT mTRP based on the Rel-16 Type-II codebook, SD basis and FD basis are separate, each fully reusing the legacy Rel-16 DFT-based design**FL note**: This proposal was already discussed at length in round 0 | **Proposal 1.F:*** **Support/fine:** Apple, AT&T, DOCOMO, ZTE, NEC, CATT, Samsung, IDC, Spreadtrum, vivo, Lenovo, OPPO, Xiaomi, CMCC, MediaTek, Ericsson, Nokia/NSB, Intel, Google, Qualcomm, LG, Fraunhofer IIS/HHI, Sharp, Sony, CEWiT
* **Not support:** Huawei/HiSi
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| 1.7 | [109-e] **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):* Alt1. N is gNB-configured via higher-layer (RRC) signaling
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
	+ 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
	+ FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported
* Alt3. The UE reports CSI corresponding to K transmission hypotheses
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signaling
	+ FFS: supported value(s) of K, and whether the K transmission hypotheses are gNB-configured or UE-reported

**Proposal 1.G**: 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):* 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 ${1,..., NTRP}
	+ N is the number of cooperating TRPs, while NTRP is the maximum number of cooperating TRPs configured by gNB
	+ In this case, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme)
	+ FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported
	+ ~~FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported~~
* Alt3. The UE reports CSI corresponding to K transmission hypotheses
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signalling
	+ FFS: supported value(s) of K, and whether the K transmission hypotheses are gNB-configured or UE-reported
* Alt4. K>=1 values of N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP} where K is the number of transmission hypotheses
	+ 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
 | **Alt1:** Samsung, Huawei/HiSi, Xiaomi, CMCC, AT&T, Nokia/NSB, DOCOMO, Google**Alt2:** ZTE, Spreadtrum, vivo (one hypothesis), NEC, Xiaomi, CEWiT, Ericsson (one hypothesis), Sony, MediaTek, LG, CATT, Qualcomm, Apple, Intel**Alt3:** IDC, Lenovo, Xiaomi**Alt4**:  |
| 1.9 | [109-e] **Agreement** On the W2 coefficient quantization scheme for the Type-II codebook refinement for CJT mTRP:* At least for N=2, reuse *the following components* of the legacy Rel-16/17 per-coefficient quantization scheme:
	+ Alphabets for amplitude and phase
	+ Quantization of phase and quantization of differential amplitude relative to a reference, reference amplitude (with SCI determining the location of one reference amplitude), where the reference is defined for each layer and each “group” of coefficients
* Further study the following:
	+ For larger N values, if supported, whether/how to improve throughput-overhead trade-off using, e.g. lower-resolution alphabets for amplitude and/or phase than legacy, or higher/same resolution alphabets but smaller number of coefficients than legacy
	+ What constitutes a “group” (e.g. per polarization across TRPs/TRP-groups, per polarization per TRP/TRP-group, per TRP/TRP-group), the number of “groups” per layer for phase and amplitude (1 ≤*C*group,phase ≤ N, 1 ≤ *C*group,amp ≤ 2N), and how to indicate/configure “grouping”

**Proposal 1.I**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, down-select from the following alternatives:* 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
	+ Without the strongest TRP/TRP-group indicator
* Alt2. One group comprises one polarization for one TRP/TRP-group (*C*group,phase=N, *C*group,amp=2N), per-TRP/TRP-group SCI
	+ With the strongest TRP/TRP-group indicator
* 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), per-TRP/TRP-group SCI
	+ With the strongest TRP/TRP-group indicator
 | **What constitutes one “group”:*** **Per polarization, per TRP/TRP-group (natural extension of legacy:** *C*group,phase **=N,** *C*group,amp **=2N):** Xiaomi, DOCOMO (for codebook structure Alt1A), LG, ZTE, CATT, AT&T, Spreadtrum
* **Per polarization, across all TRPs/TRP-groups (***C*group,phase **=1,** *C*group,amp **=2):** Samsung, DOCOMO (for codebook structure Alt2), MediaTek (Codebook structure Alt 2), AT&T, vivo, CMCC (at least mode 2)
* *C*group,phase **=1,** *C*group,amp **=2N:** Ericsson, Nokia/NSB, Qualcomm

CJT extension of per-layer Strongest Coefficient Indicator (SCI):* Alt1. One per TRP/TRP-group: Lenovo, DOCOMO (for codebook structure Alt1A), CATT (for codebook structure Alt1A, for both per-layer and layer-common), Spreadtrum
* Alt2. One (common) across all TRPs/TRP groups: Samsung, DOCOMO (for codebook structure Alt2), MediaTek, Ericsson, ZTE, Nokia/NSB, AT&T, vivo, CMCC (at least mode 2), Qualcomm

The need for explicit/implicit strongest TRP/TRP-group indicator in addition to SCI(s)* Yes: Samsung, NEC, LG, Fraunhofer IIS/HHI, Lenovo, DOCOMO (FFS explicit or implicit), MediaTek, ZTE, CATT, Spreadtrum
* No: Nokia/NSB (may not be needed at least for single SCI)
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Table 1B Type II CJT: summary of observation from SLS

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| **Company** | **Metric** | **Key observation** |
| Huawei, HiSi | Mean UPT,5% UPT | * The CJT codebook with joint space-frequency eigenvectors basis achieves 8~14% gain for mean UPT and 5~7% gain for 5%-tile UE UPT, compared with DFT basis.
* There is a significant performance improvement at both mean UPT and 5% UPT when the number of measured/cooperated TRPs increase from 2 to 3 and 4. Four TRPs CJT leads to 20% and 30~40% performance gain improvements for mean UPT and 5% UPT respectively, compared to two cooperating TRPs.
* The full channel feedback for CJT codebook can provide about 12% gain for mean UPT and 13~22% gain for mean UPT and 5% UPT respectively.
* Compared to TRP independent selection of coefficients for W2, joint selection among TRPs can provide about 5~7% and 3~6% performance gains for mean UPT and 5% UPT, respectively, when each TRP has 32 CSI-RS ports.
* There is a significant performance gain at both mean UPT and 5% UPT when the frequency domain granularity changes from 4RB to 2RB, especially at 5% UPT (more than 28%).
 |
| ZTE | Mean UPT,5% UPT,50% UPT,95% UPT | * For SU-MIMO, compared with sTRP and NC-JT, C-JT can bring performance gains in terms of both cell-edge and mean UPT.
* For MU-MIMO, compared with sTRP, C-JT can also bring performance gains in terms of both cell-edge and mean UPT, and then performance gain introducing by CJT increases as SU-MIMO is changed to MU-MIMO
* It can be observed that, based on the receiving side information, there may be a significant performance gain, especially for CJT case.
 |
| vivo | Mean SE (spectral efficiency),5% SE,50% SE,95% SE | * Observation 3: TRP recommendation causes marginal performance loss, but it reduces feedback overhead and UE complexity significantly 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.
* Observation 4: For some potential schemes of codebook structure
	+ Compared to Alt1A, Alt2 has performance gain.
	+ Searching for the TRP-specific amplitude/phase in Alt1A may cause a significant computation complexity.
* At least for Indoor Hotspot and Intra-site CoMP(Outdoor2), for FD selection, there is almost no performance difference between per-TRP FD selection and joint FD selection at the same parameter pv. And, introducing TRP level reference amplitude has a negligible performance gain in some configurations.
* A limited performance gain is obtained for a larger R for Indoor Hotspot and Intra-site CoMP(Outdoor2).
* The TRP-specific beta may reduce the feedback of the coefficients corresponding to the strongest TRP, which leads to a decrease in performance.
 |
| CATT | Cell-average UPT,Cell-Edge UPT | It can be observed from the simulation results that compared with S-TRP transmission scheme, obvious performance gain can be achieved by the different layout coherent-JT for both cell average and cell edge. Moreover, as the number of TRP increases, both co-located and distributed layouts have significant gain for cell average and cell edge. |
| Intel | SE vs SNR (LLS) | As it can be observed from the above results, subband reporting of co-phasing coefficient outperforms wideband reporting. Also, performance improvement is observed for larger number of bits for the co-phasing coefficient. |
| Fraunhofer | UPT gain, feedback overhead | * Considering the drastic increase in the feedback overhead, the gain achieved using CJT mTRP is marginal compared to single TRP case.
* A better performance-overhead tradeoff can be achieved using a large value of $N\_{3}$.
 |
| Samsung | Mean UPT gain vs overhead | * significant gain in performance vs overhead trade-off can be achieved with $N\_{TRP}=X>N\_{TRP}=Y$ for $X>Y$ in both Outdoor1 and Outdoor2-OptA scenarios.
* Alt2 CB yields the best throughput vs overhead trade-off and Alt1A CB yields slightly better performance vs overhead trade-off than that of Alt1B in both Outdoor1 and Outdoor2-OptA scenarios.
* 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.
 |
| MediaTek | Mean UPT gain, overhead | * Alt 2 codebook structure shows a significantly better performance-overhead tradeoff compared to codebook Alt 1A.
* Alt 1A codebook structure with wideband co-phasing suffers a substantial performance loss compared to that with subband co-phasing.
* Alt 1A codebook structure suffers the problem of combining potentially different layer precoders via co-amplitude and co-phasing, which causes performance degradation.
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| Qualcomm | UPT loss over uncompressed upperbound | It can be observed that under this typical config for Rel-16 eType-II sTRP (just with some straight-forward small extension to mTRP), compression loss is not very tolerable, and some mTRP-specific optimization is needed to study. |
| Ericsson  | Mean/cell-edge SE gain | It can be seen that Alt.2 has a much better performance that Alt.1A. |
| Nokia/NSB | Mean/cell-edge SE gain | Very significant throughput gains in Outdoor 1 scenario at 700 MHz, in the order of 40% for mean UE throughput and 116% for cell-edge throughput. Gains are also significant, although smaller, for Outdoor 2A scenario at 2GHz, with increase in throughput of about 8% and 34% for mean UE and cell-edge throughput, respectively. |
| **Summary**: In general, almost all companies show significant gain in throughput over single-TRP scenarios in all the scenarios agreed in the EVM, with various feedback overhead depending on the simulated codebook structures and optimizations. * Sufficient gain is observed with 3 and 4 cooperating TRPs over 2, suggesting that N\_TRP=3,4 should be treated with equal priority
* In terms of codebook structures, Alt2 generally shows better UPT vs. PMI overhead trade-off over Alt1A, with Alt1A potentially offering some benefit when cooperating TRPs are far apart, e.g. inter-site CJT
 |

**General observation**:

* Table 1.A:
	+ [1.1]
* Table 1.B:

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Huawei, HiSilicon | For proposals 1.E and 1.F, we think the decision should be made based on comparison of feedback overhead and performance. To align the understanding of companies and to have a fair comparison between alternatives, it will be much appreciated if the information of following aspects can be provided, so that we can based on the same understanding to compare the feedback and performance gain. Our understanding of the alternatives is provided as below.

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| --- | --- | --- | --- | --- |
| Per TRP or TRP common basis for W1 and Wf | PMI obtained by SVD over separate TRP channel or over concatenated channel | W2 coefficients separately selected per-TRP or jointly selected across TRPs | Feedback overhead | Performance |
| Alt 1A/1B: per-TRP basis for W1, Wf, or Ws-fAlt 2: per-TRP basis for W1, and TRP common Wf | Alt 1A/1B/2: SVD over concatenated channel | Alt 1A/1B/2: can be jointly selected across TRPs | Alt 1A: per-TRP W1, W2, Wf feedback;Alt 1B: per-TRP W1, Ws-f feedback; long-term eigenvector basis feedback;Alt 2: per-TRP W1, W2, and TRP-common Wf feedback.The same feedback overhead for W1, W2 between alternatives. | Eigenvector basis > DFT basis;Alt 1B>Alt 1A>W2. |

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| Samsung | Re HW’s questions, in our view, the two modes are different (especially the FD bases part). So, the UE implementation for PMI calculation can also be different. In particular, in mode 1, the FD basis can be selected based on per TRP channel, whereas in mode 2, it can be selected based on aggregated (across TRPs) channel.

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| --- | --- | --- | --- | --- |
| Per TRP or TRP common basis for W1 and Wf | PMI obtained by SVD over separate TRP channel or over concatenated channel | W2 coefficients separately selected per-TRP or jointly selected across TRPs | Feedback overhead | Performance |
| Same as HW | Alt 1A/1B: SVD over per TRP channelAlt2: SVD over concatenated channel | W2 design can be the same or different for all alts | The same feedback overhead for W1. If W2 design is the same for mode 1 and mode2, then the feedback overhead for W2 will also be the same. | (Assuming DFT based Alt2B) Alt2 >Alt1A~Alt2B The perf. Of Alt2B can be improved (E.g. per element quantization of eigenvector), but @ cost of increased overhead |

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| Nokia/NSB | Regarding Huawei’s comments on P1.E/1.F: eigenvector-based $W\_{1}$-$W\_{f}$ assumes UE-specific basis vectors, which requires a redesign of $W\_{1}$ and $W\_{2}$ codebooks, for which companies may have very different proposals. We observe significant performance gains of CJT with the legacy DFT codebooks, so we don’t see the need for this laboursome redesign. Regarding feedback overhead, the difference between Mode 1 and Mode 2 depends on the design of W2 and how Wf is reported in Mode 1. But, in general, we think Mode 2 needs less overhead than Mode 1. Regarding performance, we have same assessment as Samsung in that Alt 2 shows better performance than Alt 1.  |
| vivo | **On Proposal 1.E and 1.F**We think from standard perspective, the difference between Mode 1 and Mode 2 is a same set of FD basis is selected for multiple TRPs in Mode2, while Mode 1 can allow same or different sets of FD basis for multiple TRPs. Considering this, we don’t agree with the statement that a common size of W2 is always used for both Mode 1 and Mode 2. To maintain a same number of NZ coefficients, the size of W2 can be different for the two modes considering different location distribution of the coordinated TRPs, i.e., the delay range and relative delay difference of different TRPs. Also, different total numbers of FD basis may be observed for the two TRPs. Therefore these two are actually different modes. However, we should strive to have a common design on the mechanism for the UCI reporting details.Regarding Alt 1B and joint FD/SD basis, we feel like the difference between Alt 1B and Alt 1A includes only UCI design details, which Alt 1B just uses a joint coding for FD basis and SD basis. We don’t see the need of discussing such micro-optimization of UCI signaling at this stage. |
| Intel (2) | We share similar understanding with Samsung on the different modes (proposal 1E). In our understanding different UE implementation may be assumed for different alternatives. Also, W2 design might be different for different alternatives. So, we support this proposals, other details can be considered further. |
| MediaTek | Re Proposal 1.F1. Per WID, Rel-16/17 codebook would be enhanced for CJT. Although it is up to interpretation, we believe that redesigning SD and FD bases would be much more than enhancement/refinement of these codebooks.
2. Although we agree with HW that long term feedback of eigen bases may reduce overhead, such form of long term feedback is not specified for current Rel-16/17 codebooks. For the ongoing work item on CSI enhancement for high velocities, it is mandated that SD and FD bases would not be modified, even if long term feedback is eventually agreed.

Considering these aspects, the case for joint SD-FD bases (DFT/eigen) and joint or separate eigen bases stands weak. |
| Mod (round 0) | **Thanks for the comments from companies that respond to Huawei’s inquiries re proposals 1.E and 1.F. Overall the concern on joint eigenvector basis for Rel-16-based (hence Alt1B codebook) includes unclear throughput-overhead trade-off benefit (optimization), spec impact, the amount of works involved (vs. scope/TU, time/efforts).*** **Other companies are encouraged to comment as well**

**Minor revision on proposals 1.B (including the bullet from 1.A) and 1.E (different 🡪 independent)** |
| Mod V0 | 1. **Check and, if needed, update your view in Table 1A/1B, especially on the moderator proposals**
2. **Share additional inputs here, if needed**
3. **Technical discussion re proposal 1.F from ROUND 0 is copied below.**
 |
| Qualcomm | Generally fine with **all Proposals**For Proposal 1.G, 1.I (and other aspects of this issue 1.9), added our preference with track change |
| Lenovo | - Support Proposal 1.F, 1.G and 1.I- Do not support Proposal 1.C. With the exception of 2 companies, all companies prefer to down-select to Rel-16 eType-II codebook as a baseline for Rel-18 codebook design.  |
| vivo | **Proposal 1.C**We support the enhancement to be based on Rel-16 eType II codebook. We have concern to introduce enhancement for FeType II PS due to it requires large effort for discussion. The design principle and evaluation effort are quite different for FeType II PS. Issues like calibration error modelling for multiple TRPs, etc., need to be discussed for EVM. **Proposal 1.G**We support Alt 2. We’d like to understand more about “K transmission hypotheses” in Alt 3. These transmission hypotheses correspond to what specific transmission schemes. Does it mean UE reports one CSI for CJT and another CSI for NCJT with N value configured in RRC? Or it means UE reports multiple CSIs for multiple configured N values?In Alt 4, similarly, what do the transmission hypotheses correspond to? Does it mean UE reports one CSI for CJT and another CSI for NCJT with N value reported in UCI? Or it means UE reports multiple CSIs for multiple N values selected by UE?**Proposal 1.I**We support Alt 1, which is same as legacy eType II CSI. We think a careful evaluation is needed if we want to further extend the W2 coefficient quantization scheme. Hence we suggest to add a bullet indicating that Alt 1 serves as the baseline for further evaluation. Any enhancements need to prove jusitficated gain.[Mod: I agree with you, let’s check during offline] |
| Mod V4 | **No change** |
| NTT DOCOMO | Proposal 1.C:Based on majority view, we think down-selection to - Rel-16 eType-II regular codebook is needed.Proposal 1.G:We donot understand the meaning of ‘K>=1 values of N’ in Alt4. Does it mean multiple values of N, or for a certain N, multiple transmission hypothsis on TRP combination? For example, for K=2, does it mean two cases of N=2 and N=3 can be reported by UE? Or does it mean for a UE selected N=3, two TRP combinations can be reported by UE (e.g., TRP1+2+3 CJT or TRP1+2+4 CJT)?In addition, we think the benefit of gNB configured N is clear as gNB has more NW information to make a proper configuration. We also see some companies prefer UE selection of N. We think similar discussion happened in Rel-17 NCJT and finally two CSI report modes were agreed. It is also possible that we have similar discussion for Rel-18 CJT and come out with multiple solutions. Hence, it is possible to support multiple schemes on N, instead of down-selecting to one scheme. Proposal 1.I:We think different alternative may be selected for different codebook structure. We’d like to add a note to clarify this point. |
| Spreadtrum | **Proposal 1.C**We support to enhance R16 TypeII codebook. At least there is no objection on R16 TypeII codebook refinement.**Proposal 1.F and 1.G**Support.**Proposal 1.I**Regarding W2 quantization group, we support per polarization per TRP/TRP-group. Regaring the strongest coefficients for each group, we think differential quantization is benefitial to save overhead. However, the wording “per-TRP/TRP-group SCI” may imply that differential quantization among the strongest coefficients for each TRP/TRP group will not be considered. In order to clarify it, we would like to add an FFS as below,**Proposal 1.I**: On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group and Strongest Coefficient Indicator (SCI) design, for each layer, down-select from the following alternatives:* 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
	+ Without the strongest TRP/TRP-group indicator
* Alt2. One group comprises one polarization for one TRP/TRP-group (*C*group,phase=N, *C*group,amp=2N), per-TRP/TRP-group SCI
	+ With the strongest TRP/TRP-group indicator
	+ FFS: Differential quantization of the strongest coefficients for each TRP/TRP group
* 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), per-TRP/TRP-group SCI
	+ With the strongest TRP/TRP-group indicator

FFS: Differential quantization of the strongest coefficients for each TRP/TRP group |
| CATT | Regarding the Proposal 1.G, in our understanding, the number of transmission hypothesis in current proposal is mainly about CJT transmission hypothesis (e.g. as sharing by DOCOMO, when N/N\_TRP=3 is for CJT, the different combinations for CJT can be reported additionlly). However, since NCJT support to report S-TRP transmission hypothesis and N\_TRP=1 has been supported in last online session, we think the S-TRP + CJT transmission hypothesis reporting should be supported for both alternatives. Besides, the PMI can be shared between S-TRP and CJT, the only overhead is mainly from CQI reporting, if some RI restriction between S-TRP and CJT can be enhanced for Rel.18. So our suggestion is to add one for this proposal.**Proposal 1.G**: 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):* 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 ${1,..., NTRP}
	+ N is the number of cooperating TRPs, while NTRP is the maximum number of cooperating TRPs configured by gNB
	+ In this case, the selection of N out of NTRP TRPs is also reported (FFS: exact reporting scheme)
	+ FFS: Configuration of NTRP TRPs and the value of NTRP, whether explicit or implicit
	+ Note: only one transmission hypothesis is reported
	+ ~~FFS: In addition to one transmission hypothesis, whether reporting multiple transmission hypotheses (with the same N value or possibly different N values) is supported~~
* Alt3. The UE reports CSI corresponding to K transmission hypotheses
	+ The N configured TRPs are gNB-configured via higher-layer (RRC) signalling
	+ FFS: supported value(s) of K, and whether the K transmission hypotheses are gNB-configured or UE-reported
* Alt4. K>=1 values of N is UE-selected and reported as a part of CSI report where N$\in ${1,..., NTRP} where K is the number of transmission hypotheses
	+ 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

FFS：Whether to report S-TRP transmission hypotheses if CJT transmission scheme is configured. |
| Intel | For Proposal 1C, since Wf matrix design for Rel-17 Type II PMI codebook is different it may be hard to apply similar design principles for Rel-16 and Rel-17 PMI codebooks.  |
| Sony | For Proposal 1.G, we support Alt2 or Alt4. For Proposal 1.I we prefer Alt3 since in our understanding it enforces coherent combining of the signals from the various TRPs/TRP groups. |
| CEWiT | Proposal 1.C : We suggest to downselect to Rel16 codebook based on high majorityProposal 1.G : We believe in Alt 2 to exploit dynamic channel variations, it is good for the UE to select the co-ordinating TRPs in the report rather than having a fixed list of TRPs as per Alt 1. The means and frequency of reporting the co-ordinating TRPs by the UE can be discussed further. Regarding Alt 3 and Alt 4, we believe companies should also discuss the increase in feedback overhead over the merits of the alternatives. |
| AT&T | **Proposal 1.C:** We support Proposal 1.C, however our preference is Rel-16 eType-II**Proposal 1.F:** We support Proposal 1.C, however our preference is Alt1Note: @ Huawei & @ Samsung: regarding Table 2 Additional inputs: issue 1, the 2nd column in Huawei’s comment, “PMI obtained by SVD over separate TRP channel or over concatenated channel Alt 1A/1B/2: SVD over concatenated channel”. We think SVD over the concatenated channel (rather than the SVD over per TRP channel) should be used to ensure the orthogonality and eliminate the mutual interference. The components of calculated eigen vectors can be then disaggregated to their associated TRPs.**Proposal 1.G:** We support proposal 1G, however our preference is Alt1* In Alt1, single hypothesis that includes all the cooperating TRPs is sent by each UE. The CJT-mTRP have visibility on all connected UEs (kind of a centralized solution) and can perform further optimization by selecting subset or all TRPs for transmission to enhance the performance. Consider an example (Figure is shown below) with two TRPs (TRP1 & TRP2) serving two users (UE1 & UE2), the mTRP scheduler will try to optimize the MU pairing and reduce the mutual interference. One potential optimal decision is to select TRP1 for UE1 & TRP2 for UE2.

* In Alt2, UE selects the number of cooperating TRPs and their associated PMI. This alternative acts like a distributed solution and since the UE does not have visibility on the rest of the network, it could degrade the performance. In the above Figure, UE1 could report TRP1 & TRP2 and same thing for UE2. Clearly, this does not necessarily lead to optimal CJT performance
* Alt3/Alt4: Alt3 can increase the overhead since UE will need to transmit the K transmission hypotheses. However, Alt4 tries to optimize Alt3 and lower the overhead by limiting the number of K transmission hypotheses. In Alt3/Alt4, the CJT-mTRP decides the selected hypothesis among the reported hypotheses; in this case Alt3/Alt4 reduces to Alt1 since in essence Alt1 (see the example above) does not necessarily select all the N TRPs as this decision can be left to the scheduler to make the final decision about which TRPs will be selected for each scheduled UE.
 |

### 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
 | **Support (equal priority for) both Rel-16 eType-II and Rel-17 FeType-II:** Huawei/HiSi**Down-select to only (prioritize) Rel-16 eType-II:** Apple, DOCOMO, MediaTek, NEC, Xiaomi, Samsung, Lenovo, Intel, Xiaomi. Qualcomm, Apple, DOCOMO, Ericsson, ZTE, Nokia/NSB, LG, Spreadtrum, CMCC**Down-select to only (prioritize) Rel-17 FeType-II:** Huawei/HiSi |
| 2.4 | [110] **Agreement**On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, support the assumption of the UE-side prediction * On the definition of UE-side prediction, down-select from the following alternatives:
	+ Alt1. UE “predicting” channel/CSI after the slot with a reference resource
	+ Alt2. UE “predicting” channel/CSI after slot n (where the CSI is reported)
	+ Alt3. UE “predicting” channel/CSI after the slot where CSI-RS resides

**Proposal 2.D**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities assuming the UE-side prediction, {...} | **Alt1:** Qualcomm, Samsung, LG, ZTE**Alt2:** Huawei/HiSi, vivo, Nokia/NSB (2nd pref), Lenovo, Google, Intel**,** MediaTek, Ericsson, Spreadtrum, CATT, CMCC, Apple**Alt3:** Samsung, DOCOMO, NEC, Nokia/NSB (1st pref) |
| 2.6 | [109-e] **Agreement**On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, *at least for discussion purposes*, define the following:* Assume a CSI report in slot *n*, and let the length of the DD/TD basis vector be *N*4
	+ Note that basis vector has no span/window in time-domain, only length
* CSI-RS measurement window of [*k*,*k*+*W*meas –1], representing the window in which CSI-RS occasion(s) are measured for calculating a CSI report
	+ *k* is a slot index and *W*meas is the measurement window length (in slots)
	+ Note: In the legacy Rel-16/17 CSI, the CSI-RS occasion(s) are configured in *CSI-ReportConfig*
* CSI reporting window of [*l*,*l*+*W*CSI –1], associated to the CSI report in slot *n*
	+ *l* is a slot index and *W*CSI is the reporting window length (in slots)
* CSI reference resource(s) in time-domain
	+ The location of a CSI reference resource is denoted as *n*ref (slot index)

[109-e] **Agreement**On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, consider *at least* the following alternatives for potential down-selection:* Alt1: *n*ref (CSI reference resource slot) as boundary
	+ Alt1.A:  *l* + *W*CSI –1 ≤ *n*ref
	+ Alt1.B:  *l* ≥ *n*ref
	+ Alt1.C: *l* < *n*ref and *l* + *W*CSI –1 > *n*ref
* Alt2: *n* (report slot) as boundary
	+ Alt2.A: *l* + *W*CSI –1 ≤ *n*
	+ Alt2.B: *l* ≥ *n*
	+ Alt2.C: *l* < *n* and *l* + *W*CSI –1 > *n*
* Alt3: End slot of *W*meas (*k* + *W*meas –1) as boundary
	+ Alt3.A: *l* + *W*CSI –1 ≤ *k* + *W*meas –1 with the following as a special case: *l=k,* *W*CSI = *W*meas
	+ Alt3.B: *l* ≥ *k* + *W*meas –1
	+ Alt3.C: *l* < *k* + *W*meas –1 and *l* + *W*CSI –1 > *k* + *W*meas –1 with the following as special cases:
		- *l=k,* *l* + *W*CSI = *n*
		- *l=k,* *l* + *W*CSI > *n*

FFS: whether *n*ref represents the slot index of Rel-15 CSI reference resource or a newly defined CSI reference resourceFFS: whether/how the CSI measurement window and reporting window are configured**Proposal 2.F**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, when UE-side prediction is assumed, down-select ~~at least~~ one from the following alternatives:* ~~Alt1.A:~~ *~~l~~* ~~+~~ *~~W~~*~~CSI~~ ~~–1 ≤~~ *~~n~~*~~ref~~
	+ *~~n~~*~~ref~~ ~~(CSI reference resource slot) as boundary~~
* Alt1.B:  *l* ≥ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
* Alt2.B: *l* ≥ *n*
	+ *n* (report slot) as boundary
* Alt3.B: *l* ≥ *k* + *W*meas –1
	+ End slot of *W*meas (*k* + *W*meas –1) as boundary, assuming CSI-RS measurement window of [*k*,*k*+*W*meas –1]

**FL Note**: Since we have agreed on UE-side prediction, Alt1.A should be excluded. | **Alt1.A:** Spreadtrum, Xiaomi, LG, Fraunhofer IIS/HHI, Qualcomm, DOCOMO**Alt1.B:** IDC, ZTE, LG, CMCC, DOCOMO**Alt2.B:** Huawei/HiSi, Spreadtrum, vivo, Google, OPPO, CATT, Intel, CMCC, MediaTek, Ericsson, Nokia/NSB, DOCOMO (optional)**Alt3.B:** CMCC, Fraunhofer IIS/HHI, Nokia/NSB, Samsung, NEC, [Apple]**FL Note**: This topic and proposal have been discussed OFFLINE [1]. * Alt1.A: Qualcomm, DOCOMO, LG, Intel, Xiaomi
* Alt1.B: Qualcomm, ZTE, LG, OPPO, CMCC, Intel, IDC
* Alt1.C: Qualcomm, ZTE, LG, NEC
* Alt2.A:
* Alt2.B: MediaTek, vivo, OPPO (1st pref), NEC, CMCC, CATT, Huawei, HiSi, Ericsson, Intel, Google, Nokia/NSB (2nd pref)
* Alt2.C:
* Alt3.A: Samsung, DOCOMO, MediaTek (no need to define Wmeas), Apple (gNB-side prediction $l=k, W\_{CSI}=W\_{meas}$), Fraunhofer IIS/HHI (gNB-side prediction $l=k, W\_{CSI}=W\_{meas}$), Google,
* Alt3.B: Samsung, OPPO, NEC, CMCC, Nokia/NSB (1st pref)
* Alt3.C: Samsung, NEC

Some discussion points:* Concern on x.C (UE complexity): MediaTek, Spreadtrum, Xiaomi, vivo
* Concern on gNB-side prediction (e.g. Alt3.A): vivo, Ericsson, ZTE, Nokia/NSB
* UE-side (only) prediction (x.B) is supported by a number of companies, at least as an optional feature

Based on the offline discussion, I have narrowed down the alternatives by removing the ones with concern and lack of support. *Please fit your preferences on the four remaining alternatives. Else it would be hard for us to focus our discussion.* |
| 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)[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**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:* Time-domain behaviour for each NZP CSI-RS resource: periodic, semi-persistent, aperiodic
* The use of K≥1 NZP CSI-RS resources:
	+ FFS: whether the resources are in the same CSI-RS resource set, other details
	+ FFS: whether different resources are associated with different time-domain behaviors
 | **Proposal 2.G:*** **Support:** Google, Samsung, Nokia/NSB, Lenovo, DOCOMO, MediaTek, Qualcomm, LG, Spreadtrum, ZTE, Xiaomi, NEC, OPPO, CATT, CMCC, Sharp, Apple
* **Not support:** vivo (concern on AP)
 |
| 2.8 | The need for DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook)[109-e] **Agreement**For the Type-II codebook refinement for high/medium velocities, further study the following issues:* The need for basis type indicator, if both a trivial basis (e.g. identity) and a non-trivial (e.g. DFT) basis are supported, and if so, whether implicit or explicit
* The need for DD/TD (compression) unit (analogous to PMI sub-band for Rel-16 codebook)

**Proposal 2.H**: 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
 | **Yes:** OPPO, Samsung, LG, MediaTek, Qualcomm (same as time-interval b/w two consecutive CSI-RS occasions, e.g. periodicity for P-CSI-RS), Ericsson, Spreadtrum, ZTE (configurable, and subjective to UE capability), Xiaomi, Nokia/NSB, CMCC, Sharp, Sony, CEWiT**No:**  |
|  |  |  |

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

|  |  |  |
| --- | --- | --- |
| **Company** | **Metric** | **Key observation** |
| Huawei/HiSi | SLS: avg. UPT vs overhead | * For R17 FeTypeII codebook enhancement, Alt2B can only achieve ~1% performance gain compared Alt2A.
* For R16 eTypeII codebook enhancement, Alt2B can only achieve ~0.3% performance gain compared Alt2A.
* For R17 FeType II and R16 eTypeII codebook enhancement, there’s no obvious difference between performance of Alt1A, Alt1B and Alt2.
 |
| ZTE | SLS: (Avg, 5%, 95%) UPT | Regarding On the CSI reporting and measurement for the Type-II codebook refinement for high/medium velocities, based on SLS simulation results in UMa, we can observe:* Under UE-side prediction (H-based with Wiener filter and extrapolation), a dominant performance can be obtained via exploring Doppler-domain information compared with legacy under the same RS overhead.

In 20~30km/h, a maximal performance gains over legacy can be observed (it implies that a typical scenario for this CSI enhancement), and then lower or larger than this range, the performance gain is decreased. |
| Vivo | NMSE vs reporting window | * It is effective that UE adopts Auto Regressive to predict channel based on prior raw channel information, on the contrary, there is little performance gains if gNB predicts channel based on DFT basis and corresponding projection coefficients reported in CSI.
* For CSI prediction in UE side,
	+ In medium/high velocity scenario, it requires a number of CSI-RS occasions (e.g., >10 occasions) for UE measurement to achieve acceptable performance.
	+ With sufficient number (e.g., 16, 32, …) of CSI-RS occasions for measurement, UE can predict CSI in a larger size of CSI reporting window (e.g., more than 10 ms)
	+ The configuration of CSI-RS for measurement (e.g., periodicity) needs to match the UE speed.
 |
| OPPO | SLS: UPT | Observation 1: * Supporting TD unit (e.g., 4 slots@15kHz) can reduce UE complexity without obvious performance degradation
* The performance gain of oversampling is negligible at medium velocity (30km/h)

Observation 2: Performance of DFT/DCT/Slepian are similar. Identity basis degrades performance-overhead tradeoff severely.Observation 3: CQI prediction has 2%-3% performance gain for 30km/h-60km/h velocity. |
| Intel | LLS | As it can be seen from the evaluation results, the performance for 1 and 2 Doppler-domain basis vectors is similar while significant performance gains are observed with 4 and 8 Doppler-domain basis vectors.As it can be observed from the above results. Reporting of robust PMI with single Doppler domain basis vector leads to performance improvement comparing to the legacy Rel-16 PMI codebook. |
| Samsung | SLS: UPT vs overhead | * DFT-based gNB-side prediction does not outperform Rel-16 baseline
* UE-side prediction achieves improved UPT vs overhead trade-off, but requires multiple CQIs
 |
| Fraunhofer IIS/HHI | SLS: UPT s overhead | 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. |
| MediaTek | SLS. UPT | * With a good balance between CSI-RS overhead and prediction performance, reducing CSI-RS periodicity and CSI feedback period can provide a higher throughput gain.
* Linear prediction does not perform well under CSI-RS burst measurement.
* For Type-II codebook refinement for high/medium velocities, CSI interpolation can be a good alternative to reduction of CSI-RS periodicity and CSI feedback period.
* For UMa 60 km/h, it is beneficial to support lower CSI-RS periodicity and CSI feedback period.
 |
| Qualcomm | SLS: UPT, overhead | Evaluations in Figure 4 shows certain gain can be observed for beam-specific TD basis selection over beam-common.Observation 3: Alt.B(s) have shorter TD basis length N4 than Alt.C(s), and certain performance loss can be observed at a same extrapolation length. Diagram  Description automatically generatedFigure 10. Rel-18 gain over baseline Rel-16 |
| Ericsson | SLS: UPTLLS: Throughput vs SNR | SLS: Based on the results we have presented so far with Alt3 codebook structure of Rel-18 Type II Doppler codebook, we can see that how many W2’s need to be reported is scenario specific.SLS: UE-side predictionWe note that for Scenario (a) 1 CSI per report performs roughly the same as 5 CSI per report, which indicate that predicting and accounting for the scheduling delay yields the main performance benefit. For Scenario (b) the 5 CSI per report clearly outperforms the 1 CSI case, however, accurate AR based predictions require more and denser sampled CSI measurements for Scenario (b).LLS:For the considered channel, measurement window and the prediction method used; it can be observed that feeding back a single CSI derived from a predicted channel when accounting for the feedback delay performs as good as the case of feeding back 5 CSI, as shown by the (1 CSI, AR, B=10, d=5, R=5) curve. |
| Nokia/NSB | LLS: cdf of cosine similarity, cdf of CQISLS: UPT vs speed | * When comparing MMSE channel predictor performance to a zero-order holder baseline, the gain observed in eigenvector-based cosine similarity distortion tends to be much smaller for CQI, which is more indicative of system-level throughput.
* To compare Type-II-Doppler with baseline Type-II, we assume the same CSI-RS and CSI reporting periodicity. If the comparison is done by assuming, for the baseline, a CSI reporting periodicity $N\_{4}$ times smaller than that of Type-II-Doppler such that the same number of CSIs are reported on average per given period, compression gain rather than prediction gain would dominate as we increase $N\_{4}$, even at low Doppler spread.
* A comparison between R16 Type-II with one CSI per reporting period and Type-II-Doppler with UE-side prediction and two CSIs per reporting period, assuming the same CSI reporting periods for the two systems, shows gains of 2%, 2.6, 2.7% in mean UE throughput for speeds of 10,30,60 km/h, respectively, and gains of 4.6%, 1.3%, 1.4% in cell-edge UE throughput, for speeds of 10,30,60 km/h, respectively.
 |
| **Summary**: * Some companies show significant gain in throughput with Doppler-domain compression at various UE speeds, while other show quite marginal gain at around 10kmph (and almost no gain at higher speeds such as 30/60 kmph). In terms of using Doppler-domain compression, a few companies argue that no compression (identity basis) with multiple W2/CQI (in time) seems to offer better performance.
* Some companies, based on their simulation results, suggest that UE-side prediction (with spec support in measurement and calculation behavior) is necessary to guarantee the observed gain while gNB-side prediction isn’t beneficial.

  |

**General observation**:

* Table 3.A:
	+ [2.1]
* Table 3.B:

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Vivo (from ROUND 0) | **Proposal 2.G**We have concern on supporting aperiodic CSI-RS for this high/medium CSI enhancement. Based on our study, to have a satisfied prediction performance, it is needed to use sufficient number of CSI-RS occasion (e.g., 16 for 2-ms CSI-RS periodicity) to perform measurement. 16 CSI-RS occasions mean at least 32 ms to measure CSI-RS. In 30kHz SCS, it is 64 slots. Such huge delay makes to trigger aperiodic CSI-RS nearly impossible as it introduces large CSI latency. It does not make sense that gNB triggers CSI-RS and wait more than 64 slots to get the CSI. Further, if the CSI-RS periodicity is larger, saying 4-ms, more CSI-RS occasions will be needed to ensure the performance, e.g., 32 occasions in our evaluation. Such latency will increase to 256 slots, which is not practical at all for aperiodic CSI-RS.Further, the need to have multiple CSI-RS resources for measurement is not justified. In our understanding, at least periodic or semi-persistent CSI-RS does not require multiple resources to measure. UE can just uses the multiple periodic CSI-RS occasions. |
| Mod V0 | 1. **Check and, if needed, update your view in Table 3A/B, especially on the moderator proposals**
2. **Share additional inputs here, if needed**
 |
| Qualcomm | Fine with **proposal 2.A, 2.G, 2.H**Re **proposal 2.D**We support UE-side prediction, while suggesting not to preclude W-based prediction (only way for gNB-side prediction) by only reporting observed CSI-RS occasions.One obvious benefit is UE complexity, and another benefit has not been specifically discussed till current study: **Robust to random phase over time occasions**, An intuitive explanation is, W only take into account the relative phase b/w ports/beams, it does not matter if a port-common random phase $D\_{Tx}\left(t\right)$ is introduce over time $t$Mathmatical proof is provided below (can be skipped for a quick read):

|  |
| --- |
| Denoted respective random phase over time for Rx and Tx as$D\_{Rx}\left(t\right)=\left[\begin{matrix}e^{jϕ\left(t\right)}&&\\&\ddots &\\&&e^{jϕ\left(t\right)}\end{matrix}\right]$ (size $N\_{Rx}×N\_{Rx}$), $D\_{Tx}\left(t\right)=\left[\begin{matrix}e^{jθ\left(t\right)}&&\\&\ddots &\\&&e^{jθ\left(t\right)}\end{matrix}\right]$ (size $N\_{Tx}×N\_{Tx}$)Channel H with random phase is $H\_{D}\left(t\right)=D\_{Rx}\left(t\right)H\left(t\right)D\_{Tx}\left(t\right)=H\left(t\right)e^{jθ\left(t\right)+jϕ\left(t\right)}$W-based extrapolation can naturally cancel the random phase over time:$$SVD\left(H\_{D}^{H}\left(t\right)H\_{D}\left(t\right)\right)=SVD\left(H^{H}\left(t\right)H\left(t\right)\right)=V\left(t\right)Σ^{2}V\left(t\right)$$ |

For H-based extrapolation, this random phase is not able to be cancelled. However, unfortunately, no random phase is assumed in our EVM (e.g. phase-continiuty assumed even for tens of slots), thus current results comparison is a little unfair for W-based.As for whether W-based prediction can provide a tolerable performance, at least one company provided similar performance b/w W-based and H-based. From our perspective, we want to have more time to study before directly shutting down the door.Re **proposal 2.F**As in the above reply, we suggest not to remove Alt1.A for W-based prediction by gNB, at least not in this RAN1#110.Another Alt.C(s) (observation+prediction) also needs further study, in our view, since it has longer N4 than Alt2.B and provides better performance  As for some companies’ concern on UE complexity regarding more time occasions with longer N4, firstly, keeping Alt.C(s) does not mean to preclude Alt2.B – UE can still have complexity-perfornance trade-off probably according to UE capabilitySecondly, longer N4 does not always mean higher complexity – it may depend on UE-implementation regarding how to extrapolate (note UE can also do W-based extrapolation), and, how to do SVD (e.g. single-SVD over all time&subbands as Fraunholfer mentioned).**Suggested proposal 2.F**:

|  |
| --- |
| **Proposal 2.F**: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, down-select one of Alt1/2/3.B, and/or additionally with Alt1/3.A and/or Alt1/3.C from the following alternatives:* Alt1/3.A:  *l* + *W*CSI –1 ≤ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
* Alt1.B:  *l* ≥ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
* Alt2.B: *l* ≥ *n*
	+ *n* (report slot) as boundary
* Alt3.B: *l* ≥ *k* + *W*meas –1
	+ End slot of *W*meas (*k* + *W*meas –1) as boundary
* Alt1/3.C:  *l* + *W*CSI –1 ≤ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
 |

In our view, Alt1/3 does not make too much difference and can be merged (anchor slot both according to timeline), while Alt2’s anchor slot is report slot[Mod: Re Altx.C I still haven’t received any indication that the opponents have changed their mind. I have mentioned that you (and/or Samsung) can check first with them before repeating this request invain over and over (since I will not be able to accommodate it).Re including Altx.A, it is not needed in the recent revision per Lenovo’s comment since Altx.A doesn’t accommodate UE-side prediction] |
| Lenovo | - Do not support Proposal 2.A. With the exception of 1 company, all companies prefer to down-select to Rel-16 eType-II codebook as a baseline for Rel-18 codebook design. - Proposal 2.D is not needed. Preference is to discuss gNB predicton later. - For Proposal 2.F, we propose the following update (highlighted text)***Proposal 2.F****: On the CSI reporting and measurement for the Rel-18 Type-II codebook refinement for high/medium velocities, down-select ~~at least~~ one from the following alternatives for UE-side prediction:** ~~Alt1.A:~~ *~~l~~* ~~+~~ *~~W~~*~~CSI~~ ~~–1 ≤~~ *~~n~~*~~ref~~
	+ *~~n~~*~~ref~~ ~~(CSI reference resource slot) as boundary~~
* Alt1.B:  *l* ≥ *n*ref
	+ *n*ref (CSI reference resource slot) as boundary
* Alt2.B: *l* ≥ *n*
	+ *n* (report slot) as boundary
* Alt3.B: *l* ≥ *k* + *W*meas –1
	+ End slot of *W*meas (*k* + *W*meas –1) as boundary, assuming CSI-RS measurement window of [*k*,*k*+*W*meas –1]

*[Mod: Good point]*- For Proposal 2.G, we propose the following for clarity, which is in line with previous RAN1#109-e agreement***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:** *Time-domain behaviour for each NZP CSI-RS resource: periodic, semi-persistent, aperiodic. FFS: whether different resources are associated with different time-domain behaviors*
* *The use of K≥1 NZP CSI-RS resources:*
	+ *FFS: whether the resources are in the same CSI-RS resource set, other details*

[Mod: ok] |
| vivo | **Proposal 2.A**Similar concern as 1.C on FeType II PS. We think to include it requires much more effort for discussion. We need to re-discuss EVM again on issues like whether and how to model FDD reciprocity in doppler domain, etc..**Propsoal 2.D**gNB can only acquire the CSI after the slot carrying the CSI report. If UE does not predict the CSI after such slot, there is no point for UE to predict such CSI. Hence we think Alt 2 should be supported at least. We suggest to agree on Alt 2 first, and then further discuss whether to extend the start position to include the slot(s) before slot n.[Mod: Yes, we will check temp offline and try to choose one]**Propsoal 2.F**We agree that given we already have supported UE prediction, we can exclude Alt 1.A.**Proposal 2.G**We still have concern on aperiodic CSI-RS. Technical issues for it can be found in the previous comment from us above. We can be okay if * + Aperiodic CSI-RS is removed or further studied
	+ FFS the use of K>1 resources

[Mod: I’ll note your concern in Table 3.A]**Propsoal 2.H**OK |
| Mod V4 | **Revised proposals 2.F and 2.G per Lenovo’s comments** |
| Fraunhofer IIS/Fraunhofer HHI | Proposal 2.A: We also share the same opinion as Lenovo/Motm. we do not support Alt 2.A in the current form. Proposal 2.F: we also think that Alt 3.C should not be precluded at this stage. In our understanding, Alt 3.c allows UE to perform either W-based prediction or H- based prediction, as the reporting window also includes a part of the measurement window. With Alt 3.C, gNB will have information about past as well as future CSI and this would further allow gNB to extrapolate CSI for future slots as well. We think this alternative is more robust compared to other alternatives in proposal 2.F as this codebook is specifically aimed for UE mobility scenarios.   |
| Spreadtrum | **Proposal 2.A**We support to enhance R16 TypeII codebook. At least there is no objection on R16 TypeII codebook refinement.**Proposal 2.D**Considering that gNB scheduling can be optimized after receiving the CSI report, the predicted CSI corresponds to the slot after CSI report is more useful. Alt2 is preferred.**Proposal 2.F, 2.G and 2.H**Support. |
| CATT | **Propsoal 2.D:** We are fine with vivo’s suggestion.**Propsoal 2.F:** Support**Proposal 2.G:** Support**Propsoal 2.H:** Support |
| Intel | Proposal 2A:Assumption on DD reciprocity is not clear for Rel-17 PMI codebook.Proposal 2D: Support Alt 2. From our perspective there is no sense to predict the PMI before the report. |
| Sony | In general, we are okay with all the proposals. |

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

Table 5A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | [109-e] **Agreement**The work scope of TRS-based TDCP reporting focuses on the following use cases for evaluation purposes:* Targeting medium and high UE speed, e.g. 10-120km/h as well as HST speed
* Aiding gNB to determine
	+ CSI reporting configuration and CSI-RS resource configuration parameters,
	+ Precoding scheme, using one of the CSI feedback based precoding schemes or an UL-SRS reciprocity based precoding scheme
* Aiding gNB-side CSI prediction

[109-e] **Agreement**For Rel-18 CSI enhancements, proceed to support and specify the following features (the previously agreed work scopes apply):* Type-II codebook refinement for CJT mTRP
* Type-II codebook refinement for high/medium UE velocities exploiting time-domain correlation/Doppler-domain information
* UE reporting of time-domain channel properties (TDCP) measured via CSI-RS for tracking
	+ The use case of aiding gNB-side CSI prediction is to be confirmed in RAN1#110

**Conclusion 1.A**: For the Rel-18 TRS-based TDCP reporting, there is no consensus in confirming the use case of aiding gNB-side CSI prediction.**FL Note**: Need to decide whether this use case is kept or not. This topic has been discussed OFFLINE [1] | **TDCP use case of “aiding gNB-side CSI prediction”*** **Confirm**: CATT, DOCOMO
* **Remove**: Huawei/HiSi, [Lenovo], Ericsson, vivo

[Mavenir] Propose to add additional use cases:* Aiding gNB to determine
	+ whether to enable joint channel estimation for PUSCH/PUCCH or not and the time domain window size if applicable.

[Mod: Similar proposal was brought up in the last meeting but it was opposed by many. It is not within the scope of CSI agenda item 9.1.2]* + TDCP-aware (Doppler shift aware) LA

[Mod: It is not within the scope of CSI agenda item 9.1.2][Mod: Re use cases, we appreciate the proposals for new use cases. But the use cases have been finalized in the last meeting. Unless the group can agree on adding new use cases, we cannot go back and add new ones.] |
| 3.2 | [109-e] **Agreement**The work scope of TRS-based TDCP reporting includes down selection from the following TDCP parameters:* Alt1. Doppler shift
* Alt2. Doppler spread **(=max Doppler shift)**
* Alt3. Cross-correlation in time
* Alt4A. Relative Doppler shift of a number of peaks in CIR
* Alt4B. Relative Doppler shifts of different TRSs
* Alt5: CSI-RS resource and/or CSI reporting setting configuration assistance

**Proposal 3.B**: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives by RAN1#110bis-e:* AltA. Based on Doppler profile
* AltB. Based on time-domain correlation profile
	+ E.g. correlation within one TRS resource, correlation across multiple TRS resources
* AltC: CSI-RS resource and/or CSI reporting setting configuration parameter(s) to assist network
 | **AltA:** IDC, Samsung, Spreadtrum, Mavenir, Google, OPPO, CATT, Xiaomi, LG, CEWiT, Apple, Sharp, DOCOMO, ZTE, Huawei/HiSi, vivo, CEWiT, Nokia/NSB**AltB:** vivo, OPPO, CEWiT, Ericsson**AltC:** MediaTek, Qualcomm |
|  |  |  |

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

|  |  |  |
| --- | --- | --- |
| **Company** | **Metric** | **Key observation** |
| Mavenir | LLS: RMS error, standard deviation, bias | * Higher speed would take more RMS error when SNR is enough high, but RMS error in lower speed could be slightly higher when SNR is lower. Standard deviation and bias are higher with increasing speed.
* RMS error, standard deviation and bias is higher with longer delay spread.
 |
| CATT | LLS: normalized TP vs SNR | Compared with no gNB-side CSI prediction, the single Doppler reporting has slight performance gain (0.5dB), and obvious performance gain (1-2dB) can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm. |
| Ericsson | SLS: Avg. UPT vs UE speedLLS: mean autocorrelation estimate vs correlation lag | SLS* Reciporcity-based precoding has better performance at 3km/h for both SU-MIMO and MU-MIMO; however, at UE speeds above 10km/h the feedback-based precoding outperforms the reciprocity-based.
* Type II CSI gives better performance at 3km/h, but at UE speeds above 10km/h and higher, type I CSI gives better performance.
* Precoding based on Type I CSI feedback is more robust to channel aging than precoding based on Type II CSI feedback.
* The cross-over points of performance for both evaluated use cases are at low speed, e.g, 10km/h.

LLS* 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.
* Estimating maximum Doppler shift from the autocorrelation function has lower bias and standard deviation than from estimates of channel peaks.
* Estimates based on intra-TRS autocorrelation lags doesn’t give decent accuracy below 50km/h.
* 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.
 |
| **Summary**: * Companies demonstrate the increasing challenge in estimation accuracy as the UE speed is increased. One company suggests that correlation-based TDCP offers better accuracy than Doppler-shift-based TDCP
 |

**General observation**:

* Table 5.A:
	+ [3.1]
* Table 5.B:

Table 6 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Ericsson | On **Issue 3.2,** in our view, we should first decide about report parameters/quantities for TDCP reporting for this meeting. [Mod: Agree but currently the view diverges. From FL perspective we can agree on 3.C before this. Then we will spend time on 3.2 to discuss the details of each candidate scheme and possible merging of, e.g. Doppler-based proposals]In our contribution [R1-2207505](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_110/Docs/R1-2207505.zip) we’ve provided simulation results to show the use cases where using TDCP measurement can give significant gains to decide what CSI-feedback scheme to use or whether to use reciprocity based precoding. We’ve explained in depth with simulation on how **autocorrelation** (i.e. Option 3: cross-correlation) can be used as a straight forward and reliable TDCP reporting parameter. To address the use cases we are after, we need a measure of the channel variability in time, and the autocorrelation is a direct measure of this.We show that the Doppler spread metric fmax, i.e. the maximum Doppler shift, is a very bad measure of channel variability in time since different channels with the same fmax can have very different autocorrelation as shown in the figure below.Chart, line chart  Description automatically generatedThe square root of the second moment of the Doppler power spectrum is another potential measure of the Doppler spread. It correctly describes the behavior of the autocorrelation for low lags, since the second moment of the Doppler power spectrum is proportional to the second derivate of the autocorrelation function at lag zero. However, it doesn’t give any information about the zero-level crossing point of the Autocorrelation function (as can be seen from the figure above) which is also important to know.We also note that most likely a Doppler spread measure would in reality be estimated based on measurements of the Autocorrelation function, and since it’s the channel variability we are interested in, it then makes more sense to report the autocorrelation directly. One can in principle estimate Doppler spread based on the Doppler shift of identified peaks in the channel impulse response. We have tried this, but it gives much worse accuracy than the autocorrelation based method and it’s also a very complex measurement. In the figure below we compare a peak based estimate of the maximum Doppler shift with an autocorrelation based estimate. 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. Hence, the best option is to report the autocorrelation function for multiple autocorrelation lags. This gives the gNB maximum information and the signaling load is anyway very small. We suggest to perform down-selection among the alternatives in **Issue 3.2** based on evaluation results.Chart, line chart  Description automatically generated |
| CATT | Update our views in the above Table 5A, add our observation from LLS in the above Table 5B again.**On conclusion 1.A:** Not support. For TDD system, the problem of expired CSI still exists, but there is no solution currently. And the aiding of gNB-side is a simple and effective solution. In addition, there are very few companies expressing their attitudes, and the objecting companies did not give a clear reason and evaluation results at least for TDD system. Hence, we think it's too early to draw this conclusion at this stage. Based our contribution in R1-2206377, we provide the feasibility Analysis and simulation results for the use case gNB-side prediction. It can be observed from the simulation results that compared with no gNB-side CSI prediction, the single Doppler reporting have slight performance gain(0.5dB), and obvious performance gain (1-2dB) can be achieved by the solutions with multiple Doppler reporting with the enhanced matching algorithm.[Mod: Please note that this conclusion is based on observation that some companies want to remove this use case, hence the group cannot confirm this in RAN1#110 (i.e. need to be removed). Since it was agreed that we need to confirm this by RAN1#110 (to avoid delaying work on TDCP), we cannot postpone this. However, since this doesn’t impact proposal 3.C, I can give some time for the proponents (e.g. CATT) to try to convince companies wanting to remove this use case until the last online session on CSI, i.e. it will not be presented for endorsement on day 1] **Figure 1 Performance comparisons of alternatives, TDD, 60Km/h, MCS 4** |
| Mod V0 | 1. **Check and update your view in Table 5, especially on the moderator proposals**
2. **Share additional inputs here if needed**
 |
| Qualcomm | Fine with Proposal3.B |
| Lenovo | - Propose the following minor wording changes to Proposal 3.B is not clear. ***Proposal 3.B****: For the Rel-18 TRS-based TDCP reporting, down select one of the following alternatives [by RAN1#110bis-e]:** *AltA~~C~~. ~~Based on~~ Doppler profile parameter(s)*
* *AltB. ~~Based on~~ time-domain correlation profile parameter(s)*
	+ *E.g. correlation within one TRS resource, correlation across multiple TRS resources*
* *AltC: CSI-RS resource and/or CSI reporting setting configuration ~~assistance~~ paramer(s) to assist the network*

[Mod: Thanks for spotting typo. I don’t think “parameters” is the only possibility. During offline I plan to add more details on each to facilitate better comparison] |
| vivo | **Proposal 1.C**We support the enhancement to be based on Rel-16 eType II codebook. We have concern to introduce enhancement for FeType II PS due to it requires large effort for discussion. The design principle and evaluation effort are quite different for FeType II PS. Issues like calibration error modelling for multiple TRPs, etc., need to be discussed for EVM. **Proposal 1.G**We support Alt 2. We’d like to understand more about “K transmission hypotheses” in Alt 3. These transmission hypotheses correspond to what specific transmission schemes. Does it mean UE reports one CSI for CJT and another CSI for NCJT with N value configured in RRC? Or it means UE reports multiple CSIs for multiple configured N values?In Alt 4, similarly, what do the transmission hypotheses correspond to? Does it mean UE reports one CSI for CJT and another CSI for NCJT with N value reported in UCI? Or it means UE reports multiple CSIs for multiple N values selected by UE?[Mod: Not sure ☺ I was hoping the proponents can clarify during offline today]**Proposal 1.I**We support Alt 1, which is same as legacy eType II CSI. We think a careful evaluation is needed if we want to further extend the W2 coefficient quantization scheme. Hence we suggest to add a bullet indicating that Alt 1 serves as the baseline for further evaluation. Any enhancements need to prove jusitficated gain.[Mod: I tend to agree.] |
| vivo | **Proposal 3.B*** Our understanding on Alt A and Alt B is that they can be equivalent to some extent, as the channel correlation profile can be the Fourier transform of doppler profile if sufficient information is provided in doppler profile. Is this correct?

[Mod: One point Ericsson brought up is that correlation is simpler to derive since Doppler profile would require an additional processing. We will discuss Ericsson’s arguments offline.]* For Alt C, we think gNB and UE may have different implemation details (e.g., different switch thresholds) to determine which configuration fits the channel profile best. Hence what UE considers as the best configuration may not be the best for gNB. It’s better to report the channel profile to gNB and let gNB to make the decision.
 |
| Mod V4 | **Revision per Lenovo’s comment** |
| Ericsson | Thanks to FL for Proposal 3.B:We would like to propose some more detailed examples for Alt A and Alt B as shown *below in red*:* AltA. Based on Doppler profile
	+ *E.g., Doppler spread derived from the 2nd moment of Doppler power spectrum*
* 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 condiered. The lags may be within one TRS burst or different TRS bursts*

Regarding AltC, we share similar understanding as vivo that gNB and UE may have implementation details. So what is recommended by UE may not be suitable for gNB. For example, consider the case the UE recommends a CSI report setting with type II CSI to the gNB. But if the gNB does not see an opportunity to do MU-MIMO scheduling, it may simply schedule with type I CSI. Also, one question for the proponents of AltC. Could you provide some high level description of this alternative? We assume this is still based on TRS measurements of some sort that trying to quantify how much the channel is changing? |
| CATT | Fine with Lenovo’s suggestions because multiple Doppler shifts/parameters should be reported in order to reflect more accurate channel state. |

# References

|  |  |  |  |
| --- | --- | --- | --- |
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| 4 | [R1-2205920](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110/Docs/R1-2205920.zip) | CSI enhancement for high/medium UE velocities and CJT | ZTE |
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