**3GPP TSG RAN WG1 #109-e R1-2205470**

**e-Meeting, May 9th – 20th, 2022**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#5 on Rel-18 CSI enhancements: ROUND 5

**Document for:** Discussion and Decision

## Introduction

The scope given in the Rel-18 NR Evolved MIMO WID [1] 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 |

## Summary of companies’ views

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.3 | Work scope: Rel-16/17 Type-II codebook/PMI components to be refined or reused for CJT extension   1. SD and FD basis vector designs (not precluding adding new values of N1, N2, N3) 2. SD and FD basis selection schemes (not precluding per-TRP or joint-across-TRPs selection, this refers to, e.g. the combinatorial indication and two-step FD basis selection) 3. W2 coefficient quantization scheme   **FL Note**: Considering work scope and continuity with legacy design (some already being deployed), we should strive for maximum reuse of legacy designs. Although one may claim that evaluation is needed to ensure whether reusing as such results in desirable performance, the above parameters are primarily “format” issue. | **1 (SD/FD basis design):**   * **Fully reuse legacy:** Huawei/HiSi (for R17), Lenovo, Samsung, Apple, DOCOMO, NEC, vivo, CMCC, Nokia/NSB, IDC, Fraunhofer IIS/Fraunhofer HHI, Intel, MTK, CATT, ZTE, CEWiT, IITK, Ericsson, Qualcomm, Xiaomi, AT&T, Sony * **Refinement:** Huawei/HiSi (Joint SD-FD eigen-vector basis for R16)   **3 (W2 quantization):**   * **Fully reuse legacy:** Samsung, Apple, vivo, CMCC, Nokia/NSB (re. co-scaling, both reference amplitudes may need reporting for TRPs other than the strongest), Intel (same as Nokia), CATT, ZTE, CEWiT, IITK, Ericsson, AT&T * **Refinement:** Xiaomi (TRP specific phase and amplitude) |

**Proposal 1.G**: On the spatial-domain (SD) and frequency-domain (FD) basis design for the Type-II codebook refinement for CJT mTRP, down-select only one of the following alternatives:

* Alt1 (separate, legacy DFT): SD basis and FD basis are separate, each fully reusing the legacy Rel-16/17 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

**Proposal 1.H**: On the W2 coefficient quantization scheme for the Type-II codebook refinement for CJT mTRP:

* At least for N={2, [3]}, reuse the following components of the legacy Rel-16/17 per-coefficient quantization scheme:
  + Alphabets for amplitude and phase
  + Quantization of phase relative to a reference, and quantization of differential amplitude relative to a reference, where the reference is defined for each layer and each ”group” of coefficients
* Further study the following:
  + For N={[3], 4}: whether lower-resolution alphabets for amplitude and/or phase than legacy are used to improve throughout-overhead trade-off
  + What constitutes a “group” (e.g. polarization per TRP/TRP-group, TRP/TRP-group, combination of the two), the number of “groups” (1 ≤ Cgroup ≤ 2N), and how to indicate/configure “grouping”

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Share your inputs, if any, on moderator proposals** |
| Nokia/NSB | **Proposal 1.G**  We agree one alternative is enough to keep the design simple. We also support Alt1 as we don’t see a strong enough justification to depart from earlier Type-II design  **Proposal 1.H**  A small suggestion to clarify that differential quantisation applies to amplitude coefficients   * + Alphabets for amplitude and phase, quantization of differential amplitude relative to a reference, the reference defined for each layer and each polarization   [Mod: OK] |
| Lenovo | **Proposal 1.G**  Support  **Proposal 1.H**  Since for CJT the CSI report can be up to 4 time larger than that of single-TRP CSI (at N=4), in our opinion quantization should be discussed, at least in terms of the amplitude/phase codebook sizes. We do not think tuning the number of non-zero coefficients would suffice to reduce the overall CSI report size. Given that, we suggest adding a second alternative, as follows:  **Alt2: Lower resolution of amplitude and phase quantization compared with legacy Rel. 16/17 quantization are considered for N> α TRPs. FFS: value of α**  [Mod: This is a very good point since personally I think we need good overhead reduction scheme especially for N=4. Parameter combination has been proposed but quantization resolution of W2 is a valid candidate. Please check the latest version] |
| Apple | We are supportive of both proposals |
| Samsung | Proposal 1.G: support  Proposal 1.H   * We support reusing R16 quantization for differential amplitude and phase * Re the reference amplitude, we are not sure we need 2N reference amplitudes (if we follow R16 and have one reference amplitude for each polarization). We prefer to study this. Propose to revise the 2nd bullet as follows:   **Proposal 1.H**: On the W2 coefficient quantization scheme for the Type-II codebook refinement for CJT mTRP:   * Reuse the following components of the legacy Rel-16/17 per-coefficient quantization scheme:   + Alphabets for amplitude and phase, quantization of differential relative to a reference, the reference defined for each layer and each group of coefficients ~~polarization~~ * Further study the following:   + ~~Whether per-TRP/TRP-group references are needed~~   + Number of groups for reference amplitudes across all TRPs, say x, where 2<=x<=2N   + how to group coefficients for a given x?   [Mod: OK, but the proposed wording is a bit ambiguous. If I understand your proposal correctly, 1 group comprises a set of coefficients and a single reference. Revised the wording] |
| LG | Proposal 1.H: we have similar view with Samsung and would like to further study whether the group can be defined based on per polarization, per TRP, or across all TRP. We revise the range of x values including 1.  **Proposal 1.H**: On the W2 coefficient quantization scheme for the Type-II codebook refinement for CJT mTRP:   * Reuse the following components of the legacy Rel-16/17 per-coefficient quantization scheme:   + Alphabets for amplitude and phase, quantization of differential relative to a reference, the reference defined for each layer and each group of coefficients ~~polarization~~ * Further study the following:   + ~~Whether per-TRP/TRP-group references are needed~~   + Number of groups for reference amplitudes across all TRPs, say x, where ~~2~~1<=x<=2N   + how to group coefficients for a given x?   [Mod: OK] |
| MediaTek | Minor comment on Alt 1 of Proposal 1.G: Rel-17 FeType II codebook being a port selection codebook, does not use SD basis (DFT/any other). For more clarity, we could remove “legacy Rel-17”.  [Mod: Correct but DFT is still used for FD even in Rel-17. The current wording seems ok as long as “legacy” is there.] |
| NTT DOCOMO | Proposal 1.G: Okay.  Even though three alternatives are listed here, we believe Alt1 should be the starting point.  Proposal 1.H  ‘per TRP/TRP-group’ exists in many proposals/agreements. We’d like to clarify, whether TRP-group information (how to group multiple TRPs) is configured by NW or selected/reported by UE. We assume it should be the former.  [Mod: Good point, please check ZTE comment below. This will be discussed in one of the FFS we agreed on re spec entity related to TRP, which also applies to TRP group] |
| ZTE | Proposal 1.G: Support  Proposal 1.H: We think that Samsung’s update looks good. We tend to agree with Samsung the the lower bound should be 2, unless that we want to reverse the direction of ‘per polarization’ based reference, as in Rel-16. The motivation is unclear for us. That is, lower bound should 2 rather than 1.  Then, regarding how to group coefficients for a given x, we think that per TRP group should be clarified for facilitating the subsequent discussion. In our views, it is relevant to per-TRP or per TRP-group.   * + how to group coefficients for a given x, e.g., per TRP group?   [Mod: OK]  Regarding DOCOMO’s question, we are open to both. But, technically speaking, TRP-group configured by gNB side seems to be more typical. |
| Xiaomi | Proposal 1.G: support and prefer Alt 1  Proposal 1.H: support |
| Ericsson | For proposal 1.G, we think the starting point should be Alt 1. But we are ok to list the options and downselect later.  For proposal 1.H, we have some suggestion since there is a single phase reference while for amplitude, there is reference per polarization:   * Alphabets for amplitude and phase, quantization of ~~differential~~ phase relative to a reference for each layer , and quantization of differential amplitude relative to a ~~the~~ reference defined for each layer and each polarization   [Mod: Thanks, this is more accurate ☺] |
| CMCC | Proposal 1.G: Support.  Proposal 1.H: We prefer Samsung’s version, which seems more inclusive. |
| Mod V14 | **Revised proposals per inputs** |
| LG | Proposal 1.H:  For N=3,4, we should first discuss whether it is supported. We suggest the following revision on top of the FL’s latest proposal.  **Proposal 1.H**: On the W2 coefficient quantization scheme for the Type-II codebook refinement for CJT mTRP:   * At least for N=~~{~~2~~, [3]}~~, reuse the following components of the legacy Rel-16/17 per-coefficient quantization scheme:   + Alphabets for amplitude and phase   + Quantization of phase relative to a reference, and quantization of differential amplitude relative to a reference, where the reference is defined for each layer and each ”group” of coefficients * Further study the following:   + ~~For N={[3], 4}: w~~Whether lower-resolution alphabets for amplitude and/or phase than legacy are used to improve throughout-overhead trade-off   + What constitutes a “group” (e.g. polarization per TRP/TRP-group, TRP/TRP-group, combination of the two), the number of “groups” (1 ≤ Cgroup ≤ 2N), and how to indicate/configure “grouping” |
| CATT | **Proposal 1.G：**Support the updated proposal.  **Proposal 1.H：**Support the updated proposal.  We just want to clarify one question for the current description of ‘per TRP/TRP-group’, which also appeared many times in the previous agreements. Does it mean both per TRP and per TRP-group can be considered, but finally, there will be only one choice between the definition of TRP and TRP-group? Since the restriction on maximum number TRPs, the two corresponding codebook designs and overhead considerations will be different. |

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

Table 3 Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
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**Proposal 2.G**: On 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 N4
  + Note that basis vector has no span/window in time-domain, only length
* CSI-RS measurement window of [k,k+Wmeas –1], representing the window in which CSI-RS occasion(s) are measured for calculating a CSI report
  + k is a slot index and Wmeas is the measurement window length (in slots)
* CSI reporting window of [l,l+WCSI –1], in which the CSI report in slot n represents
  + l is a slot index and WCSI is the reporting window length (in slots)
* CSI reference resource(s) in time-domain
  + The location of a CSI reference resource is denoted as nref (slot index)

**Proposal 2.H**: On the Type-II codebook refinement for high/medium velocities, ... (added after 2.G is stable enough with companies’ inputs) (alternatives)

Table 4 Additional inputs: issue 2

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| **Company** | **Input** |
| **From previous round** | |
| Qualcomm | One more parameter to be considered:  Time-location of the TD codebook, probably including the following two options  Opt1: Relative to CSI-RS observations (burst);  Opt2: Relative to CSI reference resource (Rel-15 reference resource as a starting point)  The FFS bullet 2 in the updated proposal 2.E.2 is aligned with our proposed opt1, which assumes the time-location (let’s say starting slot for instance) relative to (e.g. aligned with) the starting CSI-RS slot in W;  Our proposed opt2, however, has different definition of time-location based on CSI reference resource, which can be more aligned with the mechanism of legacy releases (since time-location is part of the purpose of defining a reference resource) |
| Samsung | We suggest to add an FFS.   * FFS: the relation b/w TD/DD basis vector length (say N4) and the CSI-RS measurement window (W), e.g. whether N4 is within W or can be outside W |
| Nokia | We suggest adding another aspect for study or incorporate it in the second bullet, in case the time intervals are outside the measurement window (UE-side extrapolation):   * The need to configure a time reporting window in addition to the CSI-RS measurement window, e.g. as formed by time intervals outside the measurement window |
| MTK | We support the revised Proposal 2.E.  The proposals from Qualcomm and Samsung can be separated into a different proposal from 2.E, as they are not related to the codebook structure:  Proposal 2.G: On the Type-II codebook refinement for high/medium velocities, the application window is down selected from the following alternatives:  Alt. 1: DD/TD unit(s) ends at R15 CSI reference resource  Alt. 2: DD/TD unit(s) after the CSI reporting slot  Alt. 3: DD/TD unit(s) from a CSI-RS transmission occasion before R15 CSI reference resource until some time after the CSI reporting slot |
| **Round 5** | |
| Mod V0 | **Share your inputs, if any, on moderator proposals** |
| Qualcomm | Thanks FL’s proposal 2.G  What we meant for “time-location” in our original input above is just parameter “*l*” in bullet 3.  For bullet 2, we think for either the measurement window’s time-location “k” or window size “Wmeas”, we cannot preclude another possibility that this can be up to UE implementation, at least at current stage.  [Mod: Agree. Note that the terms are “at least for discussion purposes” for now. Whether to specify is next step. ]  According to our understanding, as long as the time-location of the TD CSI is clear, how to calculate the corresponding CSI more precisely (or how to measure) can be up to UE implementation  Just want to point out the above understanding.  [Mod: This is one option – proposal 2.H will list options to select]  As for the wording of this proposal, we are fine with current proposal saying “for discussion purposes” with bullet 2  Last comment, suggest to represent the time length (in slots) according to TD compression unit (e.g. denoted as Tunit slots) as agreed in Proposal 2.E.2. For instance, N4 --> N4Tunit, WCSI --> WCSITunit, Wmeas --> WmeasTunit  [Mod: I agree with you if we have agreed on TD compression unit. But in Round 4, several companies commented that it’s too early to decide whether TDCU is supported (hence 2.E.2 is still a study). That’s why for now, for discussion purposes, I use slots for everything. If we agree on TDCU, this will be a better unit]  Besides, a typo in bullet 3: to be valid  [Mod: OK thanks] |
| Nokia/NSB | **Proposal 2.G**   * + First bullet. There seems to be a typo (basis vector length is dimensionless, as stated in the note) * Assume a CSI report in slot n, and let the length of the basis vector be N4 ~~(in slots)~~   + Note that basis vector has no span/window in time-domain, only length   + Second bullet. Small suggestion: “occasions” may be more general than “burst(s)” at this stage, as we do not know yet if a “burst” needs different configuration from legacy * CSI-RS measurement window of [k,k+Wmeas], representing the window in which CSI-RS ~~burst(s)~~ occasions are measured for calculating a CSI report   + k is a slot index and Wmeas is the measurement window length (in slots)   + Third bullet. It may be worth adding a similar sub-bullet as for the previous bullet * CSI reporting window of [l,l+WCSI], representing the window in which the CSI report in slot n is expected to be valid   + l is a slot index and WCSI is the reporting window length (in slots)   + Fourth bullet. We suggest simplifying the wording, because the CSI reference resource is defined both in frequency and time domain and it is not only used for CQI calculation. It also determines the latest CSI-RS occasion that can be measured before a CSI report, hence, for example, we may need to assume that * CSI reference resource in the time domain~~, representing (just as in Rel-15) the CSI-RS resource used as a reference for CQI requirement (10% BLER in Rel-15) associated with the CSI report in slot n~~   + ~~The location of CSI reference resource~~ is denoted as nref (slot index)   [Mod: Really appreciate the thorough review and inputs! I agree with all the above.] |
| Apple | * Bullet 1: It is not clear what “Note that basis vector has no span/window in time-domain, only length” means, clarification would be appreciated.   [Mod: N4 denotes the length of the basis vector of the codebook. This has no unit since it is just a construct component from the abstracted precoding matrix. The length is simply the number of elements in the vector.  Later when we discuss how this can be associated with slots or, if agreed, TDCUs, there will be an association with a time-domain unit. But as of now, it is unitless.]   * Bullet 2: On “CSI reference resource, representing (just as in Rel-15) the CSI-RS resource used as a reference for CQI requirement (10% BLER in Rel-15) associated with the CSI report in slot n”,   We still need to discuss whether a single CQI or multiple CQIs (e.g., each for a slot) is/are reported in slot n, e.g. a single CSI reference resource or multiple CSI reference resources are needed at this time. Then we suggest to add “one or more CSI reference resource(s), each representing (just as in Rel-15) ~~the~~ a CSI-RS resource used as a reference for CQI requirement (10% BLER in Rel-15) associated with the CSI report in slot n”  [Mod: Agree, OK] |
| Samsung | **Proposal 2.G**  1st bullet: similar to the definition of N3 in R16, we can define N4 as a number of precoding matrices in TD/DD, each associated with a TD/DD unit. A TD/DD unit comprises >=1 slots (TD/DD unit size).  [Mod: Not really. This is valid only, e.g. for critically sampled DFT basis. Since the choice of basis hasn’t been finalized, this definition is not generally true. Perhaps when the choice of basis is finalized, you can bring this up again] |
| LG | **Proposal 2.G:**  Support Nokia’s revision.  On third bullet point: the wording “valid” is unclear. We suggest to revise wording as follows.   * CSI reporting window of [l,l+WCSI], ~~representing the window~~ in which the CSI report in slot n ~~is expected to be valid~~ represents.   [Mod: OK] |
| MediaTek | Thanks for FL’s Proposal 2.G to facilitate discussion.  We support Proposal 2.G with all of Nokia’s suggestions.  To align understanding, the alternatives in our original Proposal 2.G, i.e.,  Alt. 1: DD/TD unit(s) ends at R15 CSI reference resource  Alt. 2: DD/TD unit(s) after the CSI reporting slot  Alt. 3: DD/TD unit(s) from a CSI-RS transmission occasion before R15 CSI reference resource until some time after the CSI reporting slot  , can be translated as  Alt. 1: l+WCSI <=nref  Alt. 2: l > n  Alt. 3: l < nref and l+WCSI > n  [Mod: We will get to this once 2.G is stable ☺] |
| NTT DOCOMO | **Proposal 2.G**  Support in general.   * First and second bullet: Just for our better understanding, can we understand that the range of N4 and Wmeas is totally up to future discussion (i.e. no restriction at this stage)?   [Mod: Correct, we are still defining terms so that we are on the same page when we discuss this issue you/Samsung pointed out. Without aligning terms, companies may have different understanding. Especially since TD/DD compression is a very new topic ☺]   * Third bullet: we agree with Nokia that the unit of WCSI can be added.   [Mod: Me too] |
| ZTE | **Proposal 2.G:**   * + Regarding first bullet, we have different views from Nokia. Of course, basis vector length is dimensionless, but we need to provide a physical interpretation for a basis. It is much relevant to the effective time-domain duration of CSI prediction. If ‘in slots’ is controversial, how about providing detailed description as follows.   [Mod: Please see my comment for Apple. There is no unit for N4 as of now. It’s just the number of elements in the vector.  Association with unit is the next step but we cannot do so before we discuss whether TDCU is needed or not (still FFS). I plan to finalize that in Aug since many issues depend on this]   * + Regarding second bullet, it should be k+Wmeas -1.   + Regarding third bullet, firstly okay for Nokia’s update. Then, it should be 1+WCSI -1. Then, we are not sure, why the CSI report is in the slot n, but the starting point is from 1. Does that corresponds to CSI reference resource? But, then the following, the CSI reference resource is in the slot-n. If so, what’s the meaning of ‘1’ as following highlighted herein?   [Mod: Thanks for the excellent catch, you are correct ☺]  **Proposal 2.G**: On 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 time-domain duration corresponding to the basis vector be N4 (in slots)   + Note that basis vector has no span/window in time-domain, only length * CSI-RS measurement window of [k,k+Wmeas -1], representing the window in which CSI-RS burst(s) are measured for calculating a CSI report   + k is a slot index and Wmeas is the measurement window length (in slots) * CSI reporting window of [l,l+WCSI -1], representing the window in which the CSI report in slot n is expected to be valid   + l is a slot index and WCSI is the reporting window length (in slots) * CSI reference resource, representing (just as in Rel-15) the CSI-RS resource used as a reference for CQI requirement (10% BLER in Rel-15) associated with the CSI report in slot n   + The location of CSI reference resource is denoted as nref (slot index)   [Mod: CSI is reported in slot n. the index l is the start of what we usually call “validity window”. In general l < n. But it can be different now. Not the same as n for sure, especially since we haven’t discussed, e.g. whether UE-side prediction should be assumed in CSI calculation. This is for next level discussion.]   * + Finally, regarding MTK’s comment, we prefer Alt2. |
| Xiaomi | **Proposal 2.G**  Forthefirstbullet: N4 is used to denotes the total number of precoding matrices. In order to avoid confusing, the note in the first bullet can be revised as.   * N4 is the total number of precoding matrices.   [Mod: Not really. Please check my comments to Samsung who made the same suggestion. This is only true when we use, e.g. critically sampled DFT basis.]  Forthethirdbullet: both *l* and WCSI needs to be clarified.  [Mod: Done with Nokia suggestion]  For the fourth bullet: We share similar view with Apple, more CSI-RS reference resources can be considered for calculating more CQI if needs.  [Mod: OK] |
| Ericsson | In first sub-bullet, it is better to clarify that the basis vector refers to Doppler/time domain basis vecotor:   * Assume a CSI report in slot n, and let the length of the Doppler/time domain basis vector be N4 (in slots)   [Mod: OK]  On the sub-bullet, ‘Note that basis vector has no span/window in time-domain, only length’, we have similar clarification question as Apple on what this means. Doesn’t the basis vector have to be mapped to a time span?  [Mod: Please check my comment for Apple and ZTE]  The following bullet only applies to UE based prediction right?   * CSI reporting window of [l,l+WCSI], representing the window in which the CSI report in slot n is expected to be valid   [Mod: It basically accommodates discussion whether UE side prediction is assumed or not in CSI calculation, depending on the values of l and W\_CSI. This is for next-level discussion]  On the last bullet, “The location of CSI reference resource is denoted as nref (slot index)”, should the reference be multiple slots, not a single slot?  [Mod: Even if CSI-RS occasion is a burst (multiple slots), the reference should be a single location/slot index. In legacy measurement, this is also the case, it is possible for the UE to measure CSI from SP CSI-RS for instance. Which is a burst. But n\_ref is still a slot index.] |
| CMCC | **Proposal 2.G**  Support ZTE’s revision.  Besides, we are also a little confused with the meaning of *l,* what’s the relationship between *l* and CSI reporting time?  [Mod: Please check my comment to ZTE and Ericsson, and hope it clarifies the confusion/misunderstanding] |
| Mod V14 | **Revised proposals per inputs** |
| LG | Support the latest FL’s update. |
| CATT | Support the updated proposal. |
| Spreadtrum | We have two questions for clarification:   1. For 3rd bullet, we are not clear about the relationship between l and n. In our mind, since it is for CSI prediction at UE side, it seems to be natural that n should be <=l, right? 2. For 4th bullet, it only refers to the denotation of the time location of CSI reference resource, not the definition. Our understanding is that we would discuss it maybe next meeting. So could we add one ‘FFS: the definition of CSI reference resource(s)’ for providing general guidance. |

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

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