**3GPP TSG RAN WG1 #112bis-e R1-2304065**

**e-Meeting, April 17th – April 26th, 2023**

**Agenda item:** 9.1.2

**Source:** Moderator (Samsung)

**Title:** Moderator Summary#3 on Rel-18 CSI enhancements: Round 2

**Document for:** Discussion and Decision

## Introduction

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

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

## Summary of companies’ views

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

Table 1A Summary: issue 1

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| **#** | **Issue** | **Companies’ views** |
| 1.1 | [110bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding W2 quantization group, for each layer:   * Support the following: (Alt1) One group comprises one polarization across all N CSI-RS resources (*C*group,phase=1, *C*group,amp=2)   + FFS: Amplitude quantization table enhancement   + For the amplitude group other than the group associated with the SCI, the reference amplitude is reported * Working assumption: Alt3 is supported in addition to Alt1 (to be confirmed in RAN1#111)   + (Alt3). One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (Cgroup,phase=1, Cgroup,amp=2N)     - For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported * If the support Alt3 in addition to Alt1 is confirmed, only one of the two schemes will be a basic feature for UEs supporting Rel-18 Type-II CJT codebook   **Proposal 1.A.1**: On the Type-II codebook refinement for CJT mTRP, *revert* the following working assumption:   * Working assumption: Alt3 is supported in addition to Alt1 (to be confirmed in RAN1#111)   + (Alt3). One group comprises one polarization for one CSI-RS resource with a common phase reference across N CSI-RS resources (Cgroup,phase=1, Cgroup,amp=2N)     - For each of the (2N–1) amplitude groups (other than the group associated with the SCI), the reference amplitude is reported   **FL Note**: Just as what we did in RAN1#110bis-e, this has to be decided based on empirical evidence (i.e. SLS results). Per agreement this needs to be concluded in this meeting. Since the WA was made conditioned upon the benefit of Alt3 over Alt1   * If there is no confirmed benefit from Alt3 over Alt1 in the alleged scenarios (inter-site CJT, 500m ISD), the WA should be **reverted** (hence no support of Alt3). * Otherwise, **confirmed** as an agreement.   The available SLS results are summarized as follows for the alleged “missing” scenarios from Alt3 proponents in RAN1#110bis-e (500m ISD or larger, inter-site CJT):   * “Notable” (small in FL perspective) gain: Huawei (2-3% mean UPT), ZTE (0.2-1.2% mean UPT) * No demonstrable gain: Samsung, vivo | **Support/fine (want to revert WA):** vivo, Samsung, OPPO, MediaTek, Fraunhofer IIS/HHI, Apple, DOCOMO, Intel, Nokia/NSB, Ericsson, Sharp, Google, Sony, AT&T  **Not support (want to confirm WA)**: ZTE, Spreadtrum, CATT, LG, Huawei/HiSi, Lenovo/MotM, Fujitsu, NEC, Xiaomi, |
| 1.3 | [112bis-e] **Agreement**  On the Parameter Combination of Type-II codebook refinement for CJT mTRP, for Rel-17 FeType-II based,   * For =1, the Rel-17 legacy Parameter Combination is fully reused * Regarding the combinations {*M*, **}, it is proposed to reuse the legacy as below, with restriction on *M*=2.  |  |  |  | | --- | --- | --- | | **M** | **** | **Condition** | | 1 | ½ |  | | ¾ |  | | 1 |  | | 2 | ½ | FFS: NTRP≤3, NL=1 | | ¾ | FFS: NTRP≤3,  NL =1 |  * n combinations for are derived from the *Ln* combinations for Rel-16 based refinement, where each entry in the combination is the nearest value of min{1, 2 *Ln* /} to {1/2, ¾, 1}, .   + Note: no other dependency of combinations is introduced, such as dependency on   + FFS: pruning on combinations   **Question 1.3:** Please share your view on the following 2 issues:   * Whether the restriction for M=2 in the FFS should be supported or not * Pruning of the SD combination | |
| 1.4 | [112bis-e] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding CBSR, amplitude restriction is CSI-RS-resource-specific.   * FFS: Whether CBSR is always configured for each CSI-RS resource or not   **Proposal 1.D.3:** On the Type-II codebook refinement for CJT mTRP, regarding CBSR, the first of the NTRP configured CSI-RS resources must be configured with CBSR, while the remaining (NTRP –1) configured CSI-RS resources can be optionally configured with CBSR   * Note: if CBSR of one particular resource is absent, it means no restriction for SD basis selection for the resource.   **FL Note:** This proposal is already a compromise between two views  **MOVED TO EMAIL ENDORSEMENT 3** | **Proposal 1.D.3:**   * **Support/fine:** Huawei/HiSi, NEC, Nokia/NSB, Intel, Qualcomm, Huawei/HiSi, LG, ZTE, Spreadtrum, Samsung, vivo, Fujitsu, CMCC, OPPO, CATT, Sony, vivo, * **Not support (configure all):** [MediaTek, Ericsson, Lenovo/MotM] |
| [112bis-e] **Conclusion:**  On the Type-II codebook refinement for CJT mTRP, regarding CBSR for NTRP>1, there is no consensus in supporting the additional optional soft amplitude restriction. Therefore, only hard amplitude restriction (per CSI-RS resource, based on the legacy design) is supported.  **Question 1.4**: For NTRP=1, please share your view on the following alternatives for CBSR amplitude restriction:   * Alt1. Hard-only * Alt2. Hard + optional soft (analogous to legacy) | **Alt1. Hard-only:**  **Alt2. Hard+soft:** Samsung |
| 1.5 | [112] **Agreement**  On the Type-II codebook refinement for CJT mTRP, regarding UCI omission, down-select between the following three alternatives (by RAN1#112-bis where n denotes the n-th CSI-RS resource):   * Alt1. Prio(,l,m,n)=() .N.RI.P(m)+N.RI.l(n)+N.n   + Note: This implies that CSI-RS resource is designated the highest priority * Alt2. Prio(,l,m,n)=2L’.Q(n).RI.N3+2L’.RI. P(m)+RI.l(n)+   + Note: This implies that CSI-RS resource is designated the lowest priority (after FD basis)   + Note: L’ denotes the max value of Ln from all selected N CSI-RS resources   + FFS: Q(n) maps the index n according to a rule, e.g., Q(n)=n, or Q(n)=0 if n corresponds to strongest TRP/SCI. * Alt3. Replace SD basis index *l* in legacy Prio calculation with , i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.+RI.l(n)+   FFS: FD permutation P(.) as Rel-16-analogous, or no permutation i.e. P(m)=m  **Proposal 1.E.1**: On the Type-II codebook refinement for CJT mTRP, regarding UCI omission, support reusing the legacy UCI omission mechanism while (Alt3) replacing SD basis index *l* in legacy Prio calculation with , i.e., SD basis index over all resources: Prio(,l,m,n) = 2Ltot.RI.P(m)+ RI.+RI.l(n)+   * FFS: FD permutation P(.) as Rel-16-analogous, or no permutation i.e. P(m)=m   **FL Note**: This was discussed offline [1].   * Based on the available SLS results, Alt2 results in larger performance loss over Alt3 upon UCI overflow * Alt2 opponents argue that since UE reporting of dynamic TRP selection is already supported, truncating CJT reporting to sTRP in case of UCI overflow is overkill and leaves NW with the least CSI for CJT operation (which is technically valid)   **MOVED TO EMAIL ENDORSEMENT 3** | **Proposal 1.E.1:**   * **Support/fine:** Samsung, NTT DOCOMO, MediaTek (P=m), LG, NEC, vivo, Intel, Xiaomi, Nokia/NSB, Ericsson, Google, AT&T, ZTE (ok, 2nd pref though 1st pref is Alt2), OPPO, Qualcomm (P=m), CMCC, IDC, Sony, Apple, Huawei/HiSi (ok, although still prefer Alt2), Fujitsu (ok, although still prefer Alt2), Fraunhofer IIS/HHI (ok, although still prefer Alt2), Spreadtrum (ok, although still prefer Alt2), Lenovo/MotM (ok, although still prefer Alt2), CATT (ok, although still prefer Alt2) * **Not support**: |

Table 1B Type II CJT: summary of observation from SLS

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| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| Huawei/HiSi | 1.1 | Mean UPT gain vs overhead | Observation 9: For inter-site CJT with large inter-site distance, Alt 3 (Cgroup,amp=2N) has better performance compared to Alt1 (Cgroup,amp=2). |
| 1.3 | Mean UPT gain vs overhead | For {Ln} combinations where each Ln equals 2, adding overhead by increasing pv and/or beta (such as {pv, beta} combo #3~#6) has no significant performance improvement compared with other {Ln} combinations.  For a given NTRP, the {Ln} combinations with at least one Ln=4 have similar performance-overhead tradeoff. It may be hard to select some of the pairs. Therefore, it is more reasonable to configure {Ln} and {pv, beta} pairs based on gNB implementation other than predefined pairs/linkage.  Observation 6: For {Ln} combinations where each Ln equals 2, adding overhead by increasing pv and/or beta has no significant performance improvement.  Observation 7: The uneven {Ln} combination and its permutations with the same Ltot (such as {2,2,4},{2,4,2}, {4,2,2}) should be treated as one combination, due to the same overhead and performance with proper gNB configuration.  Observation 8: Adding {Ln} combinations including Ln=6 does not increase the overhead and UE complexity as long as Ltot does not exceed the current maximum Ltot value, and can increase performance. |
| ZTE | 1.1 | Avg UPT gain vs overhead,  5% UPT gain vs overhead | We observe that 0.2%~1.2% average UPT gain and 2.2%~12.1% cell-edge UE gain can be achieved using Alt 3 compared with Alt1. |
| 1.3 | Avg UPT gain vs overhead | Ln=6 combination pairs for NTRP=2/3 can also show good performance under medium & high overhead; then considering the CSI report overhead is still acceptable, we prefer to have them as in the candidate list for SD-basis.  Then, clearly, pv = {1/2,1/2} combined with Ln={4,6} can provide good performance under medium & high overhead. |
| 1.5 | Avg UPT gain | That can be observed that, if going with Alt-2, n (n-th CSI-RS resource) should be taken as the most significant parameter (after FD basis), that is, fall-back to less co-ordinated TRP(s). That is beneficial for releasing some TRPs for serving other Ues, which is the reason why we observe some performance benefits for that. |
| Vivo | 1.1 | SE gain vs overhead | Alt3 shows negligible performance improvement over Alt1 for the scenario with 500m ISD and the high payload case of the scenario with 200m ISD.    Combining the payload and the SE gain, Alt1 outperforms Alt 3. |
| Nokia/NSB | 1.3 | Average UPT gain vs mean overhead | We observe that for , the combination(s) with a single achieves most of the UPT gain of the combination with ,, but with smaller overhead and complexity.  For , we note that, with 16 ports per TRP, the combinations with achieve similar UPT-overhead trade-off as with . Therefore, we propose to keep the same restrictions and supported combinations as for Rel16, with applicable only for 32 ports. |
| Samsung | 1.1 | Average UPT gain vs overhead | There is no benefit of Alt3 over Alt1 shown in our SLS results for both mode 1 and mode 2 cases even in the inter-site inter-cell scenarios. |
| 1.3 | Average UPT gain vs overhead | We support the offline proposal 1.C.1 as we have verified that the selected linkages yield good performance overall compared to other linkages and the overhead of them are well uniformly-spaced. |
| 1.5 | Average UPT loss w.r.t. paraComb | UCI omission with Alt3 is more beneficial than Alt2 in CJT operation. |
| MediaTek | 1.1 | Average UPT gain vs different paraComb | We observe that Alt 3 cannot provide consistent performance benefit over Alt 1. Further, the cost of this little performance benefit must be borne by the increased overhead of feeding back multiple reference amplitudes. Therefore, supporting quantization Alt 3 is not necessary. |
| Ericsson | 1.3 | Average and cell-edge UPT vs overhead | Evaluated the performance of the six combinations with and for three TRPs. For , only combinations #1 and #2 may be supported, while for , all 6 combinations of may be supported. |

Table 2 Additional inputs: issue 1

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| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 1A** |
| Samsung | **Question 1.3**  Based on the agreement, the candidates of SD combos can be derived as follows:   |  |  | | --- | --- | | **NTRP** | **combination** | | | 2 | {1/2,1/2} | | {1/2,1}, {1,1/2} | | {3/4,3/4} | | {1,1} | | 3 | {1/2, 1/2, 1/2} | | {1/2, 1/2, 3/4}, and its permutations | | {1/2, 1/2, 1}, and its permutations | | {3/4, 3/4, 3/4} | | ~~{1, 1, 1}~~ | | 4 | {1/2, 1/2, 1/2, 1/2} | | {1/2, 1/2, 1/2, 3/4} and its permutations | | {1/2, 1/2, 3/4, 3/4} and its permutations | | {1/2, 1/2, 1/2, 1} and its permutations | | ~~{1/2, 1/2, 1, 1} and its permutations~~ | | ~~{3/4, 3/4, 3/4, 3/4}~~ | | ~~{1, 1, 1, 1}~~ |   We prefer to have up to 4 combos for each , and suggest to keep first 4 combos in each considering the reporting overhead, as shown in the above table.  On the restriction for M=2, we think it is needed to not allow the max overhead too high, but we are open to further discuss on it.  **Proposal 1.D.3**  Our view was to allow configuring CBSR always for each CSI-RS resource, which could be a direct extension of the legacy framework. But, given that the majority of companies is supporting this proposal, we can be OK with this proposal to move forward for the sake of progress.  **Question 1.4**:  We prefer to follow the legacy framework when , i.e., support Alt2. |
| Mod V3 | **Proposals 1.D.3 and 1.E.1 are moved to EMAIL ENDORSEMENT 3** |
| Xiaomi | Q1.3  We prefer to support the restriction for M=2.  Q1.4  We prefer Alt 1: hard-only |
| NTT DOCOMO | **Question 1.3**  OK to remove the restriction.  For the candidates of SD combos and permutations, based on SS’s suggestion, we prefer to keep {1,1,1} and {1,1,1,1}.  **Proposal 1.D.3**  OK.  **Question 1.4**  We support Alt2. |

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

Table 3A Summary: issue 2

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| **#** | **Issue** | **Companies’ views** |
| 2.1 | [112] **Agreement**  …   * X=2 and   + The 1st CQI is associated with the first/earliest slot of the CSI reporting window (slot *l*) and the first/earliest of the *N*4 **W**2 matrices, and   + The 2nd CQI is associated with the middle slot of the CSI reporting window (slot *l*+*WCSI*/2) and the (*N*4 /2)-th**W**2 matrix   + FFS: Whether/how to include CQI overhead reduction for X=2   **Proposal 2.A.2**: For the Type-II codebook refinement for high/medium velocities, when a UE is configured with X=2 for CQI calculation and reporting, the 2nd CQI includes 4-bit wideband CQI and 2-bit sub-bands CQIs calculated independently from the 1st CQI  **FL Note**: This topic was discussed OFFLINE [1] and the current situation  **V1:**   * **Support/fine**: Samsung, NTT DOCOMO, ZTE, vivo, Spreadtrum, OPPO, Qualcomm, Intel, Xiaomi, Nokia/NSB, Ericsson, IDC, CMCC, Sony, CATT, Sharp, Apple * **Cannot accept**:   **V2:**   * **Support/fine**: MediaTek, Huawei/HiSi, Lenovo/MotM, Google, NEC, Fraunhofer IIS/HHI, Fujitsu, * **Cannot accept (additional complexity with no measurable gain)**: Samsung, ZTE, Intel, Spreadtrum, CATT   **V3:**   * **Support/fine**: LG * **Cannot accept (additional complexity with no measurable gain)**: Samsung, ZTE, Intel, Spreadtrum, CATT   From SLS results, it seems UPT vs overhead performance between v1 and v2 is almost none. At the same time v2 offers 2 bits 😊 of “overhead saving”  **Proposal 2.A.2 (V1)**: For the Type-II codebook refinement for high/medium velocities, when a UE is configured with X=2 for CQI calculation and reporting, the 2nd CQI includes 4-bit wideband CQI and 2-bit sub-bands CQIs calculated independently from the 1st CQI  **Proposal 2.A.2 (V2)**: For the Type-II codebook refinement for high/medium velocities, when a UE is configured with X=2 for CQI calculation and reporting, the 2nd CQI includes 2-bit wideband CQI and 2-bit sub-bands CQIs   * The 2nd (differential) wideband CQI is defined relative to the 1st wideband CQI, reusing the alphabet from the legacy 2-bit differential CQI table * The 2nd (differential) sub-band CQIs are calculated relative to the 2nd (differential) wideband CQI, reusing the alphabet from the legacy 2-bit differential CQI table   **Proposal 2.A.2 (V3)**: For the Type-II codebook refinement for high/medium velocities, when a UE is configured with X=2 for CQI calculation and reporting, the 2nd CQI includes 1-bit wideband CQI and 2-bit sub-bands CQIs   * The 2nd (differential) wideband CQI is defined relative to the 1st wideband CQI, reusing the alphabet from the legacy differential CQI table corresponding to 00/01 * The 2nd (differential) sub-band CQIs are calculated relative to the 2nd (differential) wideband CQI, reusing the alphabet from the legacy 2-bit differential CQI table | **Proposal 2.A.2**   * **Support/fine**: Samsung, NTT DOCOMO, ZTE, vivo, Spreadtrum, OPPO, Qualcomm, Intel, Xiaomi, Nokia/NSB, Fujitsu, Ericsson, IDC, CMCC, Sony, CATT, Sharp, Apple * **Cannot accept**: |
| 2.2 | [112bis-e] **Agreement**  For the Type-II codebook refinement for high/medium velocities, regarding the bitmap(s) for indicating the locations of the NZCs,   * When the UE is configured with Q=1: for each layer, one 2-dimensional bitmap of size-2LM reusing the legacy design is used * When the UE is configured with Q=2: for each layer,   + Basic feature: two 2-dimensional bitmaps, each of size-2LM reusing the legacy design for each of the two selected DD basis vectors, are used   + Optional feature, if the following down-selection succeeds: down-select from the following two alternatives in RAN#112bis-e:     - Alt3A: A single 2-dimensional bitmap of size to report the selected pairs of FD basis vector and DD basis vector and a single 2-dimensional bitmap of size for indicating the location of the NZCs, where each row corresponds to a selected SD basis vector and each column corresponds to one of the selected pairs of FD basis vector and DD basis vector.     - Alt4’: Q different bitmaps are supported for each layer, each of the Q bitmaps corresponds to DD basis q = 0 or 1.       * For each polarization, each of the Q bitmaps contains bits included in a set of SD basis and FD basis pairs , satisfying , where         + ,         + is the SD basis indicated by SCI         + Two polarizations have same set of in the bitmap   **Proposal 2.B.2:**  For the Type-II codebook refinement for high/medium velocities, regarding the bitmap(s) for indicating the locations of the NZCs,   * When the UE is configured with Q=2: for each layer, as an optional feature, only in high overhead regime (i.e. paraComb(s) with )   + Two-level bitmap for each layer,   + The first level selects , q=0,1 from M bases and is reported using a bitmap of length MQ bits, where S = + is RRC configured or fixed, and is the number of selected FD bases for DD basis q determined by the UE.   + For q-th DD component, the second level uses the distance metric to only include the bits around SCI selected from , bits per pol as follows:     - For each polarization, the second level bitmap contains bits included in a set of SD basis and selected Sq basis pairs , satisfying , where       * + ,         + is the SD basis indicated by SCI         + Two polarizations have same set of in the bitmap.   + FFS: Values of S, D and paraComb(s)   **FL Note**: | **Proposal 2.B.2:**   * **Support/fine:** Fraunhofer IIS/HHI, vivo, Samsung (ok), Spreadtrum, Huawei/HiSi, CMCC, NEC, * **Cannot accept:** ZTE, Fujitsu, OPPO, Xiaomi, CATT, Intel   **Optional Q=2**   * **Alt3A**: Fraunhofer IIS/HHI, NEC, ZTE, OPPO, Intel, MediaTek, Lenovo/MotM, Huawei/HiSi, Ericsson, Sony * **Alt4’**: vivo |
| 2.3 | [112bis-e] **Agreement**  ….   * Select at most 3 additional Parameter Combinations from the list below  |  |  |  |  |  | | --- | --- | --- | --- | --- | |  |  | |  | **Companies’**  **views** | |  |  | | 2 | 1/8 | 1/16 | ¼ | **Support/fine**: **ZTE, Huawei/HiSi, CATT, Intel,**  **Not support**: Qualcomm | | 2 | 1/8 | 1/16 | ½ | **Support/fine**: **ZTE, Intel**  **Not support**: Qualcomm | | 2(\*) | ¼ | 1/8 | ¼ | **Support/fine**: **Samsung, OPPO, Nokia/NSB**, vivo, MediaTek, Qualcomm, Ericsson, LG, Xiaomi  **Not support**: | | 2 (\*) | ¼ | 1/8 | ½ | **Support/fine**: **Samsung, OPPO, Nokia/NSB, Intel**, vivo, MediaTek, Qualcomm, Ericsson, LG, Xiaomi  **Not support**: | | 4 | 1/8 | 1/16 | ¼ | **Support/fine**: **ZTE, Huawei/HiSi, CATT**  **Not support**: Qualcomm | | 4 (\*) | ¼ | 1/8 | ¼ | **Support/fine**: **Samsung, OPPO, Huawei/HiSi, Nokia/NSB, CATT**, vivo, MediaTek, Ericsson, LG, Xiaomi  **Not support**: Qualcomm |   **Blue**: Companies with SLS results  (\*) Note: From legacy.  **FL Note**: The proposal below is made based on the submitted SLS results while, also, considering the preferences from companies without SLS results.    **Proposal 2.C.2**: For the Type-II codebook refinement for high/medium velocities based on Rel-16 eType-II regular codebook, in addition to the already agreed six Parameter Combinations, the following three Parameter Combinations are supported:   |  |  |  |  | | --- | --- | --- | --- | |  |  | |  | |  |  | | 2 | 1/8 | 1/16 | ¼ | | 2 (\*) | ¼ | 1/8 | ½ | | 4 (\*) | ¼ | 1/8 | ¼ | | **Proposal 2.C.2:**   * **Support/fine:** Samsung * **Cannot accept:** |
| 2.5 | [112bis-e] **Agreement**  On the Type-II codebook refinement for high/medium velocities, regarding UCI omission, support reusing the legacy UCI omission mechanism with (Alt3) the following priority function: Prio(l,l,m,q)=2L.RI.Mv.q + 2L.RI.P(m)+ RI.l + l where P(m) = m   * Note: This implies that DD basis is designated the least priority * FFS: Details on the location of the new UCI parameters in G0/1/2   **Question 2.5:** Please share your view on the location of the new UCI parameters in G01/2 | |

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

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| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| Issue # 2.1 | | | |
| Samsung | 2.1 | UPT vs overhead | There is no benefit with Alt1.2/1.3 (differential w.r.t. the 1st CQI) over Alt1.1 (independent of the 1st CQI) |
| Issue # 2.2 | | | |
| Huawei | 2.2 | UPT vs overhead | Alt.3A has better UPT vs. overhead tradeoff than Alt.1. |
| ZTE | UPT vs overhead | ***On Alt1 vs 4’***  In addition, we evaluate the performance on average UPT vs overhead between Alt1, Alt4\_1 based on d=3 and Alt4\_2 based on d=5 in Figure 2. Parameter combination is shown in Table2. There are some performance benefits in the case of low-overhead region in Figure 2. However, serious performance loss is observed in SLS on Alt4 both d=3 and d=5 in Figure 2 in high-overhead region.  ***On Alt3A***  For Alt3A, we have the concerns that Alt3A may violate previous agreements for “Q different two-dimensional bitmaps”, to some extent. Then, we provide SLS simulation in Figure 2 with Alt3A\_1 based on S = 0.5\*MQ and Alt3A\_2 based on S = 0.75\*MQ. It is observed that, with sufficient small parameter (e.g., S =0.5\*MQ) for reducing value of S, there are some performance benefits in the case of low CSI report overhead. |
| Vivo | UPT vs overhead | * Under Q=2 and legacy CB parameter combinations (pv, beta, L), Alt 4’ UPT-overhead curve outperforms Alt 1 and Alt 3A. * For lower overhead or ideal prediction, for each (pv, beta, L) configuration, Alt 4’ can save about 50 bits for each layer with nearly no performance loss. * The benefit from Alt 4’ in terms of performance is even clearer in high overhead and real prediction. Alt 4’ can address the issue of coefficient unreliability caused by prediction error. * Alt 3A does not provide better performance-overhead trade-off than Alt 1. |
| OPPO | UPT vs overhead | Alt3A can reduce 10% overall overhead without UPT loss. |
| Fraunhofer | UPT vs overhead | Alt 3A with results in feedback overhead saving of 48 bits, 160 bits and 84 bits for parameter combinations 1-4, 5 and 6, respectively, compared to Alt 1 with negligible loss in performance.  For Alt 3A, using S = 0.5MQ results in a similar average UPT to that of Alt 1 with large feedback overhead saving. |
| CATT | UPT vs overhead | The average throughput versus bitmap overhead is shown in Figure 1. Based on the simulation results, it is observed that Alt3A has negligible performance loss compared with Alt1 with less bitmap overhead. |
| Intel | UPT vs overhead | * Performance degradation of up to 0.8% in average UE throughput and up to 2% for cell-edge UE throughput is observed for Alt3A comparing to Alt1. * 48 bits can be saved for configurations with M = 4 and 84 bits for configuration with M = 7 for Alt3A comparing to Alt1 |
| Samsung | UPT vs overhead | * Alt3A and Alt1 are similar in UPT vs overhead trade-off for all of avg. UPT, 50% UPT, and 5% UPT. * For any (UPT, overhead) achieved by Alt3A, there is a similar (UPT, overhead) achieved by Alt1 * Alt4’ can improve UPT vs overhead trade-off |
| MediaTek | UPT vs overhead | NZC indication by Alt 3A can provide 50~60 bits overhead saving compared with Alt 1 with <1 % performance loss.  NZC indication by Alt 4 and D = 3 can achieve similar performance as Alt 1 without significant overhead saving.  NZC indication by Alt 4 and D = 2 degrades in performance especially at higher parameter combinations, due to forcing zero coefficients in certain SD, FD positions. |
| Qualcomm | Separate UPT, and overhead | For Type-II-Doppler, Alt1 2-stage (MQ+2LS)-bit bitmap (Alt3A) achieves similar average throughput as 2LMQ-bit 3D bitmap, while overall feedback overhead can be reduced by more than 10% (659 to 575 bits). |
| Ericsson | Separate UPT, and overhead | Bitmap alternative Alt1 with reporting of only non-empty DD bitmaps is close to Rel-16 Type-II implementation in complexity and is a simpler reporting format |
| Issue # 2.3 | | | |
| Huawei | 2.3 | UPT vs overhead | The following values paraComb achieves the best UPT vs overhead trade-off:   |  |  |  |  |  | | --- | --- | --- | --- | --- | | *paramCombination-Type II doppler* |  |  | |  | |  |  | | 1 | 2 | 1/8 | 1/16 | ½ | | 2 | 4 | 1/8 | 1/16 | ¼ | | 3 | 4 | 1/8 | 1/16 | ½ | | 4 | 4 | ¼ | 1/8 | ¼ | | 5 | 4 | ¼ | 1/8 | ½ | | 6 | 4 | ¼ | ¼ | ½ | | 7 | 6 | ¼ | 1/8 | ½ | | 8 | 6 | ¼ | ¼ | ½ | |
| ZTE | UPT vs overhead | Based on SLS results, the following is proposed   |  |  |  |  | | --- | --- | --- | --- | |  |  | |  | |  |  | | 2 | 1/8 | 1/16 | 1/8 | | 2 | 1/8 | 1/16 | ¼ | | 4 | 1/8 | 1/16 | 1/8 | | 4 | 1/8 | 1/16 | ¼ | | 4 | ¼ | ¼ | ¼ | | 4 | ¼ | ¼ | ½ | | 4 | ¼ | ¼ | ¾ | | 4 | ½ | ½ | ½ | | 6 | ¼ | ¼ | ½ | | 6 | ¼ | ¼ | ¾ | |
| OPPO | UPT vs overhead | We evaluated R16 and R17 parameter combination, where AP CSI-RS overhead is not considered. For R17 parameter combination, legacy parameter is good. For R16, we used and there is no any significant gain for large K0, which imply legacy parameter combination can be reused for N4 > 1 |
| CATT | UPT vs overhead | Based on our simulation results, we identified several Parameter Combinations that offer a good tradeoff between performance and overhead. As a result, we recommend using the Parameter Combinations outlined in Table 2    Table 2 Codebook parameter configurations for *L*, and   |  |  |  |  | | --- | --- | --- | --- | | *L* |  | |  | |  |  | | 2 | 1/8 | 1/16 | ¼ | | 2 | 1/8 | 1/16 | ½ | | 4 | 1/8 | 1/16 | ¼ | | 4 | 1/8 | 1/16 | ½ | | 4 | ¼ | 1/8 | ½ | | 4 | ½ | ¼ | ½ | | 6 | 1/8 | - | ½ | | 6 | ¼ | - | ½ | |
| Intel | UPT vs overhead | * Parameter combinations {p1,2, beta} = {1/8, ¼}, {1/8, ½}, {1/4, ½}, {1/4, ¾} provide good performance/overhead tradeoff considering both average and cell-edge UE throughput |
| Nokia | UPT vs overhead | * For Type-II-Doppler, for average and cell-edge UPT gain over Rel-16 Type-II increase with overhead, for the same parameter combinations. * For Type-II-Doppler, cell-edge UPT gain over Rel-16 Type-II tend to be noticeably higher than average UPT gain. |
| Samsung | UPT vs overhead | Different (smaller) beta than legacy (beta=1/8)   * Smaller than legacy can be beneficial * Weak coefficients increase overhead, but don’t provide UPT gain (🡪 beta can be small) |

Table 4 Additional inputs: issue 2

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 3A** |
| Samsung | From Round 1:  P 2.A.2: support V1. V2 is worse than V1 in terms UPT vs overhead tradeoff, as shown in our contribution (copied below). Besides, the overhead saving tiny. We therefore can’t accept V2.  ***Observation 11****: there is no benefit with Alt1.2/1.3 (differential w.r.t. the 1st CQI) over Alt1.1 (independent of the 1st CQI)*  Figure |
| vivo | **Proposal 2.B.2**  As we indicated in Round 1 summary, we have strong technical concern on supporting Alt 3A, which performs no better than Alt 1 based on multiple companies’ results including vivo’s. Our first preference is Alt 4’, but we can compromise to Proposal 2.B.2 due to the following reasons.   * + The current 2.B.2 is built based on Alt 3A, and it addresses our technical concern on the original Alt 3A. The original Alt 3A aims to reduce overhead, but it still uses free NZC selection from UE side. This causes issues due to prediction error in real prediction. Prediction error impacts the final performance a lot. (Companies use same argument to defend Alt 3 in Type II Doppler UCI omission in a previous agreed proposal.) Hence if the coefficients are freely selected by UE, prediction error will cause UE to select some weak coefficients which look large due to prediction error. In Proposal 2.B.2 from FHG, the second bitmap uses a restriction pattern on UE’s coefficient selection, which means the coefficients around SCI after cyclic remapping are selected. It is beneficial to increase the reliability of NZC selection. This is also shown in multiple companies’ simulation results, e.g., in vivo’s and Samsung’s contributions.   + Some companies raised concern on the complexity of proposal 2.B.2. We would like to clarify the UE complexity is not higher than the previous Alt 3A. With S0 and S1 determined, the pattern and size of the bitmap are determined, as other than S0 and S1, only RRC parameters impact the bitmap pattern and bitmap size. Further, as the size of the 2nd-level bitmap reduces, the UE buffer size to store the bitmap and non-zero coefficients is also reduced. Hence the UE complexity is actually lower than Alt 3A. |
| Samsung | **Proposal 2.A.2**: support due to reasons explained above  **Proposal 2.C.2**: we are ok for progress, although we still think legacy combinations are sufficient  **Issue 2.5**   * 2nd TD CQI: we can use the solution similar to legacy Rel. 15, rank>4 Type I CSI   + WB 2nd TD CQI in G0   + even-numbered SB 2nd TD CQI in G1   + odd-numbered SB 2nd TD CQI in G2 * When N4>1   + DD basis indicator: G0   SCI (): if is reported via a separate indicator, both ( in G0 |
| Mod V3 | **--** |
| Xiaomi | **Proposal 2.B.2**  We are fine for the first and the second sub-bullets, i.e, two-level bitmap indication for each layer and S FD-DD basis pairs are indicate by using a bitmap of length MQ bits. For the third sub-bullets, in our view, the second level is used to indication of NZC(non-zero coefficients). However, how to determine the location of NZC depends on UE’s implementation. UE can determine the location of NZC by using different metrics. The sub-sub-bullets of the third sub-bullets in this proposal is one of metrics to determine the location. It is not necessary to restrict any metric to choose NZC. Based on this reason, we suggest the proposal is reworded as follows for compromise.  **Proposal 2.B.2:**  For the Type-II codebook refinement for high/medium velocities, regarding the bitmap(s) for indicating the locations of the NZCs,   * When the UE is configured with Q=2: for each layer, as an optional feature, only in high overhead regime (i.e. paraComb(s) with )   + Two-level bitmap for each layer,   + The first level selects , q=0,1 from M bases and is reported using a bitmap of length MQ bits, where S = + is RRC configured or fixed, and is the number of selected FD bases for DD basis q determined by the UE.   + For q-th DD component, the second level selects K0 NZCs and is reported using a bitmap of follow two alternatives,     - Alt1: (polarization0-specific)     - Alt2: including SCI (polarization0-common)   + FFS: Values of S~~, D~~ and paraComb(s)   **Proposal 2.C.2**  We are fine with it for the sake of progress.  **Question 2.5**  For the location of NZC, we prefer to reusing the legacy method. i.e., half of NZCs with higher priority is included in G1, the remained NZCs is included in G2 |

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

Table 5A Summary: issue 3

|  |  |  |
| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 3.1 | [112bis-e] **Agreement**  For the Rel-18 TRS-based TDCP reporting, for TDCP measurement and calculation,   * KTRS ≥1 TRS resource set(s) can be configured in the CSI reporting setting when ReportQuantity is ‘tdcp’   + Note: the TRS resource set(s) configured for TDCP report do not impact or impose any new requirements on the UE behavior when processing TRS used as QCL type A/D source for reception of PDxCH. * No further spec enhancement on TRS is supported * All the TRS resources in the configured resource set(s) share the same RE locations * FFS: Whether to add further restrictions on the TRS resource set(s) on, e.g. QCL relationship, power control, slot offset between TRS resource set(s), relation with resource set used for legacy usage   **Question 3.1**: Please share your views on whether to add further restrictions on the TRS resource(s) | |
| 3.2 | [112bis-e] **Agreement**  For the Rel-18 TRS-based TDCP reporting, regarding the quantization of wideband normalized amplitude value,   * At least the following size-*Q* quantization alphabet is supported: where   + TBD: supported value(s) of *N* (e.g. or a larger value), *Q*, s (e.g. ½, ¼, 1/8, …), whether a center threshold is also supported (and if so, higher-layer configured) * FFS: Whether different schemes can be supported for different use cases   **Proposal 3.B.2**: For the Rel-18 TRS-based TDCP reporting, regarding the quantization of wideband normalized amplitude value, down-select (by RAN1#113) from the following candidates:   * Alt1: N=2Q-1 where Q=5, s={1/5, ¼, 1/3} * Alt2: N=2Q where Q=3, s={¼, 1/3, ½, 2/3, ¾} * Alt3: N=2Q where Q=4, s={¼} * Alt4: N=[2Q+1-1, 2Q-1] (i.e., 7-15) where Q=3, s={¼, 1/3, ½, 2/3, ¾}   Once an alternative is selected, reducing the number of candidate values for s is not precluded.  Companies can simulate each alternative with and without a configurable center threshold  **FL Note**: Below is the summary of inputs from previous rounds  N value(s):   * 2^Q-1: Qualcomm (0 included), Ericsson, Xiaomi, * 2^Q: ZTE, MediaTek, Lenovo/MotM, Fujitsu * Larger than 2^Q-1: Samsung, Nokia/NSB   Q value(s)   * 3: Samsung, ZTE, Nokia/NSB, Lenovo/MotM, Fujitsu, * 4: ZTE * 5: MediaTek, Ericsson   S value(s):   * ¼, 1/3, ½, 2/3, ¾: Samsung, Nokia/NSB * ½ for Q=3: ZTE, Lenovo/MotM, Fujitsu * ¼ for Q=4: ZTE * for Q=5: MediaTek * 1/3, ¼ with Q=5: Ericsson   Configurable center:   * Yes: Samsung, Nokia/NSB, * No: ZTE, MediaTek, Lenovo/MotM, Huawei/HiSi, Ericsson, Fujitsu, Xiaomi | **Proposal 3.B.2:**   * **Support/fine:** Samsung * **Not support:** |
| **Proposal 3.B.3**: For the Rel-18 TRS-based TDCP reporting, regarding phase quantization, down-select (by RAN1#113) from the following candidates:   * Alt1. 1-bit (early vs. late) phase indicator * Alt2. 3-bit (8-PSK) uniform quantization * Alt3. 4-bit (16-PSK) uniform quantization (full reuse of Rel-16 eType-II W2 phase quantization) * Alt4. Adaptive/gNB-configurable phase quantizer e.g. based on some combination of Alt1/2/3   The evaluation should consider the impact of delay tracking operation at the UE where the phase difference between two slots can be close to zero.  **FL Note**: Below is the summary of inputs from previous rounds   * **1 bit (early late – due to DLL):** Ericsson, Google, * **3 bits:** ZTE * **4 bits, full reuse of Rel-16 W2 phase:** Lenovo/MotM, Intel, Apple * **Adaptive (depending on delay value):** Samsung | **Proposal 3.B.3:**   * **Support/fine:** Samsung * **Not support:** |
| 3.3 | [112] **Agreement**  For aiding gNB determination of codebook switching and SRS periodicity with the Rel-18 TRS -based TDCP reporting, support reporting quantized wideband normalized amplitude/phase of the time-domain correlation profile with Y≥1 delay(s) as follows:   * Basic feature: Y=1 with delay≤ Dbasic symbols, only wideband quantized normalized amplitude is reported   + FFS: Candidate values for delay * Optional feature: Y=1 with delay>Dbasic symbols and Y≥1, wideband quantized normalized amplitude and phase for each delay are reported   + For Y>1, the phase can be configud to be absent for all the Y delays   + TBD: Whether the value of Y is configurable or following the delays from the configured TRS resource   + TBD: Candidate value(s) for Y>1 * FFS: Value of Dbasic   **Proposal 3.C.2:** For the Rel-18 TRS-based TDCP reporting, Dbasic is equal to 2 slots   * Support the following D (delay) values: 4 symbols, 1 slot, 2 slots, 3 slots, 4 slots, 5 slots * Working assumption: Support the following D (delay) values in a separate UE Feature Group: 6 slots, 10 slots   FFS: Applicability of each D value candidate for different SCS values and/or other parameters (e.g. Y, quantization)  **FL Note**: This proposal is already a compromise  **MOVED TO EMAIL ENDORSEMENT 3** | **Proposal 3.C.2:**   * **Support/fine:** NEC (remove 4), ZTE (include 10), vivo, NTT DOCOMO, MediaTek (6 in brackets), CMCC, Qualcomm, Ericsson (keep 6), Samsung, Spreadtrum, Fujitsu, Xiaomi * **Not support:** NEC (remove 4symbols) |

Table 5B TDCP: summary of observation from simulation

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **SLS results** | | |
| **Issue #** | **Metric** | **Observation** |
| ZTE | 3.2 | UPT vs speed,  use case = SRS periodicity | *Amplitude quantization scheme*  outperforms and with higher DL throughput in the use case of SRS periodicity determination.   1. 1   *Phase quantization scheme q1 outperforms q0 and q2 with higher throughput in the use case of SRS periodicity determination* |
| OPPO | 3.2 | SE vs UE speed, use case: T1/T2 CB switch | *Observation 2: The threshold of codebook switching is close to 1, and R16 amplitude is coarse for TDCP reporting.* |
| Xiaomi | 3.1 | Switching accuracy vs delay | *Observation 1: Two TRS resource sets with delay 5 slots can obtain better TDCP measurement.* |
| Nokia | 3.2 | UPT vs UE speed, use case: T1/T2 CB switch | By comparing the performance gains in 1ms delay scenario and 10ms delay scenario one can notice that codebook with N=41 shows best performance, while all other codebooks lead to preferring Type-II too often, what is explained by the fact that highest quantisation level is still is not high enough for 1ms delay correlation profile calculation. But in case of 10ms delay (see Figure 15) codebook with N=20 shows best performance, and N=41 shows very poor performance.    Performance degradation of Type-I/Type-II switching with noisy TDCP measurements does not increase for shorter delays. |
| Mavenir | 3.3 | Doppler spread vs UE speed | Observation 2. 20-slot delay has shown worse accuracy. Delay <= 5 slots can ensure the estimation for time variation of channel. 5-slot delay is better for smaller UE velocity (<=30km/h), whereas 1-slot delay is suitable in scenario of higher velocity. |
| Samsung | 3.2 | UPT vs UE speed, use case: T1/T2 CB switch | *For T1/T2 CB switch based on threshold = 0.86, and Y=1*   * *3-bit R16-based quantization is sufficient*   + *1-v^2 is the best at low speed (<=10kmph)*   + *1-v is good overall* * *4-bit/5-bit doesn’t offset any gain over 3-bit*   *Based on LLS evaluations,*   * *The BLER performance of un-quantized and 1st 8 levels from Rel-16 legacy 4-bit reference codebook is almost same*   *Based on LLS evaluations,*   * *The BLER performance with 16-PSK for phase quantization is least, provides close match with un-quantized performance* * *QPSK has highest BLER among 3 phase quantization methods.* |
| MediaTek |  | UPT vs speed, use case: T1/T2 CB switch | If are the quantization levels from E-Type amplitude quantization, then using for TDCP quantization offers better quantization performance compared to for TDCP values well below 1. |
| Ericsson | 3.1 | UPT vs UE speed, use case: T1/T2 CB switch | In Figure 15 ,we show the performance of time correlation-based switching between CSI Type I and CSI type II for 100MHz bandwidth for small correlation delays, without averaging over time and with averaging over ten consecutive measurement occasions. In both cases we see that there is a significant improvement in performance when averaging over time is done. |
| 3.2 | UPT vs UE speed, use case: T1/T2 CB switch | In the simulations in Figure 8 and Figure 9 we see the performance for the quantization schemes for s equal to ½, 1/3, ¼ and 1/8 for a correlation delay of 5 slots and 3 slots. We see that higher granularity (i.e. smaller s) gives better performance but the difference is small, less than one percent in throughput  …  Thus, we confirm that at least for the use case of CSI Type I – Type II switching, already the granularity is sufficient.  For TDCP amplitude, an upper limit of 0.995 for the quantization range needs to be considered. |
| 3.3 | UPT vs speed, use case: T1/T2 CB switch | For case with TRS colliding with PDSCH, a delay of 84 symbols gives the best performance at low SNRs.  For case with TRS colliding with PDSCH, a delay of 36 symbols gives good performance at medium to high SNRs.  For case with TRS colliding with TRS, a delay of 140 symbols is needed for good switching performance. |

Table 6 Additional inputs: issue 3

|  |  |
| --- | --- |
| **Company** | **Input** |
| Mod V0 | **Please share your inputs on each of the issues and, if applicable, proposals in TABLE 5A** |
| Samsung | Issue 3.1:   * Measurement window: for TRS measurement, the UE needs to be measurement TRS overhead a window. So, the following is needed for TDCP reporting.   + higher layer parameter *timeRestrictionForChannelMeasurements* in *CSI-ReportConfig* is set to *'notConfigured'*, * The value KTRS: what are the candidate values? We think at least {1,2} is needed.   Proposal 3.B.2   * As shown in our revised Tdoc 3901 (copied below), N>2^Q-1 can achieve better MSE than N=2^Q-1. So, we suggest to include the following: * Alt2a: N=[2Q+1-1, 2Q-1] (i.e., 7-15) where Q=3, s={¼, 1/3, ½, 2/3, ¾}   Proposal 3.B.3: OK    Figure    Figure    Figure    Figure    Figure    Figure |
| Mod V3 | **Proposal 3.C.2 is moved to EMAIL ENDORSEMENT 3** |
| Xiaomi | **Question 3.1:**  When KTRS>2, the slot offset between TRS resource set should be same. At least one of TRS resource set is used for legacy usage.  **Proposal 3.B.2**:  For Alt3, we observed that some quantization values between 0.9 and 1 cannot be obtained if s<0.5 in our tDoc when Q=4, as shown in the figure. Therefore, s=½, 2/3, ¾ should be included in Alt3.    **Proposal 3.B.3**  Support  **Proposal 3.C.2:**  We prefer to larger value Dbasic, e.g., Dbasic =5 slot for lower speed. But we are fine with the proposal for the sake of progress if all companies can support it. |

# References