**3GPP TSG-RAN WG1 #103-e R1-200xxxx**

**e-Meeting, October 26th – November 13th, 2020**

**Source: Moderator (Apple Inc.)**

**Title: Feature lead summary #3 on reduced PDCCH monitoring**

**Agenda item:** **8.6.2**

**Document for:** **Discussion and Decision**

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# 1 Introduction

Contributions made under the “reduced PDCCH monitoring” agenda item of the Rel-17 study item on “Study on support of reduced capability NR devices” as well as initial evaluation results in [29] were summarized in FL summary #1 (FLS1) in R1-2008471.

This document captures the following RAN1#103e RedCap email discussion.

|  |
| --- |
| [103-e-NR-RedCap-03] Email discussion for reduced PDCCH monitoring– Hong (Apple)   * 1st check point: 10/29 * 2nd check point: 11/4 * 3rd check point: 11/10 * Last check point 11/12 |

This summary was organized based on the structure of latest TR 38.875 [1] to document the evaluation results of reduced PDCCH monitoring provided in Phase-2 post-102-e-meeting email thread [102-e-Post-NR-RedCap-01] into section 2. In addition, section 3 intends to discuss potential conclusions for this study item based on the finding in section 2.

Follow the naming convention in this example:

* RedCapPDCCHFLS2-v000.docx
* RedCapPDCCHFLS2-v001-CompanyA.docx
* RedCapPDCCHFLS2-v002-CompanyA-CompanyB.docx
* RedCapPDCCHFLS2-v003-CompanyB-CompanyC.docx

# 8.2 Reduced PDCCH monitoring

## 8.2.1 Description of feature

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| The following three reduced PDCCH monitoring schemes were studied and evaluated:  **Scheme #1: Reduced maximum number of Blind Decoding (BD) per slot**   * In Rel-15 and Rel-16 NR, the limits on maximum number of BDs and CCEs per slot are defined for different SCS configurations, as summarized in Table 1. Scheme #1 is to reduce the maximum number of BDs in a slot. The BD reduction maybe achieved by reducing the DCI size budget. The total number of different DCI sizes configured to monitor in Rel-15/16 is up to 4 with 3 for DCI sizes with C-RNTI and 1 for other RNTIs. One alternative of Scheme #1 is to reduce the maximum number of different DCI format sizes for C-RNTI to Y, where .   Table 1: Blind decoding and CCE limits in NR.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **SCS [kHz]** | **15** | **30** | **60** | **120** | | **Max # BD per slot (in NR)** | 44 | 36 | 22 | 20 |   **Scheme #2: Extending the PDCCH monitoring span gap to X slots (X>1)**   * In Rel-15/16 NR, the range of PDCCH monitoring periodicity is configurable, which is in a range of a few symbol (s) to 2560 slots subject to UE capability. Scheme#2 is to limit the minimum PDCCH monitoring periodicity value to be X slots, where and keep the same maximum number of BDs in a slot as that in Rel-15/16.   **Scheme #3**: **Dynamic adaptation of PDCCH monitoring parameters**   * In Rel-15/16, the parameters of PDCCH monitoring is configured by RRC signaling on a per search space set basis. Scheme #3 is to dynamically adapt PDCCH monitoring parameters e.g. number of PDCCH candidates and time separation between two consecutive spans.   **Scheme#4: One PDCCH schedules multiple PDSCH/PUSCH**   * In Rel-15/16, for dynamic scheduling manner, one PDCCH schedules one PDSCH/PUSCH. In scheme #4, one PDCCH could schedule more than one contiguous PDSCH/PUSCHs. |

**Proposal 8.2.1-1**: **Incorporate the above section 8.2.1 into text proposal for the Redcap TR. If not, what changes(s) are needed in order to add into Redcap TR? Please comments “Yes or no” per Scheme e.g. Scheme 1 or Scheme 2, …, or simply ‘Yes’ means ‘all’. If a particular scheme is generally ok but need some modifications on the exact wording, please provide modified wording in the ‘comments’ column.**

* Please kindly note that capturing scheme in this section is purely for documenting the corresponding evaluation results provided by companies. Whether or not these schemes will be added into observation part and/or conclusion section of TR 38.875 are totally separate discussion. In other words, capturing the schemes in this section is some sort of editorial work as we usually did in before for other study items.

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| CATT | N for scheme 2. | From PDCCH monitoring reduction perspective, there is no difference between extending span gap X and configuring a search space with periodicity larger than 1 slot. It should be noted that span is defined by FG3-5b which is a kind of advanced capability. For a RedCap UE, it is well known a low end UE. The motivation of discussing a capability on basis of FG 3-5b is not clear. |
| Xiaomi |  | Besides the schemes listed by the FL, we also think the multi-TB scheduling is one efficient way to reduce the PDCCH monitoring, especially in scenario of low mobility. So, we list it as scheme 4.  In our opinion, this scheme could achieve similar power saving gain compared with reducing the maximum BD per slot. It is kind of way to reduce the “average”number of BD per slot.  In addition, this scheme could work independently or can be combined with other PDCCH reduction scheme |
| LG | Scheme 1 Yes  Scheme 2 No  Scheme 3 No | The scope is ‘Reduced PDCCH monitoring by smaller numbers of BD/CCE limits’, however, Scheme 2 mentions ‘keep the same maximum number of BDs in a slot’. Thus, we don’t think the Scheme 2 is in the scope.  The discussion on Scheme 3 may be a relevant topic to this agenda item but a similar work is being done in Rel-17 UE power saving enhancements WI in a broader scope. As we had a consensus to minimize duplicate works among different WIs/SIs, our recommendation is not to study this technique in RedCap SI. |
| vivo |  | We suggest the following additions to scheme#1 and #2. For scheme#3, we are wondering whether it is more suitable for power saving WI.  **Scheme #1: Reduced maximum number of Blind Decoding (BD) per slot**   * In Rel-15 and Rel-16 NR, the limits on maximum number of BDs and CCEs per slot are defined for different SCS configurations, as summarized in Table 1. Scheme #1 is to reduce the maximum number of BDs in a slot. The BD reduction maybe achieved by reducing the number of monitored PDCCH candidates or DCI size budget. The total number of different DCI sizes configured to monitor in Rel-15/16 is up to 4 with 3 for DCI sizes with C-RNTI and 1 for other RNTIs. One alternative of Scheme #1 is to reduce the maximum number of different DCI format sizes for C-RNTI to Y, where . Methods to reduce the DCI size budget include but not limited to DCI size alignment, decoupling the configuration of non-fallback DCI in for DL and UL, etc.   Table 1: Blind decoding and CCE limits in NR.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **SCS [kHz]** | **15** | **30** | **60** | **120** | | **Max # BD per slot (in NR)** | 44 | 36 | 22 | 20 |   **Scheme #2: Extending the PDCCH monitoring span gap to X slots (X>1)**   * In Rel-15/16 NR, the range of PDCCH monitoring periodicity is configurable, which is in a range of a few symbol (s) to 2560 slots subject to UE capability. Scheme#2 is to limit the minimum PDCCH monitoring periodicity value to be X slots, where and keep the same maximum number of BDs in a slot as that in Rel-15/16. For X>1, there will be throughput loss due to the limitation that only one DL grant and up to two UL grant can be processed by the UE within a monitoring span. Allowing multi-slot scheduling from a single monitoring span by either separate grants or a single grant can be considered to compensate the throughput loss. |
| Huawei, HiSilicon | Scheme 1 Yes  Scheme 2 No  Scheme 3 No | Scheme#2 and Scheme#3 are out of the scope of the study item. Also, for both of them, only single company provides the evaluation results. And we are not sure how to make any observation/conclusion based on a single company evaluation. |
| Spreadtrum | Scheme 1 Yes  Scheme 3 No | For scheme 3, we share the same view with LG and Vivo, it is more suitable for power saving WI. |
| Panasonic | Scheme 1 Yes  Scheme 2 No  Scheme 3 No | Agree with Huawei. The TR should only capture Scheme#1 because it has been clearly targeted in the SID, and it is basically assumed the simulation evaluation for most companies. That is why Schemes#2 and #3 are only evaluated by one single company. In general, Scheme#3 and newly added Scheme#4 can be studied in the Rel-17 Power Saving Enhancement WI, and it should be open for RedCap UEs to make use of those schemes. |
| Sharp | Scheme 1 Yes  Scheme 2 Yes (with modification)  Scheme 3 No | For Scheme 2, remove “*keep the same maximum number of BD in a slot as that in Rel-15/16*” to consider the possibility of a maximum number of BD per multi-slot.  Scheme 3 should not be captured in TR. |
| Samsung | Yes | The agreed template for collection of simulation results only considers PDCCH BD reduction rate of 25% and 50% regardless of triggering methods.  All three schemes can achieve target the PDCCH BD reduction rate. So, all of them should be Incorporated in the TR. The details whether to support or how to achieve or trigger target BD reduction can be discussed during the WI phase.  The SID doesn’t exclude any type of solutions - both static and dynamic type solutions are in scope. As for the other schemes, Scheme #3 can apply to RedCap UEs only to avoid overlapping with Rel-17 PS enhancement – it also has clear advantages over schemes #1 and #2 for both UEs and gNB in terms of avoiding static/semi-static configurations for scheduling by the gNB and reducing UE power consumption.  Companies also proposed other techniques to compensate for the reduced PDCCH monitoring capability. For example, enhancements to reduce PDCCH blocking, such as UE group scheduling or partial search space set dropping. Those enhancements should also be captured. |
| Nokia | Scheme 1 Yes  Scheme 2 No  Scheme 3 No Scheme 4 No | Schemes 2,3 and 4 are out of the scope of the study item. |
| Qualcomm | Yes | We are fine to capture the above results in RedCap TR. Some clarification are as follows   * For scheme #1, when DCI size budget is reduced to mitigate the blocking probability increase, the reduction can be a network implementation or can have UE impact. UE should be guaranteed that BD limit is reduced, but there may not be such an explicit rule for the DCI size budget reduction. Whether explicit rules are needed to enable DCI size budget reduction at UE, by UE capability or network implementation can be further specified. * For scheme #2, it can be clarified the sparse PDCCH monitoring by extended span gap > 1 slot is not a mandatory feature. Otherwise, latency sensitive use cases will be impacted. Hence, scheme #2 cannot be the only solution for power saving for all RedCap devices. * For scheme #3, dynamic PDCCH adaptation is part of Rel-17 power saving enhancements for connected mode UEs. At least specification of some techniques can be still carried out in Rel-17 power saving enhancements. In the meanwhile, there are RedCap specific dynamic adaptation techniques such as UE requesting SS, piggy-back DCI on SCH [24]. |
| MediaTek | Scheme #1 Yes  Schemes 2, 3 & 4 No | Only scheme #1 is with the SI scope. |
| InterDigital | Y | We think both dynamic and static type solutions are in the SID scope. |
| Fraunhofer | Y | We do not see the benefit of scheme #2 if the number of BDs per slot is not reduced compared to Rel 15/16. However, in combination with a relaxed minimum scheduling time increasing the span gap helps the PDCCH blocking probability. Our understanding is that this is covered by scheme #3, hence we are supportive of that. |
| Futurewei | Scheme 1 only | In our view, the SID allows scheme only. Other schemes (e.g.3), as mentioned by Qualcomm, should be studied in power savings.  Scheme 1 encompasses multiple schemes and should be split into several options, with at least:  1a. Keep same number of DCIs to decode but reduce number of BD per DCI (we don’t support)  1b. Keep number of BD the same per DCI, but reduce the number of DCIs to monitor (we would be okay with that)  But ok to start with scheme 1 as a whole and to discuss sub-options later |
| Ericsson | Y for Scheme 1,  N for Schemes 2, 3 and 4. | Most companies haven’t evaluated the power saving benefit of schemes other than scheme #1 because there was no agreement to study those schemes. Therefore, only Scheme #1 should be captured in the TR.   |  | | --- | | Agreements:   * Study the impact of BD and CCE limits reduction on power saving and PDCCH blocking probability (quantitatively) and impacts on latency and scheduling flexibility (at least qualitatively). |   We also agree with LG and MediaTek that Schemes other than #1 are out of scope of the SID.  For the text on scheme #1, we propose the following update:   * In Rel-15 and Rel-16 NR, the limits on maximum number of BDs and CCEs per slot are defined for different SCS configurations, as summarized in Table 1. Scheme #1 is to reduce the maximum number of BDs in a slot. The BD reduction maybe achieved by reducing the DCI size budget. The total number of different DCI sizes configured to monitor in Rel-15/16 is up to 4 with 3 for DCI sizes with C-RNTI and 1 for other RNTIs. One alternative of Scheme #1 is to reduce the maximum number of different DCI format sizes for C-RNTI to Y, where . Note that the BD reduction can already be achieved by using existing Rel-15/16 mechanisms, for instance, by configuration of the number of PDCCH candidates per aggregation level (except for Type0/Type0A/Type2-PDCCH CSS) and the number of DCI sizes to monitor. |
| Intel | N for schemes 2, 3, and 4 | According to the SID description “Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits”, schemes that are targeted to reduce limits should be prioritized. To this end, we suggest to update description of Scheme # 1 as follows:   * In Rel-15 and Rel-16 NR, the limits on maximum number of BDs and CCEs per slot are defined for different SCS configurations, as summarized in Table 1. Scheme #1 is to reduce the maximum number of BDs in a slot. The BD reduction can be achieved by reducing the limits compared to Rel-15. The BD reduction maybe also achieved by reducing the DCI size budget, under the assumption of a limited number of BDs per DCI format size. The total number of different DCI sizes configured to monitor in Rel-15/16 is up to 4 with 3 for DCI sizes with C-RNTI and 1 for other RNTIs. One alternative of Scheme #1 is to reduce the maximum number of different DCI format sizes for C-RNTI to Y, where .   Table 1: Blind decoding and CCE limits in NR.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **SCS [kHz]** | **15** | **30** | **60** | **120** | | **Max # BD per slot (in NR)** | 44 | 36 | 22 | 20 | |
| DOCOMO | Scheme 1 Yes  Scheme 2 Yes  Scheme 3 No  Scheme 4 No | Agree with Sharp that Scheme 2 has possibility of a maximum number of BD per span. In that sense, Scheme 2 can be discussed together with Scheme 1.  Scheme 3 can be discussed in Power saving WI and/or NR-U UE feature and hence, should not be included into the TP.  Scheme 4 is out of the scope of this SI |
| CMCC | Yes | We are fine to capture all the four schemes in the TR, because we think all these schemes can reduce PDCCH monitoring power consumption.  But considering the overlapping between R17 Power saving WI, we suggest the Scheme#1 can be studied in RedCap WI, and Scheme#2, #3 and #4 can be studied in Power saving WI. |
| Lenovo, Motorola Mobility | Yes | We think that scheme 3 is necessary to provide scheduling flexibility, if scheme 1 is adopted.  For scheme 3, we propose the following modification:  **Scheme #3**: **Dynamic adaptation of PDCCH monitoring parameters and monitored DCI formats**   * In Rel-15/16, the parameters of PDCCH monitoring is configured by RRC signaling on a per search space set basis. Scheme #3 is to dynamically adapt PDCCH monitoring parameters e.g. number of PDCCH candidates and time separation between two consecutive spans, and/or monitored DCI formats.   We think schemes 2 (e.g. less frequent PDCCH monitoring occasion) and scheme 4 (i.e. one DCI scheduling multiple PDSCH/PUSCH) are useful for UE power saving, especially for delay-tolerant RedCap UE applications. For example, gNB can buffer DL data for a UE and schedule multiple packets in one shot. |
| OPPO | Scheme 1 Yes  Scheme 2 No  Scheme 3 No Scheme 4 No | The study should give clear indication on scope. Otherwise, companies put rare evaluation on scheme will not help for clear conclusion. Scheme 1 have clear common understanding for companies study.  Schemes 2 and 3 can be considered in PS WI. |
| ZTE,sanechips | Yes | As mentioned, the scope is ‘Reduced PDCCH monitoring by smaller numbers of BD/CCE limits’. From our understanding both dynamic or semi-static methods are included. Therefore, scheme1 and scheme 3 should be considered.  Further, in scheme 1, besides reducing the DCI size budget for BD reduction, the maximum PDCCH candidates and monitored PDCCH candidates can also be considered for BD reduction. Based on this, we agree the scheme1 modification from Intel and VIVO. More specifically, it can be written as following:  **Scheme #1: Reduced maximum number of Blind Decoding (BD) per slot**  In Rel-15 and Rel-16 NR, the limits on maximum number of BDs and CCEs per slot are defined for different SCS configurations, as summarized in Table 1. Scheme #1 is to reduce the maximum number of BDs in a slot. The BD reduction maybe achieved by reducing the number of monitored PDCCH candidates or DCI size budget or reducing the limits. The total number of different DCI sizes configured to monitor in Rel-15/16 is up to 4 with 3 for DCI sizes with C-RNTI and 1 for other RNTIs. One alternative of Scheme #1 is to reduce the maximum number of different DCI format sizes for C-RNTI to Y, where .  Scheme 2 can be discussed together with scheme1. For example, the maximum BDs reduction can be defined on multiple slots, which is also a method in the SID scope.  As for the scheme 4, as an auxiliary way to mitigate blocking impact, it can be discussed further in the WI stage. |

**Summary of 1st round email discussions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Schemes | Yes | | No | |
| Companies | # Companies | Companies | # Companies |
| 1 | CATT, LG, vivo (with modification), Huawei, HiSilicon, Spreadtrum, Panasonic, Sharp, Samsung, Nokia, Qualcomm, MediaTek, InterDigital, Fraunhofer, Futurewei, Ericsson, Intel, DOCOMO, CMCC, Lenovo, Motorola Mobility, OPPO, ZTE, Sanechips | 24 |  | 0 |
| 2 | Samsung, Qualcomm, InterDigital, Fraunhofer, CMCC, Lenovo, Motorola Mobility, ZTE, Sanechips | 9 | CATT, LG, vivo (with modification), Huawei, HiSilicon, Panasonic, Sharp, Nokia, MediaTek, Futurewei, Ericsson, Intel, DOCOMO, OPPO | 14 |
| 3 | CATT, Samsung, Qualcomm, InterDigital, CMCC, Lenovo, Motorola Mobility, ZTE, Sanechips | 9 | LG, vivo, Huawei, HiSilicon, Spreadtrum, Panasonic, Sharp, Nokia, MediaTek, Futurewei, Ericsson, Intel, DOCOMO, OPPO, | 14 |
| 4 | Xiaomi, CMCC, Lenovo, Motorola Mobility, ZTE, Sanechips | 6 | Nokia, Ericsson, Intel, DOCOMO, OPPO | 5 |

The following text proposal for Redcap TR 38.875 was therefore proposed:

**FL proposal:**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ---------------------------------- Start of Text Proposal ------------------------------------------------------  8.2.1 Description of feature  The following reduced PDCCH monitoring schemes were studied and evaluated:  **Scheme #1: Reduced maximum number of Blind Decoding (BD) per slot**  In Rel-15 and Rel-16 NR, the limits on maximum number of BDs and CCEs per slot are defined for different SCS configurations, as summarized in Table 1. Scheme #1 is to reduce the maximum number of BDs in a slot. The BD reduction maybe achieved by reducing the maximum number of monitored PDCCH candidates or DCI size budget compared to Rel-15. The total number of different DCI sizes configured to monitor in Rel-15/16 is up to 4 with 3 for DCI sizes with C-RNTI and 1 for other RNTIs. One alternative of Scheme #1 is to reduce the maximum number of different DCI format sizes for C-RNTI to Y, where . Methods to reduce the DCI size budget include but not limited to DCI size alignment, decoupling the configuration of non-fallback DCI in for DL and UL, etc.  Table 1: Blind decoding and CCE limits in NR.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **SCS [kHz]** | **15** | **30** | **60** | **120** | | **Max # BD per slot (in NR)** | 44 | 36 | 22 | 20 |   ---------------------------------- End of Text Proposal ------------------------------------------------------ |

## 8.2.2 Analysis of UE power saving

Most contributions have pointed out that reducing maximum number of BDs in a slot compared to Rel-15/16 reference NR UE enables reduced power consumption. The power saving gain has been extensively evaluated for both FR1 and FR2.

Contribution [5] suggests replacing the power scaling rule in the working assumption by P(α) = max (PMicro-sleep + X, α ∙ Pt + (1 – α) ∙ 0.7Pt), where X is a positive value where X>0. It is mainly motivated by the consideration that no matter how much the BD is reduced, the power consumption should not be equal to micro-sleep due to the power consumption of channel estimation.

For FR1 and FR2, the power saving gains of scheme 1~3 reported in post-meeting email discussion [102-e-Post-NR-RedCap-01] are provided in Table 2~11 for different traffic models corresponding to two cases below:

* Case 1: Power saving gain at approximately 25% reduction in BDs.
* Case 2: Power saving gain at approximately 50% reduction in BDs.

### 8.2.2.1 FR1 Results

Table 2: Power Saving gain, FR1, 1 Rx antenna, Revised

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | IM traffic model | | Heartbeat traffic model | | | | VoIP traffic model | | Schemes (Note 4) | Notes |
| Case 1 | Case 2 | Inactivity timer (IAT) = 200ms | | IAT = 80ms | | Case 1 | Case 2 |
| Case 1 | Case 2 | Case 1 | Case 2 |
| vivo | 3.54% | 7.08% | 2.29% | 4.59% | 2.13% | 4.25% | 2.85% | 5.70% | S1 | Note 1 |
| 3.13% | 4.77% | 1.95% | 2.98% | 1.80% | 2.75% | 2.47% | 3.76% | S1 | Note 2 |
| Ericsson | 0.70% | 1.30% | 0.01% | 0.02% | 0.01% | 0.02% | 1.19% | 2.22% | S1 | Note 1, Note 5 |
| 0.66% | 0.81% | 0.01% | 0.01% | 0.01% | 0.01% | 1.14% | 1.39% | S1 | Note 2, Note 5 |
| 2.42% | 4.49% | 0.01% | 0.02% | 0.01% | 0.02% | 2.64% | 4.90% | S1 | Note 1, Note 6 |
| 2.39% | 2.91% | 0.01% | 0.02% | 0.01% | 0.02% | 2.62% | 3.19% | S1 | Note 2, Note 6 |
| Samsung | 4.50% | 9% | 2.70% | 5.50% | 2.60% | 5.10% | 3.50% | 7% | S1, S2 | Note 2, Note 6 |
| Qualcomm | 3.22% | 6.44% | 0.96% | 1.92% | 0.65% | 1.30% | 1.53% | 3.06% | S1 | Note 1, Note 7 |
| 2.82% | 4.30% | 0.79% | 1.20% | 0.52% | 0.80% | 1.28% | 1.94% | S1 | Note 2, Note 7 |
| CATT | 1.83% | 3.67% | 1.10% | 2.196% | 1.04% | 2.075% | 0.90% | 1.82% | S1 | Note 1 |
| Spreadtrum | 5.70% | 11.40% | 3.40% | 6.80% | 3.20% | 6.40% | 3.10% | 6.00% | S1 | Note 1 |
| OPPO | 3.51% | 7.02% | 2.48% | 4.96% | 2.38% | 4.76% | - | - | S1 | Note 1, Note 6 |
| 2.77% | 5.54% | 2.13% | 4.25% | 2.04% | 4.07% | - | - | S1 | Note 2, Note 6 |
| Huawei, HiSilicon | 0.71% | 1.41% | 0.21% | 0.41% | 0.18% | 0.36% | 2.58% | 5.16% | S1 | Note 1, Note 6, Note 8A, Note 14A |
| 0.75% | 1.53% | 0.21% | 0.41% | 0.18% | 0.36% | 2.75% | 5.24% | S1 | Note 1, Note 6, Note 8B, Note 14A |
| 2.57% | 5.14% | 2.11% | 4.06% | 1.96% | 3.91% | 3.71% | 6.23% | S1 | Note 1, Note 6, Note 8A, Note 14B |
| 2.88% | 5.65% | 2.15% | 4.29% | 1.98% | 3.93% | 3.88% | 6.48% | S1 | Note 1, Note 6, Note 8B, Note 14B |
| Apple | 4.46% | 8.92% | 2.66% | 5.33% | - | - | - | - | S1 | Note 1, Note 6 |
| 3.38% | 6.77% | 0.65% | 1.32% | - | - | - | - | S1 | Note 1, Note 6, Note 9 |
| 4.05% | 6.17% | 2.29% | 3.50% | - | - | - | - | S1 | Note 2, Note 6 |
| 2.98% | 4.53% | 0.54% | 0.82% | - | - | - | - | S1 | Note 2, Note 6, Note 9 |
| Futurewei | 2.70% | 5.40% | 0.50% | 1.10% | 0.30% | 0.60% | 2.20% | 4.40% | S1 | Note 1 |
| InterDigital | 5% | 10% | 1.20% | 2.40% | 0.64% | 1.28% | - | - | S1 | Note 1, Note 6 |
| Intel | 3.31% | 6.4% | 2.24% | 4.75% | 2.03% | 4.36% | - | - | S1 | Note 1, Note 10 |
| 3.2% | 6.2% | 2.1% | 4.16% | 1.76% | 3.81% | - | - | S1 | Note 1, Note 11 |
| ZTE | 4.15% | 8.29% | 2.60% | 5.21% | 2.29% | 4.57% | - | - | S1 | Note 1, Note 6 |
| vivo | - | 6.32% | - | 4.07% | - | 4.16% | - | - | S2 | Note 1, Note 12 |
| - | 9.72% | - | 4.44% | - | 4.38% | - | - | S2 | Note 12, Note 13 |
| Samsung | 4.50% | 9% | 2.70% | 5.50% | 2.60% | 5.10% | 4.50% | 3.5% | S3 |  |
| MediaTek | 2.43% | 4.45% |  |  |  |  | 2.72% | 5.41% | S1 | Note 2, Note 15 |
| 0.84% | 1.68% |  |  |  |  | 0.87% | 1.74% | S1 | Note 2, Note 16 |
| Note 1: Same slot scheduling.  Note 2: Cross-slot scheduling.  Note 4: ‘S1’ represents Scheme#1, ‘S2’ represents Scheme#2, ‘S3’ represents Scheme#3  Note 5: DL (50%) + UL (50%)  Note 6: DL-only  Note 7: slots "DDDU",  Note 8: The blocking rate in Table 9 is assumed for corresponding cases.  Note 8A: BD reduction with the same DCI size budget.  Note 8B: BD reduction by reducing DCI size budget.  Note 9 : Wake-Up Signal (WUS)  Note 10: TDD: DDDDDDDSUU  Note 11: TDD: DDDSUDDSUU  Note 12:  Note 13: Multi-slot scheduling  Note 14A: UE can only transit to micro sleep in connected mode.  Note 14B: UE can transit to micro sleep, light sleep and deep sleep in connected mode according to the sleep duration.  Note 15: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot  Note 16: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots | | | | | | | | | | |

Table 3: Power Saving gain, FR1, 2 Rx antenna, Revised

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | IM traffic model | | Heartbeat traffic model | | | | VoIP traffic model | | Schemes (Note 4) | Notes |
| Case 1 | Case 2 | IAT = 200ms | | IAT = 80ms | | Case 1 | Case 2 |
| Case 1 | Case 2 | Case 1 | Case 2 |
| vivo | 4.22% | 8.44% | 2.88% | 5.76% | 2.71% | 5.43% | 3.45% | 6.89% | S1 | Note 1 |
| 3.80% | 7.61% | 2.50% | 4.99% | 2.34% | 4.68% | 3.04% | 6.07% | S1 | Note 2 |
| Ericsson | 0.95% | 1.76% | 0.01% | 0.02% | 0.01% | 0.02% | 1.56% | 2.89% | S1 | Note 1, Note 5 |
| 0.77% | 1.44% | 0.01% | 0.02% | 0.01% | 0.02% | 1.30% | 2.41% | S1 | Note 2, Note 5 |
| 3.05% | 5.66% | 0.22% | 0.42% | 0.20% | 0.38% | 3.33% | 6.17% | S1 | Note 1, Note 6 |
| 2.46% | 4.57% | 0.64% | 0.78% | 0.58% | 0.71% | 2.71% | 5.02% | S1 | Note 2, Note 6 |
| Samsung | 4.50% | 6.90% | 2.80% | 4.20% | 2.50% | 3.90% | 3.50% | 5.30% | S1,S2 | Note 2, Note 6 |
| Qualcomm | 3.72% | 7.44% | 1.25% | 2.50% | 0.86% | 1.71% | 1.98% | 3.96% |  | Note 7 |
| 3.31% | 6.61% | 1.03% | 2.07% | 0.71% | 1.40% | 1.67% | 3.34% | S1 | Note 2, Note 7 |
| Nokia | - | 9.2% | - | 6.8% | - | 6.1% | - | - | S1 | Note 1, Note 6 |
| CATT | 2.16% | 4.12% | 1.30% | 2.61% | 1.23% | 2.46% | 1.16% | 2.32% | S1 | Note 1 |
| Spreadtrum | 6.20% | 12.30% | 4.10% | 8.20% | 3.90% | 7.80% | 3.70% | 7.20% | S1 | Note 1 |
| OPPO | 3.94% | 7.88% | 2.81% | 5.61% | 2.70% | 5.40% | - | - | S1 | Note 1, Note 6 |
| 3.10% | 6.21% | 2.43% | 4.85% | 2.33% | 4.66% | - | - | S1 | Note 2, Note 6 |
| Huawei, HiSilicon | 0.64% | 1.55% | 0.24% | 0.47% | 0.21% | 0.41% | 2.79% | 5.69% | S1 | Note 1, Note 6, Note 8A, Note 14A |
| 0.82% | 1.63% | 0.24% | 0.47% | 0.21% | 0.41% | 2.85% | 5.70% | S1 | Note 1, Note 6, Note 8B, Note 14A |
| 1.47% | 4.92% | 2.19% | 4.39% | 2.00% | 3.99% | 2.96% | 6.31% | S1 | Note 1, Note 6, Note 8A, Note 14B |
| 2.83% | 5.65% | 2.19% | 4.47% | 2.00% | 4.02% | 3.17% | 6.33% | S1 | Note 1, Note 6, Note 8B, Note 14B |
| Apple | 5.10% | 10.14% | 3.30% | 6.60% | - | - | - | - | S1 | Note 1, Note 6 |
| 4.00% | 8.06% | 0.90% | 1.80% | - | - | - | - | S1 | Note 1, Note 6, Note 9 |
| 4.69% | 9.38% | 2.90% | 5.70% | - | - | - | - | S1 | Note 2, Note 6 |
| 3.60% | 7.22% | 0.75% | 1.49% | - | - | - | - | S1 | Note 2, Note 6 Note 9 |
| Futurewei | 3.20% | 6.30% | 0.70% | 1.30% | 0.40% | 0.80% | 2.70% | 5.50% | S1 | Note 1 |
| Intel | 3.46% | 6% | 2% | 4.13% | 2.4% | 5.12% | - | - | S1 | Note 1, Note 10 |
| 2.51% | 4.9% | 1.9% | 4.04% | 2.3% | 4.43% | - | - | S1 | Note 1, Note 11 |
| ZTE | 4.77% | 9.54% | 3.03% | 6.06% | 2.94% | 5.87% | - | - | S1 | Note 1, Note 6 |
| vivo | - | 8.99% | - | 7.02% | - | 6.87% | - | - | S2 | Note 1, Note 12 |
| - | 9.58% | - | 7.56% | - | 6.89% | - | - | S2 | Note 12, Note 13 |
| Samsung | 4.50% | 6.90% | 2.70% | 4.20% | 2.50% | 3.90% | 3.50% | 5.30% | S3 |  |
| MediaTek | 2.64% | 4.83% |  |  |  |  | 2.67% | 5.30% |  | Note 2, Note 15 |
| 0.88% | 1.76% |  |  |  |  | 0.83% | 1.65% |  | Note 2, Note 16 |
| Note 1: Same slot scheduling.  Note 2: Cross-slot scheduling.  Note 3: 1-layer transmission, 1 packet requires 1 PDSCH for Heartbeat traffic model; 1 packet requires 24 PDSCHs for IM model, assuming cell center UE.  Note 4: ‘S1’ represents Scheme#1, ‘S2’ represents Scheme#2, ‘S3’ represents Scheme#3  Note 5: DL (50%) + UL (50%)  Note 6: DL-only  Note 7: slots "DDDU",  Note 8: The blocking rate in Table 9 is assumed for corresponding cases.  Note 8A: BD reduction with the same DCI size budget.  Note 8B: BD reduction by reducing DCI size budget.  Note 9 : Wake-Up Signal (WUS)  Note 10: TDD: DDDDDDDSUU  Note 11: TDD: DDDSUDDSUU  Note 12:  Note 13: Multi-slot scheduling  Note 14A: UE can only transit to micro sleep in connected mode.  Note 14B: UE can transit to micro sleep, light sleep and deep sleep in connected mode according to the sleep duration.  Note 15: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot  Note 16: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots | | | | | | | | | | |

The Table 2/3 were revised to reflect the following comments:

* Update with latest results or Notes. [Vivo, Huawei, Samsung, Intel, MediaTek]
* Remove the ‘Note 3’. [Huawei, Intel, MediaTek]

**[FLS3] Proposal 8.2.2.1-1: Incorporate the revised Table 2 and Table 3 into text proposal for the Redcap TR 38.875 at least for scheme #1.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Vivo |  | We added more results for scheme#1, i.e BD reduction by size budget reduction (decoupling configuration of DCI 0\_1 and 1\_1) as in the following table. The results are from our contribution R1-2007669. We also uploaded these results in the excel sheet [RedCapPower-v019-MTK-vivo.xlsx](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_103-e/Inbox/drafts/8.6/EvaluationResults/RedCapPower/RedCapPower-v019-MTK-vivo.xlsx) |
| Table 2: Power Saving gain, FR1, 1 Rx antenna, Revised   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Company | IM traffic model | | Heartbeat traffic model | | | | VoIP traffic model | | Schemes (Note 4) | Notes | | Case 1 | Case 2 | Inactivity timer (IAT) = 200ms | | IAT = 80ms | | Case 1 | Case 2 | | Case 1 | Case 2 | Case 1 | Case 2 | | vivo | 3.54% | 7.08% | 2.29% | 4.59% | 2.13% | 4.25% | 2.85% | 5.70% | S1 | Note 1 | | 3.13% | 4.77% | 1.95% | 2.98% | 1.80% | 2.75% | 2.47% | 3.76% | S1 | Note 2 | |  |  |  |  |  |  | 3.80% | 5.70% | S1 | Note 17 |   Note 17: Size budget reduction by decoupling the configuration of DCI format 0\_1 and 1\_1, VOIP like DL only traffic  Table 3: Power Saving gain, FR1, 2 Rx antenna, Revised   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Company | IM traffic model | | Heartbeat traffic model | | | | VoIP traffic model | | Schemes (Note 4) | Notes | | Case 1 | Case 2 | Inactivity timer (IAT) = 200ms | | IAT = 80ms | | Case 1 | Case 2 | | Case 1 | Case 2 | Case 1 | Case 2 | | vivo | 3.54% | 7.08% | 2.29% | 4.59% | 2.13% | 4.25% | 2.85% | 5.70% | S1 | Note 1 | | 3.13% | 4.77% | 1.95% | 2.98% | 1.80% | 2.75% | 2.47% | 3.76% | S1 | Note 2 | |  |  |  |  |  |  | 4.60% | 6.89% | S1 | Note 17 |   Note 17: Size budget reduction by decoupling the configuration of DCI format 0\_1 and 1\_1, VOIP like DL only traffic | | |
| OPPO | Y | We have agreements in the last GTW：   * Determine the Xx (smallest power saving gain)-Yy (largest power saving gain) value based on the smallest and largest values reported by each company at least considering:   + Separate observations with corresponding Xx-Yy values are captured at least for cross-slot and same slot scheduling cases.   + Separate observations for FR1 & FR2   To minimize the number of observations, we consider 2 more separation:  1. The Scheme #1a for power BD limit solutions Vs. Scheme #1b DCI size budget reduction.  2. The DL only power saving vs. DL + UL power saving.  Further for the separation no.1, to our understanding the most of companies evaluation is based on S1a. Essentially, the simulations are different. For S1a, you simply reduced the number of DB base on the power scaling of 38.840. For S1b, it should be further reported by companies that how to achieve 25% and 50% reduction by specific DCI budget reduction. How can a UE reduce 50 of BD by remove 1 DCI size budget. It should be based on some specific PDCCH candidate configuration. Then the corresponding traffic model generation can be done.  In short the S1b, is originally S1 with note 8a. Companies can further clarify if their results is S1b. Now seems HW and vivo have S1b. OPPO only provide S1a.  For the separation no.2, we are also fine to separate. But if there is too few samples, it may not be representative. Note, we mostly simulation DL only for power saving study.  Also related to the pending TP, we suggest to define S1b and S1a separated. They are different in terms of gains, complexity, spec. impact. |
|  |  |  |
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**Summary of Observations:**

The power saving gain evaluation results reported by different source companies were provided in Table 2~7 for 1 Rx and 2 Rx configurations, respectively. For a given traffic model, the evaluation results of power saving gain depend on the exact simulation assumption used by different companies including TDD UL/DL configuration, cross-slot scheduling etc.

**Instant Message (IM) traffic model:**

* P1 [6]: Up to 8.44% and 12.66% power saving gain can be obtained by adopting 50% and 75% reduction in BD respectively, for 2RX and same slot scheduling configuration of IM traffic model.
* P2 [7]: For instant message, power saving gain at approximately 25%~50% BD reduction is 4.27%~13.35.

**Heartbeat traffic model:**

* P3 [2]: For the heartbeat traffic, the power saving gain by reduced number of BDs is negligible.
* P4 [4]: For the heartbeat traffic model, due to the low mean inter-arrival time, small packet size as well as long C-DRX cycle, little power saving gain is obtained.
* P5 [10]: Approximately 4% and 8% power saving gain is observed for FR1 and FR2, respectively, when number of PDCCH candidates is reduced by half for heartbeat traffic model.
* P6 [7]: For heartbeat, power saving gain at approximately 25%~50% BD reduction is 5.37%~10.81%.

**VoIP traffic model**

* P7 [4]: When BD reduction with the same DCI size budget is considered, the number of outage UEs would be increased due to the higher PDCCH blocking rate.
* P8 [10]: Approximately 6% and 9-10% power saving gain is observed for FR1 and FR2, respectively, when number of PDCCH candidates is reduced by half for IM traffic model, assuming cell center UE.

**General for all traffic models**

* P9 [2]: The power saving is less for the UL+DL case compared to the DL-only case.
* P10 [2]: With a 25% BD reduction in FR1, the power saving can vary between 0.01% to 1.5% for the different considered traffic models.
* P11 [2]: With a 50% BD reduction in FR1, the power saving can vary between 0.01% to 2.8% for the different considered traffic models.
* P12 [4]: The power saving gain is about 2% and 6% for the instant message traffic model and VoIP traffic model respectively.
* P13 [4]: By reducing 50% PDCCH candidates with unreduced DCI size budget, the average PDCCH blocking rate is increased by about 40% and 20% for RedCap UEs using 2RX and 1RX respectively for reception when the simultaneously scheduled UE number are 10.
* P14 [4]: Support BD reduction by reducing the DCI size budget, which are observed by evaluation to be with no or little constraint on scheduling flexibility, lower PDCCH blocking rate and attractive power saving gain for RedCap UE.
* P15 [4]: The system impact and user experience degradation due to the reduction of BD would be more significant for UE using 1 Rx compared with UE using 2Rx for reception.
* P16 [4]: For UEs using 2Rx for reception, the average PDCCH blocking rate increases by about 170% when the simultaneously scheduled UEs are increased from 5 to 10.
* P17 [4]: For UEs using 2Rx for reception, the average PDCCH blocking rate increases by about 35% when the DCI size (not including CRC) is increased from 40 bits to 60 bits.
* P18 [6]: By reducing the maximum number of BDs per slot, the 2RX RedCap UEs can obtain more power saving gain than 1RX UEs, and there is more power saving gain due to BD reduction for UEs configured with same-slot scheduling, than cross-slot scheduling.
* P19 [6]: Depending on the scenarios, there can be 4%~15% power saving gain by PDCCH BD reduction.
* P20 [6]: To achieve same effective BD reduction, extended PDCCH monitoring span gap to multiple slots can provide slightly more power saving gain than only reduce the BD budget per slot.
* P21 [6]: On top of extended PDCCH monitoring span gap to multiple slots, allowing multiple TBs scheduling in a monitoring occasion can provide additional power saving gain and throughput gain.
* P22 [13]: Reducing the number of blind decoding candidates by 50% (from 36 to 18) for the 3 traffic models evaluated with the FR1, TDD, 2Rx configuration, yield a power saving in the range of 7-10%.
* P23 [13]: In the real world, power savings are likely to be less than 5% due to other ongoing UE processes (e.g. RRM measurements) and other overlapping search spaces, reducing the actual maximum number of usable blind decodes.
* P24 [13]: In the real deployments, optimization of existing configuration options, like the inactivity timer, can yield significant UE power savings without the drawback of increased blocking probability.
* P25 [13]: using the WUS with the maximum number of blind decodes (36) for the 3 traffic models evaluated with the FR1, TDD, 2Rx configuration, yields a power saving in the range of 10-40% without the drawback of increased blocking probability.
* P26 [15]: The power saving gain by reducing the number of BD by half is approximately 6%~14% for different traffic mode.
* P27 [17]: For FR1, PDCCH monitoring reduction of 25% can achieve about ~4.5%, ~3%, and ~3.5% power saving gain for IM, Heartbeat, and VoIP, respectively
* P28 [17]: For FR1 PDCCH monitoring reduction of 50% can achieve about ~8%, ~5%, and ~6% power saving gain for IM, Heartbeat, and VoIP, respectively
* P29 [17]: For both FR1 and FR2, dynamic adaptation on PDCCH monitoring triggered by scheduling DCI format achieves same power saving gain as fixed reduction of PDCCH monitoring.
* P30 [21]: For FR1 TDD with 2 Rx configuration, reducing the number of PDCCH blind decoding candidates by half can achieve power saving gain up to ~10.1% and ~6.6% for IM traffic and heartbeat traffic, respectively.
* P31 [21]: For FR1 TDD with 1 Rx configuration, reducing the number of PDCCH BD candidates by half can achieve power saving gain up to ~8.9% and ~5.3% for IM traffic and heartbeat traffic, respectively.
* P32 [22]: With the existing mechanisms in NR that can be used for power saving, the impact of the configured (or supported) PDCCH candidates on the power consumption is marginal.

Based on the evaluations results in Table 2~7 and observations from companies, the following observations are proposed to discuss for power saving gain for the text proposal to Redcap TP:

|  |
| --- |
| **Observation**  For the instant message traffic model, power saving gains by reducing 25% and 50% blind decoding (i.e. Scheme #1) are in the range of approximately [X1%~Y1%] and [X2%~Y2%] with same slot scheduling for the 1 Rx and 2 Rx cases, respectively. With cross-slot scheduling, the achievable power saving gains by reducing 25% and 50% BDs in Scheme #1 for instant message traffic model are varied between X3 to Y3 and between X4 to Y4 for the 1 Rx and 2 Rx cases, respectively.  For the VoIP traffic model, power saving gains by reducing 25% and 50% blind decoding (i.e. Scheme #1) are in the range of approximately [X5%~Y5%] and approximately [X6%~Y6%] with same slot scheduling for the 1 Rx and 2 Rx cases, respectively. With cross-slot scheduling, the achievable power saving gains by reducing 25% and 50% BDs in Scheme #1 for VoIP traffic model are varied between X7 to Y7 and between X8 to Y8 for the 1 Rx and 2 Rx cases, respectively.  For the Heartbeat traffic model, power saving gains by reducing 25% and 50% blind decoding (i.e. Scheme #1) are in the range of approximately [X9%~Y9%] and approximately [X10%~Y10%] with same slot scheduling for the 1 Rx and 2 Rx cases, respectively. With cross-slot scheduling, the achievable power saving gains by reducing 25% and 50% BDs in Scheme #1 for VoIP traffic model are varied between X11 to Y11 and between X12 to Y12 for the 1 Rx and 2 Rx cases, respectively. |

The following was agreed in the Wednesday Moring GTW session in RAN1 #103 e-meeting:

|  |
| --- |
| Agreements:   * Determine the Xx (smallest power saving gain)-Yy (largest power saving gain) value based on the smallest and largest values reported by each company at least considering:   + Separate observations with corresponding Xx-Yy values are captured at least for cross-slot and same slot scheduling cases.   + Separate observations for FR1 & FR2   + Additonal cases for separate observations * Capture average/mean value of Xx-Yy excluding the smallest and the largest values among companies. * Explicitly mention the result/observations if it was provided by a few source companies e.g. 1 or 2 with special setup or assumptions. * Highlighting the gain is compared to the UE with configuring the maximum blind decoding for PDCCH monitoring defined in Rel-15/Rel-16 |

**Q 8.2.2.1-1: Whether additional case(s) need to be considered for separate observations of power saving gains? If yes, please provide detailed information.**

* Note that it may result in reduced source companies for each case if the results are split too much.
* If additional separation is needed, each company needs to provide the corresponding evaluation assumptions. As one example, if power saving gains for different UL/DL configuration are separated, UL/DL configuration information needs to be collected to determine the Xx/Yy values**.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| vivo | N | We think the it is sufficient to separate observations for cross-slot/same-slot and FR1/FR2. |
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**Q 8.2.2.1-2: What other aspects (e.g. above listed <P1, …, P32>) need to be added into text proposal for the TR 38.875?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| LG | Above listed will be fine except for P21. |
|  |  |
| Qualcomm | In addition, it would be necessary to note that very diverse results are observed for heartbeat traffic. In our evaluation [24], we assumed after 10sec without any traffic, the UE enters idle mode. Then duty cycle for UE in connected mode is low and power saving gain for PDCCH BD reduction is small. For this, we propose to add the following to heartbeat power evaluation   * Px [24]: For the heartbeat traffic, if the UE enters idle mode after 10sec without any traffic, duty cycle for UE to stay in connected mode is low and power saving gain for PDCCH BD reduction is limited. |
| Futurewei | Other observations, if included, should be quantitative. The qualitative observations should be discarded |
| Ericsson | P3, P4, P9, P10, P11 and P18 should be captured.  For P10 and P11, we propose the following clarification:   * P10 [2]: With a 25% BD reduction in FR1, the power saving can vary between 0.01% to 1.5% for the different considered traffic models, with 50% traffic in DL and 50% traffic in UL. * P11 [2]: With a 50% BD reduction in FR1, the power saving can vary between 0.01% to 2.8% for the different considered traffic models, with 50% traffic in DL and 50% traffic in UL.   In our view, it is also very important to capture that the same power saving gain as Scheme #1 can already be achieved by proper configuration by the network using existing Rel-15/16 configuration parameters. |
| OPPO | We also observed in the update contribution R1-2008894 that:  For same-slot scheduling, the power saving gain by BD reduction is slightly higher than that for cross-slot scheduling. However, the gain will be consistently achieved on top of the power efficiency by cross-slot scheduling.  This can be synthesized as that significant power saving gain over existing power saving techs can be observed in the BD reduction of 25% and 50%. Note we simulated WUS and BWP. |

### 8.2.2.2 FR2 Results

Table 4: Power Saving gain, FR2, 1 Rx antenna, Revised

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | IM traffic model | | Heartbeat traffic model | | | | VoIP traffic model | | Scheme  (Note 4) | Notes |
| Case 1 | Case 2 | IAT = 200ms | | IAT = 80ms | | Case 1 | Case 2 |
| Case 1 | Case 2 | Case 1 | Case 2 |
| Ericsson | 1.94% | 3.59% | 0.03% | 0.07% | 0.03% | 0.06% | 2.52% | 4.66% | S1 | Note 1 Note 5 |
| 1.40% | 2.70% | 0.02% | 0.04% | 0.02% | 0.04% | 1.94% | 3.60% | S1 | Note 2 Note 5 |
| 4.37% | 8.10% | 0.04% | 0.08% | 0.04% | 0.07% | 4.66% | 8.64% | S1 | Note 1 Note 6 |
| 3.65% | 6.76% | 0.03% | 0.06% | 0.03% | 0.05% | 3.94% | 7.31% | S1 | Note 2  Note 6 |
| Samsung | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S1, S2 | Note 2  Note 6 |
| 6.30% | 12.70% | 4.20% | 8.30% | 3.90% | 7.60% | 6.50% | 13.10% | S3 | Note 2  Note 6 |
| CATT | 4.53% | 9.07% | 2.97% | 5.93% | 2.75% | 5.50% | 2.88% | 5.76% | S1 | Note 1 |
| Spreadtrum | 6.60% | 13.10% | 4.30% | 8.60% | 4.00% | 7.90% | 5.00% | 9.40% | S1 | Note 1 |
| Futurewei | 4.40% | 8.70% | 2.00% | 1.00% | 0.50% | 1.10% | 3.90% | 7.90% | S1 | Note 1 |
| Intel | 5.48% | 10.62% | 4.78% | 7.94% | 3.36% | 6.6% |  |  | S1 | Note 1  Note 7 |
| ZTE | 5.76% | 11.52% | 3.55% | 7.11% | 3.09% | 6.18% |  |  | S1 | Note 1 Note 6 |
| MediaTek | 3.61% | 6.81% |  |  |  |  | 3.80% | 7.55% | S1 | Note 2, Note 8 |
| 1.96% | 3.92% |  |  |  |  | 2.06% | 4.12% | S1 | Note 2, Note 9 |
| Note 1: Same slot scheduling.  Note 2: Cross-slot scheduling.  Note 4: ‘S1’ represents Scheme#1, ‘S2’ represents Scheme#2, ‘S3’ represents Scheme#3  Note 5: DL (50%) + UL (50%)  Note 6: DL-only  Note 7: TDD: DDDSUDDDSU  Note 8: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot  Note 9: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots | | | | | | | | | | |

Table 5: Power Saving gain, FR2, 2 Rx antenna, Revised

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | IM traffic model | | Heartbeat traffic model | | | | VoIP traffic model | | Scheme  (Note 4) | Notes |
| Case 1 | Case 2 | IAT = 200ms | | IAT = 80ms | | Case 1 | Case 2 |
| Case 1 | Case 2 | Case 1 | Case 2 |
| Ericsson | 2.45% | 4.54% | 0.04% | 0.10% | 0.04% | 0.09% | 3.10% | 5.74% | S1 | Note 1 Note 5 |
| 1.89% | 3.50% | 0.03% | 0.07% | 0.03% | 0.06% | 2.45% | 4.54% | S1 | Note 2 Note 5 |
| 4.84% | 8.96% | 0.06% | 0.11% | 0.05% | 0.10% | 5.13% | 9.51% | S1 | Note 1 |
| 4.12% | 7.64% | 0.04% | 0.08% | 0.04% | 0.07% | 4.44% | 8.22% | S1 | Note 2  Note 6 |
| Samsung | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S1,S2 | Note 2  Note 6 |
| 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S3 | Note 2  Note 6 |
| CATT | 4.81% | 9.61% | 3.34% | 6.68% | 3.12% | 6.06% | 3.19% | 6.39% | S1 | Note 1 |
| Spreadtrum | 6.80% | 13.60% | 4.90% | 11.90% | 4.60% | 9.20% | 5.50% | 10.50% | S1 | Note 1 |
| Futurewei | 4.60% | 9% | 1.10% | 2.10% | 0.50% | 1.00% | 4.50% | 8.90% | S1 | Note 1 |
| Intel | 4.43% | 9.73% | 4.2% | 7.80% | 4.57% | 8.74% | - | - | S1 | Note 1 Note7 |
| ZTE | 6.01% | 12.03% | 4.03% | 8.07% | 3.64% | 7.29% | - | - | S1 | Note 1  Note 6 |
| MediaTek | 3.63% | 6.86% |  |  |  |  | 3.72% | 7.39% | S1 | Note 2, Note 8 |
| 1.96% | 3.91% |  |  |  |  | 1.97% | 3.95% | S1 | Note 2, Note 9 |
| Note 1: Same slot scheduling.  Note 2: Cross-slot scheduling.  Note 4: ‘S1’ represents Scheme#1, ‘S2’ represents Scheme#2, ‘S3’ represents Scheme#3  Note 5: DL (50%) + UL (50%)  Note 6: DL-only  Note 7: TDD: DDDSUDDDSU  Note 8: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot  Note 9: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots | | | | | | | | | | |

**Proposal 8.2.2.2-1: Incorporate the above Table 4 and Table 5 into text proposal in the Redcap TR for FR2. If not, what changes to the Tables are needed in order to add into Redcap TR? Please comment Table by Table. If concerns on results from specific source(s) to be captured in TR 38.875, please explicitly comment with reasoning in ‘comments’ column.**

* Note that, similarly like FR1 results, separate tables for scheme 2/3 were merged into Table 4/5 based on comments received in morning GTW session.

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| CATT | Y |  |
| LG | Y | We are okay with the tables. |
| Huawei, HiSilicon |  | 1. We are confused by noting the 1 layer transmission as simulation assumption in Note3. It shall not impact the power saving evaluation at all considering it is already assumed that “1 packet requires 1 PDSCH for Heartbeat traffic model; 1 packet requires 24 PDSCHs for IM model, assuming cell center UE”. We propose delete the ‘1-layer transmission,’ to avoid the confusion. 2. Similar comments as that for Proposal 8.2.1-1, Scheme#3 are not in the study scope. We don’t think they can be captured in table 4 and table 5. |
| Spreadtrum | Y |  |
| Panasonic |  | Depending on the conclusion of Proposal 8.2.1-1, Scheme#3 may need to be removed from Tables 4 and 5. |
| Shapr | Y |  |
| Samsung | Y | We make the following updates highlighted in red on our results in Table 4 and Table 5.  **For Table 4:**   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Samsung | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S1, S2 | Note 2, Note 6 | | 6.30% | 12.70% | 4.20% | 8.30% | 3.90% | 7.60% | 6.50% | 13.10% | S3 | Note 2, Note 6 |   For Table 5:   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Samsung | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S1, S2 | Note 2, Note 6 | | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S3 | Note 2, Note 6 | |
| Nokia | Y |  |
| Qualcomm | Y |  |
| MediaTek | Y, with modification | 1. The table should be updated with the latest results. 2. Scheme#3 should be removed. This schemes is not supported in NR, so can’t be considered as baseline, and it is not in the SI scope. 3. It is not clear to us what “Note 3: 1-layer transmission” means. |
| InterDigital | Y |  |
| Fraunhofer | Y |  |
| Futurewei | Y | If S1 only listed, S2 and S3 results should be removed |
| Ericsson | Y (partially) | In Table 4 and table 5, we should not capture schemes other than #1, as they have not adequately studied, nor are they in the study item scope. |
| Intel | Y | We have added some new results which are uploaded to evaluation results draft folder and are also reflected in the tables above. Fine to remove ‘1 layer transmission’ from Note 3 |
| DOCOMO | Y | S3 may be removed depending on the conclusion of Proposal 8.2.1-1 |
| OPPO | Y | Only SI |
| ZTE | Y | Similar with DOCOMO, whether to remove S2/S3 depends on the conclusion of Proposal 8.2.1-1 |

**Summary of 1st round email discussions**

Similar as FR1 results, all responses agree to capture the results in Table 4/5 for Scheme#1 into TR with modifying some evaluation results or notes.

Companies views regarding the results of Scheme #3 are summarized in Table below:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Description | Companies | # of companies |
| Option 1 | Not include results of Scheme #3 or FFS | Huawei, HiSilicon, MediaTek, Ericsson, OPPO | 5 |
| Option 2 | Include all | CATT, LG, Spreadtrum, Sharp, Samsung, Nokia, Qualcomm, InterDigital, Fraunhofer, Intel | 10 |
| Option 3 | Depending on outcome of section 8.2.1 | Panasonic, Futurewei, DoCoMo, ZTE | 4 |

The Table 4/5 were revised to reflect the following comments:

* Update with latest results or Notes. [Samsung, Intel, MediaTek]
* Remove the ‘Note 3’. [Huawei, Intel, MediaTek]

**FL proposal: Incorporate the revised Table 4 and Table 5 into text proposal for the Redcap TR 38.875 at least for scheme #1.**

**Discussion Point:**

* How to handle the FR1 evaluation results for Scheme #2/3 in Table 4/5?

**Observations**

For FR2, the power saving gain evaluation results for Scheme #1 reported by different source companies were provided in Table 8 ~11 for 1 Rx and 2 Rx configurations, respectively. The following was observed based on companies contributions:

* P1 [2]: With a 25% BD reduction in FR2, the power saving can vary between 0.02% to 3.1% for the different considered traffic models.
* P2 [2]: With a 50% BD reduction in FR2, the power saving can vary between 0.04% to 5.7% for the different considered traffic models.
* P3 [17]: For FR2, PDCCH monitoring reduction of 25% can achieve about ~6.5%, ~4%, and ~7% power saving gain for IM, Heartbeat, and VoIP, respectively
* P4 [17]: For FR2, PDCCH monitoring reduction of 50% can achieve about ~13%, ~9%, and ~13.5% power saving gain for IM, Heartbeat, and VoIP, respectively

Q 8.2.2.2-1: **Which of list above (P1, P2, P3, P4) can be incorporated into text proposal in the Redcap TR for the PDCCH blocking performance impacts of reduced PDCCH monitoring? what other aspects need to be added?**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | | **Comments** | |
| LG | | P1, P2 | |
| Nokia | | P1, P2 --- should the question be rephrased? PDCCH power saving instead of PDCCH blocking performance? | |
| Qualcomm | | These are just observations from different company results. It should be ok to capture. | |
| MediaTek | | Please see our answer to “Q 8.2.2.1-1” | |
| Futurewei | | These observations are company-specific. It would be better to list RAN1 observations based on all results such as: “With a 25% BD reduction in FR2 and 1 antenna, the power saving can vary between 0.02% to 4.3% for heartbeat traffic” | |
| Ericsson | P1 and P2 should be captured.  For P1 and P2, we propose the following update to reflect the values we reported in the template.   * P1 [2]: With a 25% BD reduction in FR2, the power saving can vary between 0.02% to 3.1% for the different considered traffic models, with 50% traffic in DL and 50% traffic in UL. * P2 [2]: With a 50% BD reduction in FR2, the power saving can vary between 0.04% to 5.7% for the different considered traffic models, with 50% traffic in DL and 50% traffic in UL.   The observations P3, P4, P9 and P18 for FR1 (in Q 8.2.2.1-2) is also applicable to FR2.  In our view, it is also very important to capture that the same power saving gain as Scheme #1 can already be achieved by proper configuration by the network using existing Rel-15/16 configuration parameters.  Agree with Nokia. The question should be on power saving, instead of PDCCH blocking performance. | |
| Intel | If the question was intended to be as in **Q 8.2.2.1-1 (i.e., regarding power saving gains in FR2)**, then the range can be defined similarly as in above response for FR1, for a given assumption on % of PDCCH monitoring. | |
| DOCOMO | P1, P2 | |
| OPPO | Significant power saving gain over existing power saving techs can be observed in the BD reduction of 25% and 50%. Note we simulated WUS and BWP. | |
| ZTE | Any of P1,P2,P3, P4 is not preferred for us.  Regarding the P1 and P2, for FR2 with 50% BD reduction in P2, 0.04% means the PDCCH part power only has little impact with the portion no less than 0.3%(0.04/0.15=0.26<0.3). We do not think it is a common scenario.  Regarding the P3 and P4, it is just a simulation result in a specific scenario, which cannot cover most of the simulation results.  Therefore, it is preferred to adopt the similar description with FR1 (Xx,Yy). More specifically, a range for IM, heartbeat and VoIP should be used to cover most of the simulation results. | |

## 8.2.3 Analysis of performance impacts

The performance impacts study evaluation includes impacts of PDCCH blocking probability, latency and scheduling flexibility.

### 8.2.3.1 PDCCH Blocking probability

The PDCCH blocking probability is defined as the probability that all PDCCH candidates for a UE are blocked/overlapped with candidates used by other UEs, which is ratio between the number of the blocked UEs over the number of all UEs that need to be scheduled.

Many contributions pointed out that PDCCH blocking probability depends on various factors.

* CORESET size
* DCI format sizes
* Number of UEs needs to be scheduled simultaneously in a MO (this depends on traffic model)
* Aggregation Level (AL) distributions for AL [1,2,4,8,16].
* Number of PDCCH candidates

These factors should be carefully considered for PDCCH blocking probability analysis to ensure meaningful findings were used for Redcap devices study, taking into account the unique characteristic of Redcap devices e.g. light load, relaxed latency etc.

In the post email thread [102-e-Post-NR-RedCap-01], the following was agreed as evaluation assumptions for PDCCH blocking probability evaluation:

**Table 5 : Baseline parameters for the PDCCH blocking rate evaluation**

|  |  |
| --- | --- |
| **Parameters** | **Assumptions** |
| SCS/BW | FR1: 30KHz/20MHz; 15kHz/20MHz is optional FR2: 120KHz/[100]MHz |
| CORESET duration | 2 symbols, with 3 symbols optional |
| DCI size | 40 bits (Not including CRC) |
| Delay toleration (Slot) | 1 (1: implies that PDCCH is blocked if it can’t be scheduled in the given slot), with 2 optional |
| Note 1: “Number of users” represents the number of UEs that need to be scheduled simultaneously in a slot and and company can provide PDCCH blocking probabilities corresponding to a range of ‘number of users’ on different rows in Tab-7 | |

Contribution [6] studied the percentage of number of UE scheduled per slot for Uma (2.6GHz) scenario. The results were reported as follows. It was observed in [6] that the number of simultaneously scheduled UEs per slot is no more than 3 in nearly 99.6% cases, rarely 4 or 5 in the simulated case.

Table 6: Percentage of number of UE scheduled per slot for Uma (2.6GHz) scenario [6].

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Percentage of number of UE scheduled per slot** | **Number of scheduled UE per slot** | | | | | **System blocking probability**  **When the total CCE number is 16 (i.e. 30KHz and 2-symbol PDCCH) and 50% BD reduction** |
| 0 | 1 | 2 | 3 | 4 |
| Medium Loading (N=12, M=0), 1 Rx RedCap | 52.4% | 37.6% | 7.8% | 1.8% | 0.4% | 0.400% |
| Medium Loading (N=12, M=4), 1 Rx RedCap | 48.3% | 41.1% | 8.2% | 1.9% | 0.4% | 0.419% |
| Medium Loading (N=12, M=12), 1 Rx RedCap | 43.2% | 44.9% | 9.3% | 2.0% | 0.4% | 0.464% |
| Medium Loading (N=12, M=0), 2 Rx RedCap | 53.2% | 37.3% | 7.5% | 1.6% | 0.3% | 0.372% |
| Medium Loading (N=12, M=4), 2 Rx RedCap | 50.4% | 39.5% | 7.8% | 1.8% | 0.4% | 0.400% |
| Medium Loading (N=12, M=12), 2 Rx RedCap | 43.5% | 44.4% | 9.3% | 2.2% | 0.5% | 0.481% |

The following PDCCH AL distributions of AL [1,2,4,8,16] were evaluated by companies in Phase 2 of email thread [102-e-Post-NR-RedCap-01]:

Table 7: PDCCH AL distributions of AL [1,2,4,8,16], FR1 and FR2

|  |
| --- |
| PDCCH AL distributions of AL [1,2,4,8,16] |
| * Configuration 1 (C1): [0.5, 0.4, 0.05, 0.03, 0.02], assuming majority of the UEs are in is good coverage * Configuration 2 (C2): [0.1, 0.2, 0.4, 0.2, 0.1]: Majority of the UEs are in medium coverage * Configuration 3 (C3): [0.05, 0.05, 0.2, 0.3, 0.4]: Majority of the UEs are in poor coverage * Configuration 4 (C4): [0.3 0.5 0.1 0.06 0.04] * Configuration 5 (C5): [0.4 0.45 0.08 0.04 0.03] * Configuration 6 (C6): [0.2 0.55 0.14 0.06 0.05] * Configuration 7 (C7): [0.4 0.3 0.2 0.05 0.05] |

In addition, a set of number of PDCCH candidates for AL [1,2,4,8,16] were evaluated as summarized In Table 8:

Table 8: Number of PDCCH Candidates for AL [1,2,4,8,16]

|  |  |  |  |
| --- | --- | --- | --- |
|  | Without BD reduction | Approximately 25% reduction in BDs | Approximately 50% reduction in BDs |
| FR1 | * Configuration 1: [6, 6, 2, 2, 2] * Configuration 2: [6, 5, 4, 2, 1] * Configuration 3: [6, 4, 4, 2, 2] * Configuration 4: [18, 0, 0, 0, 0], [0, 9, 0, 0, 0], [0, 0, 4, 0, 0], [0, 0, 0, 2, 0], [0, 0, 0, 0, 1] * Configuration 5: [6, 6, 2, 2, 1] * Configuration 6: [16, 8, 4, 2, 1] * Configuration 7: [8, 6, 2, 2, 2] * Configuration 8: [2, 4, 8, 4, 2] * Configuration 9: [2, 2, 4, 6, 8] * Configuration 10 [16,14,8,4,2] | * Configuration 1: [5, 5, 1, 1, 1] * Configuration 2: [4, 3, 3, 2, 1] * Configuration 3: [6, 4, 1, 1, 1] * Configuration 4: [2, 4, 4, 2, 1] * Configuration 5: [1, 4, 4, 2, 2] * Configuration 6: [4, 4, 2, 2, 1] * Configuration 7: [13, 0, 0, 0, 0], [0, 9, 0, 0, 0], [0, 0, 4, 0, 0], [0, 0, 0, 2, 0], [0, 0, 0, 0, 1] * Configuration 8: [5,3,3,1,1] * Configuration 9: [11, 8, 2, 1, 1] * Configuration 10: [5, 4, 2, 2, 2] * Configuration 11: [1, 3, 7, 3, 1] * Configuration 12: [1,1,4,4,6] * Configuration 13: [13,11,6,2,1] * Configuration 14: [5 3 2 2 1] | * Configuration 1: [3, 3, 1, 1, 1] * Configuration 2: [3, 2, 2, 1, 1] * Configuration 3: [5, 1, 1, 1, 1] * Configuration 4: [1, 2, 4, 1, 1] * Configuration 5: [1, 1, 3, 2, 2] * Configuration 6: [9, 0, 0, 0, 0], [0, 9, 0, 0, 0], [0, 0, 4, 0, 0], [0, 0, 0, 2, 0], [0, 0, 0, 0, 1] * Configuration 7: [6 6 2 2 1] * Configuration 8: [8 4 1 1 1] * Configuration 9: [4,3,1,1,1] * Configuration 10: [1,1,5,2,1] * Configuration 11: [1,1,2,3,4] * Configuration 12: [9, 8, 3, 1, 1] * Configuration 13: [2 2 2 2 1] |
| FR2 | * Configuration 1: [4, 3, 1, 1, 1] * Configuration 2: [1,2,4,2,1] | * Configuration 1: [2, 2, 1, 1, 1] * Configuration 2: [3, 2, 0, 1, 1] * Configuration 3: [4, 3, 0, 0, 0] * Configuration 4: [1, 3, 1, 1, 1] * Configuration 5: [3, 2, 1, 1, 1] * Configuration 6: [1, 1, 3, 2, 1] | * Configuration 1: [1, 1, 1, 1, 1] * Configuration 2: [2, 2, 0, 0, 1] * Configuration 3: [4, 1, 0, 0, 0] * Configuration 4: [0, 3, 1, 1, 0] * Configuration 5: [0, 2, 1, 1, 1] |

Table 9 and Table 10A~10E summarized the evaluation results of PDCCH block probabilities on FR1 and FR2 for the following cases, which were provided in email thread [102-e-Post-NR-RedCap-01] or individual contribution for different number of UEs simultaneously scheduled by gNB in a slot:

* Case 1: Reference case with no reduction in BD limit.
* Case 2: Approximately 25% reduction in BD limit.
* Case 3: Approximately 50% reduction in BD limit.

#### **FR1 Results**

Table 9: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table 7 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table 8 | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table 8 | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table 8 | PDCCH blocking rate |  |
| Vivo | C1 | 2 | 2 | C1 | 2.02% | C1 | 3.52% | C1 | 3.59% |  |
| C1 | 3 | 2 | C1 | 3.56% | C1 | 5.03% | C1 | 5.08% |  |
| C1 | 4 | 2 | C1 | 4.82% | C1 | 6.39% | C1 | 7.01% |  |
| C1 | 5 | 2 | C1 | 5.94% | C1 | 7.64% | C1 | 9.42% |  |
| C1 | 1~5 | 2 | C1 | 0.25% | C1 | 0.41% | C1 | 0.41% | Note 1 |
| Ericsson | C1 | 3 | Up to 2 | C2 | 0.03 | C2 | 0.03 | C2 | 0.035 | Note 8 |
| C1 | 6 | Up to 2 | C2 | 0.06 | C2 | 0.07 | C2 | 0.09 | Note 8 |
| C2 | 3 | Up to 2 | C2 | 0.17 | C2 | 0.17 | C2 | 0.21 | Note 9 |
| C2 | 6 | Up to 2 | C2 | 0.4 | C2 | 0.42 | C2 | 0.46 | Note 9 |
| C3 | 3 | Up to 2 | C2 | 0.46 | C2 | 0.47 | C2 | 0.49 | Note 10 |
| C3 | 6 | Up to 2 | C2 | 0.66 | C2 | 0.67 | C2 | 0.69 | Note 10 |
| Qualcomm | C1 | 1 | 2 | C1 | 0 | C6 | 0 | C1 | 0 | Note 2 |
| C1 | 2 | 2 | C1 | 0.0042 | C6 | 0.0065 | C1 | 0.0081 | Note 2 |
| C1 | 3 | 2 | C1 | 0.01 | C6 | 0.013 | C1 | 0.0168 | Note 2 |
| C1 | 4 | 2 | C1 | 0.0162 | C6 | 0.0209 | C1 | 0.0287 | Note 2 |
| C1 | 5 | 2 | C1 | 0.0267 | C6 | 0.0327 | C1 | 0.0465 | Note 2 |
| C1 | 6 | 2 | C1 | 0.0355 | C6 | 0.0433 | C1 | 0.065 | Note 2 |
| C1 | 7 | 2 | C1 | 0.0469 | C6 | 0.0589 | C1 | 0.0872 | Note 2 |
| C1 | 8 | 2 | C1 | 0.064 | C6 | 0.0807 | C1 | 0.1152 | Note 2 |
| C1 | 9 | 2 | C1 | 0.0825 | C6 | 0.1037 | C1 | 0.143 | Note 2 |
| C1 | 10 | 2 | C1 | 0.106 | C6 | 0.1314 | C1 | 0.1736 | Note 2 |
| C1 | 1 | 2 | C4 | 0 | C7 | 0 | C6 | 0 | Note 3 |
| C1 | 2 | 2 | C4 | 0.0008 | C7 | 0.0008 | C6 | 0.0008 | Note 3 |
| C1 | 3 | 2 | C4 | 0.0048 | C7 | 0.0053 | C6 | 0.0055 | Note 3 |
| C1 | 4 | 2 | C4 | 0.0112 | C7 | 0.0117 | C6 | 0.0123 | Note 3 |
| C1 | 5 | 2 | C4 | 0.021 | C7 | 0.0216 | C6 | 0.0222 | Note 3 |
| C1 | 6 | 2 | C4 | 0.03 | C7 | 0.0304 | C6 | 0.0307 | Note 3 |
| C1 | 7 | 2 | C4 | 0.0403 | C7 | 0.0406 | C6 | 0.0411 | Note 3 |
| C1 | 8 | 2 | C4 | 0.0543 | C7 | 0.0549 | C6 | 0.0557 | Note 3 |
| C1 | 9 | 2 | C4 | 0.07 | C7 | 0.0704 | C6 | 0.0716 | Note 3 |
| C1 | 10 | 2 | C4 | 0.0895 | C7 | 0.09 | C6 | 0.0915 | Note 3 |
| C2 | 1 | 2 | C1 | 0 | C6 | 0 | C1 | 0 | Note 2 |
| C2 | 2 | 2 | C1 | 0.0393 | C6 | 0.0427 | C1 | 0.0938 | Note 2 |
| C2 | 3 | 2 | C1 | 0.1046 | C6 | 0.1119 | C1 | 0.1832 | Note 2 |
| C2 | 4 | 2 | C1 | 0.1735 | C6 | 0.1842 | C1 | 0.2572 | Note 2 |
| C2 | 5 | 2 | C1 | 0.2478 | C6 | 0.2625 | C1 | 0.3242 | Note 2 |
| C2 | 6 | 2 | C1 | 0.3212 | C6 | 0.3382 | C1 | 0.3893 | Note 2 |
| C2 | 7 | 2 | C1 | 0.3849 | C6 | 0.4037 | C1 | 0.4432 | Note 2 |
| C2 | 8 | 2 | C1 | 0.4437 | C6 | 0.4615 | C1 | 0.4919 | Note 2 |
| C2 | 9 | 2 | C1 | 0.4891 | C6 | 0.5074 | C1 | 0.5311 | Note 2 |
| C2 | 10 | 2 | C1 | 0.5321 | C6 | 0.5496 | C1 | 0.5666 | Note 2 |
| C2 | 1 | 2 | C4 | 0 | C7 | 0 | C6 | 0 | Note 3 |
| C2 | 2 | 2 | C4 | 0.0345 | C7 | 0.0345 | C6 | 0.0345 | Note 3 |
| C2 | 3 | 2 | C4 | 0.0807 | C7 | 0.0808 | C6 | 0.0809 | Note 3 |
| C2 | 4 | 2 | C4 | 0.1386 | C7 | 0.1388 | C6 | 0.1392 | Note 3 |
| C2 | 5 | 2 | C4 | 0.2107 | C7 | 0.2112 | C6 | 0.2117 | Note 3 |
| C2 | 6 | 2 | C4 | 0.2871 | C7 | 0.2879 | C6 | 0.2886 | Note 3 |
| C2 | 7 | 2 | C4 | 0.3583 | C7 | 0.3592 | C6 | 0.3598 | Note 3 |
| C2 | 8 | 2 | C4 | 0.4208 | C7 | 0.4218 | C6 | 0.4225 | Note 3 |
| C2 | 9 | 2 | C4 | 0.4725 | C7 | 0.4734 | C6 | 0.4743 | Note 3 |
| C2 | 10 | 2 | C4 | 0.5179 | C7 | 0.5189 | C6 | 0.5196 | Note 3 |
| C3 | 1 | 2 | C1 | 0 | C6 | 0 | C1 | 0 | Note 2 |
| C3 | 2 | 2 | C1 | 0.1851 | C6 | 0.1895 | C1 | 0.234 | Note 2 |
| C3 | 3 | 2 | C1 | 0.3551 | C6 | 0.3634 | C1 | 0.4001 | Note 2 |
| C3 | 4 | 2 | C1 | 0.4803 | C6 | 0.4909 | C1 | 0.5154 | Note 2 |
| C3 | 5 | 2 | C1 | 0.5679 | C6 | 0.5796 | C1 | 0.5966 | Note 2 |
| C3 | 6 | 2 | C1 | 0.6268 | C6 | 0.6395 | C1 | 0.654 | Note 2 |
| C3 | 7 | 2 | C1 | 0.6742 | C6 | 0.6882 | C1 | 0.6997 | Note 2 |
| C3 | 8 | 2 | C1 | 0.7093 | C6 | 0.723 | C1 | 0.7344 | Note 2 |
| C3 | 9 | 2 | C1 | 0.735 | C6 | 0.7483 | C1 | 0.759 | Note 2 |
| C3 | 10 | 2 | C1 | 0.757 | C6 | 0.77 | C1 | 0.7803 | Note 2 |
| C3 | 1 | 2 | C4 | 0 | C7 | 0 | C6 | 0 | Note 3 |
| C3 | 2 | 2 | C4 | 0.1794 | C7 | 0.1794 | C6 | 0.1794 | Note 3 |
| C3 | 3 | 2 | C4 | 0.3391 | C7 | 0.3392 | C6 | 0.3393 | Note 3 |
| C3 | 4 | 2 | C4 | 0.4624 | C7 | 0.4626 | C6 | 0.4629 | Note 3 |
| C3 | 5 | 2 | C4 | 0.5484 | C7 | 0.5489 | C6 | 0.5494 | Note 3 |
| C3 | 6 | 2 | C4 | 0.6076 | C7 | 0.6083 | C6 | 0.6089 | Note 3 |
| C3 | 7 | 2 | C4 | 0.6544 | C7 | 0.6552 | C6 | 0.656 | Note 3 |
| C3 | 8 | 2 | C4 | 0.6895 | C7 | 0.6905 | C6 | 0.6913 | Note 3 |
| C3 | 9 | 2 | C4 | 0.7151 | C7 | 0.7161 | C6 | 0.717 | Note 3 |
| C3 | 10 | 2 | C4 | 0.7366 | C7 | 0.7378 | C6 | 0.7389 | Note 3 |
| Nokia | C1 | 2 | 2 | C2 | 0.04 | C8 | 0.04 | C2 | 0.04 | Note 8 |
| C1 | 3 | 2 | C2 | 0.06 | C8 | 0.06 | C2 | 0.06 | Note 8 |
| C1 | 4 | 2 | C2 | 0.09 | C8 | 0.10 | C2 | 0.12 | Note 8 |
| C1 | 5 | 2 | C2 | 0.12 | C8 | 0.15 | C2 | 0.20 | Note 8 |
| C1 | 6 | 2 | C2 | 0.18 | C8 | 0.21 | C2 | 0.31 | Note 8 |
| C1 | 7 | 2 | C2 | 0.28 | C8 | 0.31 | C2 | 0.44 | Note 8 |
| C1 | 8 | 2 | C2 | 0.38 | C8 | 0.41 | C2 | 0.58 | Note 8 |
| C2 | 2 | 2 | C2 | 0.19 | C8 | 0.21 | C2 | 0.21 | Note 9 |
| C2 | 3 | 2 | C2 | 0.36 | C8 | 0.38 | C2 | 0.47 | Note 9 |
| C2 | 4 | 2 | C2 | 0.64 | C8 | 0.68 | C2 | 0.78 | Note 9 |
| C2 | 5 | 2 | C2 | 0.87 | C8 | 0.88 | C2 | 0.94 | Note 9 |
| C2 | 6 | 2 | C2 | 0.97 | C8 | 0.98 | C2 | 0.99 | Note 9 |
| C2 | 7 | 2 | C2 | 1.00 | C8 | 1.00 | C2 | 1.00 | Note 9 |
| Huawei, HiSilicon | C1 | 5 | Note 4 | C5 | 6.07% | - |  | C7 | 6.07% | Note 5 |
| C1 | 5 | 2 | C5 | 6.07% | C6 | 6.90% | C1 | 9.30% | Note 5 |
| C1 | 10 | Note 4 | C5 | 17.30% | - |  | C7 | 17.30% | Note 5 |
| C1 | 10 | 2 | C5 | 17.30% | C6 | 23.30% | C1 | 24.10% | Note 5 |
| C4 | 5 | Note 4 | C5 | 12.30% | - |  | C7 | 12.30% | Note 5 |
| C4 | 5 | 2 | C5 | 12.30% | C6 | 13.80% | C1 | 16.30% | Note 5 |
| C4 | 10 | Note 4 | C5 | 29.40% | - |  | C7 | 29.40% | Note 5 |
| C4 | 10 | 2 | C5 | 29.40% | C6 | 33.90% | C1 | 34.30% | Note 5 |
| InterDigital | C1 | 2 |  | C1 | 0.0196 | C1 | 0.0331 | C1 | 0.0343 |  |
| C1 | 3 |  | C1 | 0.0350 | C1 | 0.0508 | C1 | 0.0530 |  |
| C1 | 4 |  | C1 | 0.0467 | C1 | 0.0631 | C1 | 0.0704 |  |
| C1 | 5 |  | C1 | 0.0583 | C1 | 0.0732 | C1 | 0.0922 |  |
| C1 | 6 |  | C1 | 0.0719 | C1 | 0.0855 | C1 | 0.1176 |  |
| C1 | 7 |  | C1 | 0.0865 | C1 | 0.1005 | C1 | 0.1442 |  |
| C1 | 8 |  | C1 | 0.1082 | C1 | 0.1216 | C1 | 0.1762 |  |
| C1 | 9 |  | C1 | 0.1371 | C1 | 0.1506 | C1 | 0.2082 |  |
| C1 | 10 |  | C1 | 0.1726 | C1 | 0.1840 | C1 | 0.2423 |  |
| Intel | C1 | 2 | 1 | C6 | 1.9% | C9 | 1.9% | C8 | 1.9% |  |
| C1 | 4 | 1 | C6 | 6% | C9 | 6% | C8 | 6% |  |
| C1 | 8 | 1 | C6 | 20% | C9 | 20% | C8 | 20% |  |
| ZTE | C1 | 2 | 2 | C7 | 0.0201 | C10 | 0.0201 | C9 | 0.0421 |  |
| C1 | 4 | 2 | C7 | 0.0304 | C10 | 0.031 | C9 | 0.1079 |  |
| C1 | 6 | 2 | C7 | 0.0472 | C10 | 0.0487 | C9 | 0.1689 |  |
| C1 | 8 | 2 | C7 | 0.0731 | C10 | 0.0753 | C9 | 0.3551 |  |
| C2 | 2 | 2 | C8 | 0.095 | C11 | 0.0954 | C10 | 0.1004 |  |
| C2 | 4 | 2 | C8 | 0.247 | C11 | 0.2476 | C10 | 0.2716 |  |
| C2 | 6 | 2 | C8 | 0.3921 | C11 | 0.3942 | C10 | 0.4284 |  |
| C2 | 8 | 2 | C8 | 0.4945 | C11 | 0.496 | C10 | 0.5389 |  |
| C3 | 2 | 2 | C9 | 0.3199 | C12 | 0.3213 | C11 | 0.3223 |  |
| C3 | 4 | 2 | C9 | 0.5532 | C12 | 0.5545 | C10 | 0.5765 |  |
| C3 | 6 | 2 | C9 | 0.6635 | C12 | 0.6658 | C10 | 0.6897 |  |
| C3 | 8 | 2 | C9 | 0.7198 | C12 | 0.7246 | C10 | 0.7497 |  |
| Panasonic [5] | C7 | 4 |  | C1 | 5.93% | C14 | 7.07% | C13 | 13.9% |  |
| C7 | 6 |  | C1 | 10.1% | C14 | 13.7% | C13 | 23.2% |  |
| Samsung | C1 | 1 | 2 | C3 | 0.00, | C2 | 0.00, | C2 | 0.00 | Note 8 |
| C1 | 2 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 8 |
| C1 | 3 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.02 | Note 8 |
| C1 | 4 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.07 | Note 8 |
| C1 | 5 | 2 | C3 | 0.00 | C2 | 0.03 | C2 | 0.13 | Note 8 |
| C1 | 6 | 2 | C3 | 0.01 | C2 | 0.06 | C2 | 0.20 | Note 8 |
| C1 | 7 | 2 | C3 | 0.02 | C2 | 0.10 | C2 | 0.26 | Note 8 |
| C1 | 8 | 2 | C3 | 0.04 | C2 | 0.15 | C2 | 0.32 | Note 8 |
| C1 | 9 | 2 | C3 | 0.06 | C2 | 0.20 | C2 | 0.37 | Note 8 |
| C1 | 10 | 2 | C3 | 0.08 | C2 | 0.25 | C2 | 0.42 | Note 8 |
| C2 | 1 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00, | Note 9 |
| C2 | 2 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.03 | Note 9 |
| C2 | 3 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.07 | Note 9 |
| C2 | 4 | 2 | C3 | 0.01 | C2 | 0.03 | C2 | 0.12 | Note 9 |
| C2 | 5 | 2 | C3 | 0.02 | C2 | 0.05 | C2 | 0.18 | Note 9 |
| C2 | 6 | 2 | C3 | 0.03 | C2 | 0.08 | C2 | 0.23 | Note 9 |
| C2 | 7 | 2 | C3 | 0.05 | C2 | 0.11 | C2 | 0.28 | Note 9 |
| C2 | 8 | 2 | C3 | 0.08 | C2 | 0.15 | C2 | 0.32 | Note 9 |
| C2 | 9 | 2 | C3 | 0.11 | C2 | 0.18 | C2 | 0.36 | Note 9 |
| C2 | 10 | 2 | C3 | 0.15 | C2 | 0.22 | C2 | 0.40 | Note 9 |
| C3 | 1 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00, | Note 10 |
| C3 | 2 | 2 | C3 | 0.00 | C2 | 0.08 | C2 | 0.12 | Note 10 |
| C3 | 3 | 2 | C3 | 0.03 | C2 | 0.15 | C2 | 0.22 | Note 10 |
| C3 | 4 | 2 | C3 | 0.07 | C2 | 0.20 | C2 | 0.30 | Note 10 |
| C3 | 5 | 2 | C3 | 0.12 | C2 | 0.26 | C2 | 0.36 | Note 10 |
| C3 | 6 | 2 | C3 | 0.17 | C2 | 0.30 | C2 | 0.41 | Note 10 |
| C3 | 7 | 2 | C3 | 0.22 | C2 | 0.34 | C2 | 0.46 | Note 10 |
| C3 | 8 | 2 | C3 | 0.28 | C2 | 0.37 | C2 | 0.49 | Note 10 |
| C3 | 9 | 2 | C3 | 0.33 | C2 | 0.41 | C2 | 0.52 | Note 10 |
| C3 | 10 | 2 | C3 | 0.38 | C2 | 0.43 | C2 | 0.55 | Note 10 |
| C1 | 1 | 2 | C3 | 0.00, | C2 | 0.00 | C2 | 0.00 | Note 6, Note 8 |
| C1 | 2 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 6, Note 8 |
| C1 | 3 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 6, Note 8 |
| C1 | 4 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 6, Note 8 |
| C1 | 5 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.02 | Note 6, Note 8 |
| C1 | 6 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.02 | Note 6, Note 8 |
| C1 | 7 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.07 | Note 6, Note 8 |
| C1 | 8 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.07 | Note 6, Note 8 |
| C1 | 9 | 2 | C3 | 0.00 | C2 | 0.03 | C2 | 0.13 | Note 6, Note 8 |
| C1 | 10 | 2 | C3 | 0.00 | C2 | 0.03 | C2 | 0.13 | Note 6, Note 8 |
| C2 | 1 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 6, Note 9 |
| C2 | 2 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00, | Note 6, Note 9 |
| C2 | 3 | 2 | C3 | 0.00 | C2 | 0.0257 | C2 | 0.03 | Note 6, Note 9 |
| C2 | 4 | 2 | C3 | 0.00 | C2 | 0.0257 | C2 | 0.03 | Note 6, Note 9 |
| C2 | 5 | 2 | C3 | 0.00 | C2 | 0.0462 | C2 | 0.07 | Note 6, Note 9 |
| C2 | 6 | 2 | C3 | 0.00 | C2 | 0.0462 | C2 | 0.07 | Note 6, Note 9 |
| C2 | 7 | 2 | C3 | 0.01 | C2 | 0.0733 | C2 | 0.12 | Note 6, Note 9 |
| C2 | 8 | 2 | C3 | 0.01 | C2 | 0.0733 | C2 | 0.12 | Note 6, Note 9 |
| C2 | 9 | 2 | C3 | 0.02 | C2 | 0.1236 | C2 | 0.18 | Note 6, Note 9 |
| C2 | 10 | 2 | C3 | 0.02 | C2 | 0.1236 | C2 | 0.18 | Note 6, Note 9 |
| C3 | 1 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 6, Note 10 |
| C3 | 2 | 2 | C3 | 0.00 | C2 | 0.00 | C2 | 0.00 | Note 6, Note 10 |
| C3 | 3 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.12 | Note 6, Note 10 |
| C3 | 4 | 2 | C3 | 0.00 | C2 | 0.01 | C2 | 0.12 | Note 6, Note 10 |
| C3 | 5 | 2 | C3 | 0.03 | C2 | 0.01 | C2 | 0.22 | Note 6, Note 10 |
| C3 | 6 | 2 | C3 | 0.03 | C2 | 0.01 | C2 | 0.22 | Note 6, Note 10 |
| C3 | 7 | 2 | C3 | 0.07 | C2 | 0.03 | C2 | 0.30 | Note 6, Note 10 |
| C3 | 8 | 2 | C3 | 0.07 | C2 | 0.03 | C2 | 0.30 | Note 6, Note 10 |
| C3 | 9 | 2 | C3 | 0.12 | C2 | 0.05 | C2 | 0.36 | Note 6, Note 10 |
| C3 | 10 | 2 | C3 | 0.12 | C2 | 0.05 | C2 | 0.36 | Note 6, Note 10 |
| C1 | 1 | 2 | C3 | 0.00 | C3 | 0.00 | C3 | 0.00 | Note 7, Note 8 |
| C1 | 2 | 2 | C3 | 0.00 | C3 | 0.00 | C3 | 0.08 | Note 7, Note 8 |
| C1 | 3 | 2 | C3 | 0.00 | C3 | 0.00 | C3 | 0.14 | Note 7, Note 8 |
| C1 | 4 | 2 | C3 | 0.00 | C3 | 0.01 | C3 | 0.19 | Note 7, Note 8 |
| C1 | 5 | 2 | C3 | 0.00 | C3 | 0.01 | C3 | 0.22 | Note 7, Note 8 |
| C1 | 6 | 2 | C3 | 0.01 | C3 | 0.02 | C3 | 0.25 | Note 7, Note 8 |
| C1 | 7 | 2 | C3 | 0.02 | C3 | 0.03 | C3 | 0.28 | Note 7, Note 8 |
| C1 | 8 | 2 | C3 | 0.03 | C3 | 0.05 | C3 | 0.31 | Note 7, Note 8 |
| C1 | 9 | 2 | C3 | 0.06 | C3 | 0.07 | C3 | 0.34 | Note 7, Note 8 |
| C1 | 10 | 2 | C3 | 0.08 | C3 | 0.10 | C3 | 0.38 | Note 7, Note 8 |
| C2 | 1 | 2 | C3 | 0.00 | C4 | 0.00 | C4 | 0.00 | Note 7, Note9 |
| C2 | 2 | 2 | C3 | 0.00 | C4 | 0.01 | C4 | 0.03 | Note 7, Note9 |
| C2 | 3 | 2 | C3 | 0.00 | C4 | 0.01 | C4 | 0.06 | Note 7, Note9 |
| C2 | 4 | 2 | C3 | 0.01 | C4 | 0.02 | C4 | 0.09 | Note 7, Note9 |
| C2 | 5 | 2 | C3 | 0.02 | C4 | 0.03 | C4 | 0.11 | Note 7, Note9 |
| C2 | 6 | 2 | C3 | 0.03 | C4 | 0.05 | C4 | 0.15 | Note 7, Note9 |
| C2 | 7 | 2 | C3 | 0.05 | C4 | 0.07 | C4 | 0.18 | Note 7, Note9 |
| C2 | 8 | 2 | C3 | 0.08 | C4 | 0.10 | C4 | 0.22 | Note 7, Note9 |
| C2 | 9 | 2 | C3 | 0.11 | C4 | 0.13 | C4 | 0.25 | Note 7, Note9 |
| C2 | 10 | 2 | C3 | 0.15 | C4 | 0.16 | C4 | 0.29 | Note 7, Note9 |
| C3 | 1 | 2 | C3 | 0.00 | C5 | 0.00 | C5 | 0.00 | Note 7, Note 10 |
| C3 | 2 | 2 | C3 | 0.00 | C5 | 0.00 | C5 | 0.00 | Note 7, Note 10 |
| C3 | 3 | 2 | C3 | 0.03 | C5 | 0.03 | C5 | 0.04 | Note 7, Note 10 |
| C3 | 4 | 2 | C3 | 0.07 | C5 | 0.08 | C5 | 0.08 | Note 7, Note 10 |
| C3 | 5 | 2 | C3 | 0.12 | C5 | 0.13 | C5 | 0.13 | Note 7, Note 10 |
| C3 | 6 | 2 | C3 | 0.17 | C5 | 0.18 | C5 | 0.18 | Note 7, Note 10 |
| C3 | 7 | 2 | C3 | 0.22 | C5 | 0.23 | C5 | 0.24 | Note 7, Note 10 |
| C3 | 8 | 2 | C3 | 0.28 | C5 | 0.28 | C5 | 0.30 | Note 7, Note 10 |
| C3 | 9 | 2 | C3 | 0.33 | C5 | 0.34 | C5 | 0.35 | Note 7, Note 10 |
| C3 | 10 | 2 | C3 | 0.38 | C5 | 0.38 | C5 | 0.40 | Note 7, Note 10 |
| Futurewei | C1 | 1 | Up to 2 | C1 | 0.00 | C6 | 0.00 | C1 | 0.00 |  |
| C1 | 2 | Up to 2 | C1 | 0.00 | C6 | 0.01 | C1 | 0.01 |  |
| C1 | 3 | Up to 2 | C1 | 0.00 | C6 | 0.03 | C1 | 0.04 |  |
| C1 | 4 | Up to 2 | C1 | 0.01 | C6 | 0.04 | C1 | 0.07 |  |
| C1 | 5 | Up to 2 | C1 | 0.02 | C6 | 0.07 | C1 | 0.12 |  |
| C1 | 6 | Up to 2 | C1 | 0.03 | C6 | 0.09 | C1 | 0.15 |  |
| C1 | 7 | Up to 2 | C1 | 0.03 | C6 | 0.15 | C1 | 0.23 |  |
| C1 | 8 | Up to 2 | C1 | 0.05 | C6 | 0.17 | C1 | 0.25 |  |
| C1 | 9 | Up to 2 | C1 | 0.07 | C6 | 0.2 | C1 | 0.33 |  |
| C1 | 10 | Up to 2 | C1 | 0.11 | C6 | 0.26 | C1 | 0.36 |  |
| Note 1: Metric: the whole system blocking probability. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking probability.  Note 2: Each UE is configured with all the ALs  Note 3: Each UE is configured with a single AL  Note 4: Reference case：2；50% BD reduction case:1  Note 5: For RedCap UEs using 2RX; BD reduction by reducing DCI size budget is evaluated (i.e. 'the number of DCI sizes to monitor per PDCCH candidate' is set to 2 for the reference case and 1 for approximately 50% reduction in BD limits).  Note 6: With enhancement of UE group scheduling with 2 UEs per DCI.  Note 7: with enhancement of PDCCH drooping based on predetermined CCE AL priority order = [1 2 4 8 16]  Note 8: Good coverage  Note 9: Medium coverage  Note 10: Poor coverage | | | | | | | | | | |

The following table 10A~10E summarized the PDCCH blocking rates due to reduced blind decoding for FR1with optional values for at least one parameter in Table 13 (describe and highlighted in the Table Title)

Table 10A: PDCCH blocking rate for FR1, with 15kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table14 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate |  |
| vivo | C1 | 2 | 2 | C1 | 0.00% | C1 | 1.36% | C1 | 1.17% |  |
| C1 | 3 | 2 | C1 | 0.56% | C1 | 2.14% | C1 | 2.32% |  |
| C1 | 4 | 2 | C1 | 1.31% | C1 | 2.94% | C1 | 3.35% |  |
| C1 | 5 | 2 | C1 | 1.90% | C1 | 3.73% | C1 | 4.14% |  |
| C1 | 1~5 | 2 | C1 | 0.02% | C1 | 0.17% | C1 | 0.05% | Note 1 |
| Note 1: Metric: the whole system blocking probability. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking probability. | | | | | | | | | | |

Table 10B: PDCCH blocking rate for FR1, with 15kHz/20MHz, CORESET duration: 3 symbols, Delay toleration: 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table14 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate |  |
| vivo | C1 | 2 | 2 | C1 | 0.00% | C1 | 0.89% | C1 | 0.90% |  |
| C1 | 3 | 2 | C1 | 0.34% | C1 | 1.54% | C1 | 1.59% |  |
| C1 | 4 | 2 | C1 | 0.62% | C1 | 2.25% | C1 | 2.16% |  |
| C1 | 5 | 2 | C1 | 1.08% | C1 | 2.76% | C1 | 2.82% |  |
| C1 | 1~5 | 2 | C1 | 0.01% | C1 | 0.18% | C1 | 0.25% | Note 1 |
| Nokia | C1 | 2 | 2 | C2 | 0.00 | C8 | 0.00 | C2 | 0.00 |  |
| C1 | 3 | 2 | C2 | 0.01 | C8 | 0.01 | C2 | 0.02 |  |
| C1 | 4 | 2 | C2 | 0.02 | C8 | 0.03 | C2 | 0.06 |  |
| C1 | 5 | 2 | C2 | 0.04 | C8 | 0.07 | C2 | 0.11 |  |
| C1 | 6 | 2 | C2 | 0.10 | C8 | 0.12 | C2 | 0.16 |  |
| C1 | 7 | 2 | C2 | 0.15 | C8 | 0.17 | C2 | 0.23 |  |
| C1 | 8 | 2 | C2 | 0.18 | C8 | 0.22 | C2 | 0.31 |  |
| Intel | C1 | 2 | 1 | C10 | 0.01% | C13 | 0.01% | C12 | 0.01% |  |
| C1 | 4 | 1 | C10 | 0.02% | C13 | 0.02% | C12 | 0.12% |  |
| C1 | 8 | 1 | C10 | 0.07% | C13 | 0.07% | C12 | 0.28% |  |
| C1 | 10 | 1 | C10 | 0.20% | C13 | 0.20% | C12 | 0.6% |  |
| C1 | 15 | 1 | C10 | 1.80% | C13 | 1.80% | C12 | 2.5% |  |

Note 1: Metric: the whole system blocking probability. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking probability.

Table 10C: PDCCH blocking rate for FR1, with 15kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1 2 or 3 slots

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table14 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table 15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table 15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table 15A | PDCCH blocking rate |  |
| ZTE | C1 | 2 | 2 | C7 | 0 | C10 | 0 | C9 | 0.0014 | Note 1 |
| C1 | 4 | 2 | C7 | 0.0008 | C10 | 0.0008 | C9 | 0.0062 | Note 1 |
| C1 | 6 | 2 | C7 | 0.003 | C10 | 0.0049 | C9 | 0.0134 | Note 1 |
| C1 | 8 | 2 | C7 | 0.007 | C10 | 0.0112 | C9 | 0.0226 | Note 1 |
| C1 | 2 | 2 | C7 | 0 | C10 | 0 | C9 | 0.0006 | Note 2 |
| C1 | 4 | 2 | C7 | 0.0003 | C10 | 0.0005 | C9 | 0.0029 | Note 2 |
| C1 | 6 | 2 | C7 | 0.0015 | C10 | 0.0025 | C9 | 0.0067 | Note 2 |
| C1 | 8 | 2 | C7 | 0.0037 | C10 | 0.0061 | C9 | 0.0118 | Note 2 |
| C1 | 2 | 2 | C7 | 0 | C10 | 0 | C9 | 0.0004 | Note 3 |
| C1 | 4 | 2 | C7 | 0.0003 | C10 | 0.0004 | C9 | 0.0022 | Note 3 |
| C1 | 6 | 2 | C7 | 0.0008 | C10 | 0.0016 | C9 | 0.0046 | Note 3 |
| C1 | 8 | 2 | C7 | 0.0024 | C10 | 0.004 | C9 | 0.0084 | Note 3 |
| C2 | 2 | 2 | C8 | 0 | C10 | 0.0076 | C9 | 0.0202 | Note 1 |
| C2 | 4 | 2 | C8 | 0.0248 | C10 | 0.0428 | C9 | 0.0901 | Note 1 |
| C2 | 6 | 2 | C8 | 0.1023 | C10 | 0.1114 | C9 | 0.1691 | Note 1 |
| C2 | 8 | 2 | C8 | 0.1823 | C10 | 0.1888 | C9 | 0.2453 | Note 1 |
| C3 | 2 | 2 | C9 | 0 | C10 | 0.0003 | C9 | 0.0003 | Note 1 |
| C3 | 4 | 2 | C9 | 0.2358 | C10 | 0.2432 | C9 | 0.2661 | Note 1 |
| C3 | 6 | 2 | C9 | 0.3939 | C10 | 0.395 | C9 | 0.4155 | Note 1 |
| C3 | 8 | 2 | C9 | 0.4895 | C10 | 0.4918 | C9 | 0.515 | Note 1 |
| Note 1: Delay toleration is 1 slot  Note 2: Delay toleration is 2 slots  Note 3: Delay toleration is 3 slots | | | | | | | | | | |

Table 10D: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 3 symbols, Delay toleration: 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table14 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15A | PDCCH blocking rate |  |
| vivo | C1 | 2 | 2 | C1 | 0.67% | C1 | 1.58% | C1 | 1.48% |  |
| C1 | 3 | 2 | C1 | 1.62% | C1 | 2.95% | C1 | 3.13% |  |
| C1 | 4 | 2 | C1 | 2.34% | C1 | 4.39% | C1 | 4.80% |  |
| C1 | 5 | 2 | C1 | 3.35% | C1 | 5.74% | C1 | 5.81% |  |
| C1 | 1~5 | 2 | C1 | 0.10% | C1 | 0.20% | C1 | 0.20% | Note 1 |
| Note 1: Metric: the whole system blocking probability. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking probability. | | | | | | | | | | |

Table 10E: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1, DCI size = 60 bits (NOT including CRC)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table14 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table 15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table 15A | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table 15A | PDCCH blocking rate |  |
| Huawei, HiSilicon | C5 | 5 | Note 1 | C5 | 8.60% | - | - | C2 | 8.60% | Note 2 |
| C5 | 10 | Note 1 | C5 | 23.20% | - | - | C2 | 23.20% | Note 2 |
| C6 | 5 | Note 1 | C5 | 14.5% | - | - | C2 | 14.5% | Note 2 |
| C6 | 10 | Note 1 | C5 | 33.70% | - | - | C2 | 33.70% |  |
| Note 1: Reference case：2；50% BD reduction case:1  Note 2: For RedCap UEs using 2RX; BD reduction by reducing DCI size budget is evaluated (i.e. 'the number of DCI sizes to monitor per PDCCH candidate' is set to 2 for the reference case and 1 for approximately 50% reduction in BD limits). | | | | | | | | | | |

**Proposal 8.2.3.1-1: Incorporate the above Table 9 and Table 10A/B/C/D/E into text proposal in the Redcap TR 38.875 for FR1. If not, what changes to the Tables are needed in order to add into Redcap TR. If concerns on results from specific source(s) to be captured in TR 38.875, please explicitly comment with reasoning in ‘comments’ column.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Y/N** | | **Comments** |
| CATT | Y | |  |
| LG | Y | | We are okay with the tables. |
| vivo | N | | We have two major concerns in capturing the results like above   1. For AL distribution, C1 makes sense and most companies have simulated this case. Other configurations (C2~C7), no simulation results have been provided by any company showing those configurations are valid in any simulated scenario. Without such justification, we do not agree to capture results for C2~C7 2. For number of co-scheduled UEs, the range of 2~10 was arbitrarily chosen. From our simulation results, we observed it is rare case that number of co-scheduled UEs is 4 or 5, more than 5 co-scheduled UEs cannot be seen from the simulation. We would like to ask for justification for the number larger than 5. |
| Huawei, HiSilicon | Y | |  |
| Panasonic | Y | |  |
| Sharp | Y | |  |
| Samsung | Y with modification. | | Table 9 is quite large. It’s better to split it into three tables based on channel conditions, i.e. different assumption for AL distribution. At least C1, C2, C3 of AL distributions should be considered. It will help us to draw conclusions or observations for different channel conditions as well. |
| Nokia | Y | |  |
| Qualcomm | Y | |  |
| InterDigital | Y | |  |
| Fraunhofer | Y | |  |
| Futurewei | Y | | Regarding Vivo ‘s comment of only capturing C1: our understanding that it was up to the companies to decide which distribution to use, so other distributions should be included. Besides, C1-C6 model different scenarios (good/medium/bad coverage, etc.) and provide good insight that should be captured in the TR |
| Ericsson | Y | For consistency, we suggest using either percentage or non-percentage values in the tables.  In Table 8, some of the configurations for the number of PDCCH candidates per AL are not valid. The candidates should be among {0, 1, 2, 3, 4, 5, 6, 8} to be valid. In our view, such configurations should not be captured in the TR.  Our suggestion is to have a table summarizing the blocking rate values reported by the companies, instead of including Table 9 and Table 10A/B/C/D/E in the TR. The excel sheet can then be provided as a reference. | |
| Intel | Y for Table 9, Tables 10A/B/D | Other Tables 10C/E are not in line with baseline or optional configurations. Agreement does not include “Other values not precluded” for DCI size and CORESET duration. Hence, we suggest to capture tables based on agreed observations for more focused observations.  Also, note that we have corrected a copy-paste error and also added some new results. | |
| DOCOMO | Y |  | |
| OPPO | Y |  | |
| ZTE,sanechips | Y | From our point of view, any method for BD reduction is not precluded before evaluation. The candidates number after reduction should not be limited by the legacy candidates {0, 1, 2, 3, 4, 5, 6, 8}.  The delay tolerance has an impact on the PDCCH blocking and 2 slots can be an optional configuration according to the agreement. Therefore, the simulation about the delay tolerance should be included. Further, the delay tolerance simulation results are collected in Table10C and we made a revision for Table10C. | |

**Summary of 1st round email discussions**

All responses except companies agree to capture the results of Table 9 and Table 10A/B/C/D/Einto TR 38.875.

Companies views are summarized in Table below:

|  |  |  |
| --- | --- | --- |
|  | Companies | # Companies |
| Yes | CATT, LG, Huawei, HiSilicon, Panasonic, Sharp, Samsung (split Table 9), Nokia, Qualcomm, InterDigital, Fraunhofer, Futurewei, Ericsson, DoCoMo, OPPO, ZTE,sanechips | 17 |
| No | vivo (1st concern on results with AL distributions configuration Cx except C1; 2nd concern on co-scheduled UEs > 5) | 1 |
| Partially yes | Intel (Yes to Table 9/10A/10B/10D) | 1 |

**Discussion Point:**

* Handling results with AL distributions configuration Cx except C1 and co-scheduled UEs > 5 [vivo]
* Whether to split the Table 9 into three tables based on AL distributions configuration C1, C2, or C3? [Samsung]

**FL proposal: At least incorporate the revised Table 9 and Table 10A/10B/10D into text proposal for the Redcap TR 38.875 at least for scheme #1. FFS on others.**

**Summary of Observations**

Contribution [2,6,7,10,1113,17,22] analyze the PDCCH block probability impacts on FR1 if reduced UE number of BDs is introduced for Redcap devices. The observations are listed below:

* P1 [2]: The PDCCH blocking probability is a function several factors such as number of UEs, AL distribution, and CORESET size.
* P2 [2]: In FR1, the impact of BD reduction by 27% on the blocking probability is small.
* P3 [2]: The blocking probability for the good coverage condition and 6 UEs can increase from 5% to 7% (increase by a factor of 1.4) when reducing the BD limit by half.
* P4 [6]: In the simulated case, the number of simultaneously scheduled UEs per slot is no more than 3 in nearly 99.6% cases, rarely 4 or 5.
* P5 [6]: The PDCCH blocking probability does not exceed 5%, assuming simultaneously scheduled number of UEs is 3.
* P6 [6]: The overall PDCCH blocking probability of the system is at the level of 0.5% for 50% BD reduction, even though there is a blocking rate of 5% for the reason that the time ratio of 3 scheduled UEs per slot is only 2%.
* P7 [6]: To conclude that50% BD reduction has non-significant impact to PDCCH blocking probability.
* P8 [7]: For the good coverage, UE blocking is not sensitive for small UE number and sensitive for larger UE number by reducing the BDs
* P9 [7]: For the worse coverage, after 25% BDs reduction, UE blocking is not sensitive by reducing the BDs, and for 50% BDs reduction, UE blocking is sensitive for low UE number and not sensitive for larger UE number by reducing the BDs
* P10 [7]: Introducing delay tolerance can obviously decrease the UE blocking probability. Larger delay tolerance brings larger UE blocking probability decrease.
* P11 [10]: For AL distribution [0.5, 0.4, 0.05, 0.03, 0.02], i.e., good coverage UEs, no degradation in blocking probability is observed when number of candidates is reduced by half for 30kHz, 2OS CORESET configuration.
* P12 [10]: For AL distribution [0.5, 0.4, 0.05, 0.03, 0.02], blocking probability degradation when number of candidates is reduced by half is insignificant for 15kHz, 3OS CORESET.
  + At 5% blocking probability, 19 and 20 UEs can be simultaneously scheduled for half and full BD limit, respectively.
* P13 [11]: For AL distribution [0.5, 0.4, 0.05, 0.03, 0.02], scheduling flexibility is not compromised for 30kHz, 2OS CORESET configuration and only minimally impacted for 15kHz 3OS CORESET, when BD numbers are reduced by half.
* P14 [13]: For the “good coverage” AL probability distribution evaluation with the FR1 and 16 CCE configuration and with 8 or more UEs sharing the same search space, reducing the blind decode candidates from 18 to 9, will approximately double the blocking probability.
* P15 [13]: For the “poor coverage” AL probability distribution evaluation with the FR1 and 16 CCE configuration and with 4 or more UEs sharing the same search space, the blocking probability can reach and exceed 50% with 18 blind decode candidates.
* P16 [13]: Expanding the number of CCEs available using a 3rd symbol for the coreset, reduces the blocking probability significantly.
* P17 [17]: PDCCH blocking probability increases with respect to the increase of number of UEs and the increase of PDCCH monitoring reduction amount.
* P18 [22]: Reducing the number of CCEs supported by the UE significantly degrades the system performance by increasing the PDCCH blockage rate.

**Q 8.2.3.1-1: Which of list above (P1, P2, …, P18) can be incorporated into text proposal in the Redcap TR for the PDCCH blocking performance impacts of reduced PDCCH monitoring? what other aspects need to be added?**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | | **Comments** | |
| CATT | | P1,P3,P8,P9,P10,P12,P13,P14,P15,P17 and P18 can be incorporated into text proposal in the Redcap TR for the PDCCH blocking performance impacts of reduced PDCCH monitoring.  Besides, we provide simulation results to identify the impact on PDCCH blocking possibility from Rx reduction. Although it is not directly related to BD reduction, it is a universal and important factor to PDCCH blocking. The less Rx number, the larger aggregation level. | |
| LG | | P1, P2, P3, P14, P15, P16, P17, P18 | |
| vivo | | Prefer to discuss the AL distribution and the number of co-scheduled UEs first. | |
| Huawei, HiSilicon | | Our proposals and observations in [4] are missed here.   * Observation 7: By reducing 50% PDCCH candidates with unreduced DCI size budget, the average PDCCH blocking rate is increased by about 40% and 20% for RedCap UEs using 2RX and 1RX respectively for reception when the simultaneously scheduled UE number are 10. * Observation 8: The system impact and user experience degradation due to the reduction of BD would be more significant for UE using 1 Rx compared with UE using 2Rx for reception. * Observation 9: For UEs using 2Rx for reception, the average PDCCH blocking rate increases by about 170% when the simultaneously scheduled UEs are increased from 5 to 10. * Observation 10: For UEs using 2Rx for reception, the average PDCCH blocking rate increases by about 35% when the DCI size (not including CRC) is increased from 40 bits to 60 bits. * Proposal 3: Support BD reduction by reducing the DCI size budget, which are observed by evaluation to be with no or little constraint on scheduling flexibility, lower PDCCH blocking rate and attractive power saving gain for RedCap UE.   In our view, at least the proposal 3 and related observations should be captured in the TR:  BD reduction by reducing the DCI size budget shall not impact the PDCCH blocking rate, and therefore BD reduction by reducing the DCI size budget provides attractive power saving gain with no or little constraint on scheduling flexibility, lower PDCCH blocking rate for RedCap UE. | |
| Panasonic | | P1, P10, P17, and P18 can be captured. | |
| Sharp | | P4, P5, P17, P18  The number of simultaneously scheduled UE should be considered. | |
| Samsung | | The following observation from us in [17] is missed:  ***Observation #13: Group-based scheduling can significantly reduce PDCCH blocking probability for RedCap UEs.***  We suggest to make observations based on simulation results from all companies for the following cases:   * BD reduction rate of 25%, 50% for different channel conditions, separately. * enhancements to mitigate the PDCCH blocking probability, and/or control overhead, e.g. group-scheduling, delay tolerance. | |
| Nokia | | P1, P14, P15, P16, P17, P18 | |
| Qualcomm | | P3, P5, P6 are just raw result. When we have captured the raw results in tables already, there seems no need to further capture the raw result in words.  Besides in our study, we found that when a single AL is configured for each UE, PDCCH blocking probability increase is negligible for all cases (25% or 50% BD reduction, Case 1/2/3, 1 to 10 UEs). Therefore, we propose to add the following to the observation list   * Pn [24]: For FR1 (SCS=30kHz), when a single AL is configured per UE, PDCCH blocking probability degradation by BD reduction is negligible for all cases with 25% or 50% BD reduction in good/bad/medium coverage, and for any number of UEs evaluated. * Pn+1 [24]: For FR1 (SCS=30kHz), when multiple ALs are configured per UE, reducing the BD limit by 25% can be used without significant loss to UE PDCCH blocking probability. Reducing by 50% can be used without significant loss in bad and medium coverage. | |
| Futurewei | | These observations are company-specif. It might be better to draw observations after we decide what is captured, based on the results of the whole group (cf our previous comment). The observations should be objective, and as such, be written in a way such as: It was observed that reducing BD from 100% to 75% for N users and configuration C results in a increase of blocking probability in the range of [X, Y] % | |
| Ericsson | P1, P3, P17 and P18 should be captured.  For P3, we propose the following update to reflect the values we reported in the template.  P3 [2]: The blocking probability for the good coverage condition and 6 UEs can increase from 6% to 9% (increase by a factor of 1.5) when reducing the BD limit by half. | |
| Intel | We suggest to capture observations with respect to a given AL distribution. [0.5, 0.4, 0.05, 0.03, 0.02]. In our view, AL distributions C2 and C3 are not realistic and further justification is needed before capturing observations based on them and how they can be realized in practical deployment. | |
| DOCOMO | P1, P14, P15, P17, P18 | |
| OPPO | We suggest to capture the blocking probability in few representative cases. E.g. small/medium/higher number of simultaneously scheduled UEs. | |
| ZTE,sanechips | Our proposals and observations in [7] are missed here.   * Observation 9: Introducing delay tolerance can obviously decrease the UE blocking probability.   + Larger delay tolerance brings larger UE blocking probability decrease   Regarding the delay tolerance, it can also used to decrease the blocking rate, which should be captured in the TR also.  Some raw results or observations based on raw results are obtained by company-specific, which are not appropriate for the common observation. Instead, an overall analysis and or high level views should be expected based on the all companies results. So we are suggesting, a high level description should be considered first. Therefore, P1,P8,P9,P10 should be captured. | |

#### **FR2 Results**

Table 11: PDCCH blocking rate due to reduced blind decoding for FR2, with 120kHz, CORESET duration: 2 symbols, Delay toleration: 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | AL distribution in Table14 | # users | # DCI sizes | Case 1 | | Case 2 | | Case 3 | | Comments |
| # PDCCH candidates for AL [1,2,4,8,16] in Table15B | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15B | PDCCH blocking rate | # PDCCH candidates for AL [1,2,4,8,16] in Table15B | PDCCH blocking rate |  |
| Ericsson | C1 | 3 | Up to 2 | C2 | 0.01 | C2 | 0.012 | C2 | 0.044 | Note 1, Note 5 |
| C1 | 6 | Up to 2 | C2 | 0.039 | C2 | 0.068 | C2 | 0.14 | Note 1, Note 5 |
| C2 | 3 | Up to 2 | C2 | 0.18 | C2 | 0.2 | C2 | 0.24 | Note 1, Note 6 |
| C2 | 6 | Up to 2 | C2 | 0.36 | C2 | 0.4 | C2 | 0.44 | Note 1, Note 6 |
| C3 | 3 | Up to 2 | C2 | 0.45 | C2 | 0.47 | C2 | 0.49 | Note 1, Note 7 |
| C3 | 6 | Up to 2 | C2 | 0.63 | C2 | 0.65 | C2 | 0.67 | Note 1, Note 7 |
| Qualcomm | C1 | 2 | 2 | C1 | 0.002 | C5 | 0.004 | C1 | 0.040 |  |
| C1 | 4 | 2 | C1 | 0.011 | C5 | 0.019 | C1 | 0.114 |  |
| C1 | 6 | 2 | C1 | 0.026 | C5 | 0.045 | C1 | 0.177 |  |
| C1 | 8 | 2 | C1 | 0.051 | C5 | 0.078 | C1 | 0.235 |  |
| C1 | 10 | 2 | C1 | 0.084 | C5 | 0.120 | C1 | 0.289 |  |
| C1 | 12 | 2 | C1 | 0.127 | C5 | 0.166 | C1 | 0.335 |  |
| C1 | 14 | 2 | C1 | 0.177 | C5 | 0.215 | C1 | 0.380 |  |
| C1 | 16 | 2 | C1 | 0.229 | C5 | 0.265 | C1 | 0.417 |  |
| C1 | 18 | 2 | C1 | 0.282 | C5 | 0.314 | C1 | 0.454 |  |
| C1 | 20 | 2 | C1 | 0.335 | C5 | 0.361 | C1 | 0.487 |  |
| C2 | 1 | 2 | C1 | 0.000 | C5 | 0.000 | C1 | 0.000 |  |
| C2 | 2 | 2 | C1 | 0.074 | C5 | 0.078 | C1 | 0.108 |  |
| C2 | 3 | 2 | C1 | 0.142 | C5 | 0.153 | C1 | 0.203 |  |
| C2 | 4 | 2 | C1 | 0.204 | C5 | 0.220 | C1 | 0.280 |  |
| C2 | 5 | 2 | C1 | 0.259 | C5 | 0.279 | C1 | 0.345 |  |
| C2 | 6 | 2 | C1 | 0.312 | C5 | 0.336 | C1 | 0.404 |  |
| C2 | 7 | 2 | C1 | 0.358 | C5 | 0.384 | C1 | 0.453 |  |
| C2 | 8 | 2 | C1 | 0.403 | C5 | 0.430 | C1 | 0.497 |  |
| C2 | 9 | 2 | C1 | 0.440 | C5 | 0.467 | C1 | 0.533 |  |
| C2 | 10 | 2 | C1 | 0.475 | C5 | 0.501 | C1 | 0.566 |  |
| C3 | 1 | 2 | C1 | 0.000 | C5 | 0.000 | C1 | 0.000 |  |
| C3 | 2 | 2 | C1 | 0.212 | C5 | 0.217 | C1 | 0.231 |  |
| C3 | 3 | 2 | C1 | 0.362 | C5 | 0.370 | C1 | 0.394 |  |
| C3 | 4 | 2 | C1 | 0.468 | C5 | 0.479 | C1 | 0.505 |  |
| C3 | 5 | 2 | C1 | 0.541 | C5 | 0.554 | C1 | 0.583 |  |
| C3 | 6 | 2 | C1 | 0.595 | C5 | 0.609 | C1 | 0.638 |  |
| C3 | 7 | 2 | C1 | 0.639 | C5 | 0.654 | C1 | 0.683 |  |
| C3 | 8 | 2 | C1 | 0.672 | C5 | 0.687 | C1 | 0.715 |  |
| C3 | 9 | 2 | C1 | 0.697 | C5 | 0.712 | C1 | 0.741 |  |
| C3 | 10 | 2 | C1 | 0.717 | C5 | 0.731 | C1 | 0.761 |  |
| Nokia | C1 | 2 | 2 | C1 | 0.00 | C1 | 0.01 | C1 | 0.03 |  |
| C1 | 3 | 2 | C1 | 0.02 | C1 | 0.04 | C1 | 0.07 |  |
| C1 | 4 | 2 | C1 | 0.06 | C1 | 0.09 | C1 | 0.15 |  |
| C1 | 5 | 2 | C1 | 0.11 | C1 | 0.14 | C1 | 0.26 |  |
| C1 | 6 | 2 | C1 | 0.15 | C1 | 0.20 | C1 | 0.40 |  |
| C1 | 7 | 2 | C1 | 0.20 | C1 | 0.29 | C1 | 0.59 |  |
| C1 | 8 | 2 | C1 | 0.26 | C1 | 0.40 | C1 | 0.77 |  |
| ZTE | C2 | 2 | 2 | C2 | 0.0916 | C6 | 0.0995 | C1 | 0.2288 | Note 6 |
| C2 | 4 | 2 | C2 | 0.2605 | C6 | 0.2893 | C1 | 0.44 | Note 6 |
| C2 | 6 | 2 | C2 | 0.4086 | C6 | 0.4334 | C1 | 0.5492 | Note 6 |
| C2 | 8 | 2 | C2 | 0.5188 | C6 | 0.5434 | C1 | 0.6261 | Note 6 |
| Samsung | C1 | 1 | 2 | C1 | 0.00 | C2 | 0.05 | C2 | 0.08 | Note 5 |
| C1 | 2 | 2 | C1 | 0.00 | C2 | 0.05 | C2 | 0.08 | Note 5 |
| C1 | 3 | 2 | C1 | 0.00 | C2 | 0.07 | C2 | 0.14 | Note 5 |
| C1 | 4 | 2 | C1 | 0.01 | C2 | 0.12 | C2 | 0.22 | Note 5 |
| C1 | 5 | 2 | C1 | 0.03 | C2 | 0.18 | C2 | 0.31 | Note 5 |
| C1 | 6 | 2 | C1 | 0.07 | C2 | 0.24 | C2 | 0.38 | Note 5 |
| C1 | 7 | 2 | C1 | 0.11 | C2 | 0.31 | C2 | 0.45 | Note 5 |
| C1 | 8 | 2 | C1 | 0.16 | C2 | 0.37 | C2 | 0.50 | Note 5 |
| C1 | 9 | 2 | C1 | 0.22 | C2 | 0.42 | C2 | 0.55 | Note 5 |
| C1 | 10 | 2 | C1 | 0.26 | C2 | 0.47 | C2 | 0.59 | Note 5 |
| C2 | 1 | 2 | C1 | 0.00, | C2 | 0.40 | C2 | 0.61 | Note 6 |
| C2 | 2 | 2 | C1 | 0.11 | C2 | 0.42 | C2 | 0.61 | Note 6 |
| C2 | 3 | 2 | C1 | 0.19 | C2 | 0.45 | C2 | 0.61 | Note 6 |
| C2 | 4 | 2 | C1 | 0.25 | C2 | 0.47 | C2 | 0.62 | Note 6 |
| C2 | 5 | 2 | C1 | 0.30 | C2 | 0.50 | C2 | 0.63 | Note 6 |
| C2 | 6 | 2 | C1 | 0.35 | C2 | 0.52 | C2 | 0.64 | Note 6 |
| C2 | 7 | 2 | C1 | 0.39 | C2 | 0.54 | C2 | 0.66 | Note 6 |
| C2 | 8 | 2 | C1 | 0.43 | C2 | 0.56 | C2 | 0.67 | Note 6 |
| C2 | 9 | 2 | C1 | 0.46 | C2 | 0.58 | C2 | 0.68 | Note 6 |
| C2 | 10 | 2 | C1 | 0.49 | C2 | 0.60 | C2 | 0.69 | Note 6 |
| C3 | 1 | 2 | C1 | 0.00 | C2 | 0.20 | C2 | 0.49, | Note 7 |
| C3 | 2 | 2 | C1 | 0.15 | C2 | 0.32 | C2 | 0.58 | Note 7 |
| C3 | 3 | 2 | C1 | 0.25 | C2 | 0.42 | C2 | 0.64 | Note 7 |
| C3 | 4 | 2 | C1 | 0.34 | C2 | 0.49 | C2 | 0.68 | Note 7 |
| C3 | 5 | 2 | C1 | 0.41 | C2 | 0.55 | C2 | 0.72 | Note 7 |
| C3 | 6 | 2 | C1 | 0.47 | C2 | 0.59 | C2 | 0.74 | Note 7 |
| C3 | 7 | 2 | C1 | 0.52 | C2 | 0.63 | C2 | 0.76 | Note 7 |
| C3 | 8 | 2 | C1 | 0.56 | C2 | 0.66 | C2 | 0.78 | Note 7 |
| C3 | 9 | 2 | C1 | 0.59 | C2 | 0.68 | C2 | 0.79 | Note 7 |
| C3 | 10 | 2 | C1 | 0.62 | C2 | 0.71 | C2 | 0.80 | Note 7 |
| C1 | 1 | 2 | C1 | 0.00 | C2 | 0.05 | C2 | 0.08 | Note 3, Note 5 |
| C1 | 2 | 2 | C1 | 0.00 | C2 | 0.05 | C2 | 0.08 | Note 3, Note 5 |
| C1 | 3 | 2 | C1 | 0.00 | C2 | 0.05 | C2 | 0.08 | Note 3, Note 5 |
| C1 | 4 | 2 | C1 | 0.00 | C2 | 0.05 | C2 | 0.08 | Note 3, Note 5 |
| C1 | 5 | 2 | C1 | 0.00 | C2 | 0.07 | C2 | 0.14 | Note 3, Note 5 |
| C1 | 6 | 2 | C1 | 0.00 | C2 | 0.07 | C2 | 0.14 | Note 3, Note 5 |
| C1 | 7 | 2 | C1 | 0.01 | C2 | 0.12 | C2 | 0.22 | Note 3, Note 5 |
| C1 | 8 | 2 | C1 | 0.01 | C2 | 0.12 | C2 | 0.22 | Note 3, Note 5 |
| C1 | 9 | 2 | C1 | 0.03 | C2 | 0.18 | C2 | 0.31 | Note 3, Note 5 |
| C1 | 10 | 2 | C1 | 0.03 | C2 | 0.18 | C2 | 0.31 | Note 3, Note 5 |
| C2 | 1 | 2 | C1 | 0.00 | C2 | 0.40 | C2 | 0.61 | Note3, Note6 |
| C2 | 2 | 2 | C1 | 0.00 | C2 | 0.40 | C2 | 0.61 | Note3, Note6 |
| C2 | 3 | 2 | C1 | 0.11 | C2 | 0.42 | C2 | 0.61 | Note3, Note6 |
| C2 | 4 | 2 | C1 | 0.11 | C2 | 0.42 | C2 | 0.61 | Note3, Note6 |
| C2 | 5 | 2 | C1 | 0.19 | C2 | 0.45 | C2 | 0.61 | Note3, Note6 |
| C2 | 6 | 2 | C1 | 0.19 | C2 | 0.45 | C2 | 0.61 | Note3, Note6 |
| C2 | 7 | 2 | C1 | 0.25 | C2 | 0.47 | C2 | 0.62 | Note3, Note6 |
| C2 | 8 | 2 | C1 | 0.25 | C2 | 0.47 | C2 | 0.62 | Note3, Note6 |
| C2 | 9 | 2 | C1 | 0.30 | C2 | 0.50 | C2 | 0.63 | Note3, Note6 |
| C2 | 10 | 2 | C1 | 0.30 | C2 | 0.50 | C2 | 0.63 | Note3, Note6 |
| C3 | 1 | 2 | C1 | 0.00 | C2 | 0.20 | C2 | 0.49 | Note 3, Note 7 |
| C3 | 2 | 2 | C1 | 0.00 | C2 | 0.20 | C2 | 0.49 | Note 3, Note 7 |
| C3 | 3 | 2 | C1 | 0.15 | C2 | 0.32 | C2 | 0.58 | Note 3, Note 7 |
| C3 | 4 | 2 | C1 | 0.15 | C2 | 0.32 | C2 | 0.58 | Note 3, Note 7 |
| C3 | 5 | 2 | C1 | 0.25 | C2 | 0.42 | C2 | 0.64 | Note 3, Note 7 |
| C3 | 6 | 2 | C1 | 0.25 | C2 | 0.42 | C2 | 0.64 | Note 3, Note 7 |
| C3 | 7 | 2 | C1 | 0.34 | C2 | 0.49 | C2 | 0.68 | Note 3, Note 7 |
| C3 | 8 | 2 | C1 | 0.34 | C2 | 0.49 | C2 | 0.68 | Note 3, Note 7 |
| C3 | 9 | 2 | C1 | 0.41 | C2 | 0.55 | C2 | 0.72 | Note 3, Note 7 |
| C3 | 10 | 2 | C1 | 0.41 | C2 | 0.55 | C2 | 0.72 | Note 3, Note 7 |
| C1 | 1~10 | 2 | C1 | 0.00 | C3 | 0.10 | C3 | 0.10 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.00 | C3 | 0.10 | C3 | 0.18 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.00 | C3 | 0.10 | C3 | 0.24 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.01 | C3 | 0.11 | C3 | 0.29 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.03 | C3 | 0.13 | C3 | 0.32 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.07 | C3 | 0.16 | C3 | 0.36 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.11 | C3 | 0.20 | C3 | 0.41 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.16 | C3 | 0.25 | C3 | 0.44 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.22 | C3 | 0.30 | C3 | 0.49 | Note 4, Note 5 |
| C1 | 1~10 | 2 | C1 | 0.26 | C3 | 0.35 | C3 | 0.52 | Note 4, Note 5 |
| C2 | 1~10 | 2 | C1 | 0.00 | C4 | 0.00, | C4 | 0.20, | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.11 | C4 | 0.11 | C4 | 0.30 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.19 | C4 | 0.19 | C4 | 0.38 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.25 | C4 | 0.27 | C4 | 0.43 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.30 | C4 | 0.32 | C4 | 0.48 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.35 | C4 | 0.37 | C4 | 0.52 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.39 | C4 | 0.41 | C4 | 0.55 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.43 | C4 | 0.45 | C4 | 0.58 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.46 | C4 | 0.49 | C4 | 0.61 | Note 4, Note 6 |
| C2 | 1~10 | 2 | C1 | 0.49 | C4 | 0.53 | C4 | 0.63 | Note 4, Note 6 |
| C3 | 1~10 | 2 | C1 | 0.00, | C4 | 0.00 | C5 | 0.05 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.14 | C4 | 0.15 | C5 | 0.19 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.26 | C4 | 0.26 | C5 | 0.31 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.34 | C4 | 0.35 | C5 | 0.40 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.41 | C4 | 0.42 | C5 | 0.47 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.47 | C4 | 0.48 | C5 | 0.52 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.52 | C4 | 0.52 | C5 | 0.57 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.56 | C4 | 0.56 | C5 | 0.61 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.59 | C4 | 0.60 | C5 | 0.64 | Note 4, Note 7 |
| C3 | 1~10 | 2 | C1 | 0.62 | C4 | 0.63 | C5 | 0.67 | Note 4, Note 7 |
| Note 1: Digital Beamforming.  Note 3: With enhancement of UE group scheduling with 2 UEs per DCI.  Note 4: with enhancement of PDCCH drooping based on predetermined CCE AL priority order = [1 2 4 8 16]  Note 5: Good coverage  Note 6: Medium coverage  Note 7: Poor coverage | | | | | | | | | | |

**Proposal 8.2.3.1-2: Incorporate the above Table 11 into text proposal in the Redcap TR for FR2. If not, what changes to the Tables are needed in order to add into Redcap TR? If concerns on results from one or more source(s) to be captured in TR 38.875, please explicitly comment with reason in ‘Comments’ column.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| CATT | Y |  |
| LG | Y | We are okay with the tables. |
| Panasonic | Y |  |
| Samsung | Y with modification. | Similar as Table 9, Table 11 is quite large. It’s better to split it into three tables based on channel conditions, i.e. different assumption for AL distribution. At least C1, C2, C3 of AL distributions should be considered. It will help us to draw conclusions or observations for different channel conditions as well. |
| Qualcomm | Y |  |
| InterDigital | Y |  |
| Futurewei | Y |  |
| Ericsson | Y | In Ericsson’s results in Table 11, Note 2 (Analog Beamforming) is not applicable. It is always Note 1 (Digital Beamforming).  Our suggestion is to also have a table summarizing the PDCCH blocking rate reported by the companies, instead of including Table 11, in the TR. The excel sheet can then be provided as a reference. |
| Intel | Y |  |
| DOCOMO | Y |  |
| ZTE,sanechips | Y |  |

**Summary of 1st round email discussions**

All responses agree to capture the results in Table 11 into TR with one company clarification on note. One company suggest put the table into excel sheet. Another company suggest split the table into three based on the AL distribution configuration C1, C2 or C3.

**FL proposal: Incorporate the revised Table 11 into text proposal for the Redcap TR 38.875. It is up to TR editor to determine how to capture Table 11 into TR.**

**Summary of Observations**

Contribution [xxx] analyze the PDCCH block probability impacts on FR2 if reduced UE number of BDs is introduced for Redcap devices. The observations are listed below:

* P1 [2]: In FR2 with digital beamforming, the blocking probability for the good coverage condition and 6 UEs can increase from 3.9% to 14% (increase by a factor of 3.6) when reducing the BD limit by half.
* P2 [2]: In FR2 with digital beamforming, while the power saving gain by reducing the number of BDs to half is typically less than 4% for RedCap UEs in (DL+UL) traffic case, the blocking probability can increase by a factor of 3.
* P3 [2]: In FR2 with the analog beamforming, the impact of BD reduction on the blocking probability is negligible.
* P4 [2]: The overall blocking probability for the analog BF case can be significantly reduced by considering multiple scheduling instances.
* P5 [13]: For the “good coverage” AL probability distribution evaluation with the FR2 and 22 CCE configuration and between 2 and 8 users, reducing the blind decode candidates from 10 to 5, will more than double the blocking probability.
* P6 [17]: PDCCH blocking probability is higher in FR2 than FR1.
* P7 [17]: Enhancement of PDCCH dropping rule can help reducing PDCCH blocking probability for RedCap UEs, especially for FR2 and lower BD reduction rate, i.e. 25%.

**Q 8.2.3.1-2: Which of list above (P1, P2, …, P7) can be incorporated into text proposal in the Redcap TR for the PDCCH blocking performance impacts of reduced PDCCH monitoring? Please explain reason. What other aspects need to be added?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| CATT | P5/6/7 can be incorporated into TR.  Same comments on Rx reduction issue as **Q 8.2.3.1-1** |
| LG | P1, P2, P3, P4, P5 |
| Sharp | P6 and P7 |
| Samsung | P4, P5, P6, P7. |
| Nokia | P5, P6, P7 |
| Qualcomm | P1, P2, P5 are raw company results and do not give a big picture. There seems no need to capture them again in words after they are already captured in table.  P3, P4, P7: better to clarify these are results from only one company.  P6: not necessarily, this depends on the AL distribution, number of PDCCH candidates used for each AL, and BW of CORESET.  Similar to the corresponding FR1 question, we propose to add the following observation from our study   * Pn [24]: For FR2 (SCS=120kHz), when a single AL is configured per UE, PDCCH blocking probability degradation by BD reduction is negligible for all cases with 25% or 50% BD reduction in good/bad/medium coverage, and for any number of UEs evaluated. * Pn+1 [24]: For FR2 (SCS=120kHz), when multiple ALs are configured per UE, reducing the BD limit by 25% can be used without significant loss to UE PDCCH blocking probability. Reducing by 50% can be used without significant loss in bad and medium coverage. |
| Futurewei | Cf. previous comment: decide after table finalized, and draw observations based on the results of the group instead of individual companies’ observations |
| Ericsson | P1, P2, P3 and P4 should be captured.  We suggest updating P3 as follows:  P3 [2]: In FR2 with the analog beamforming, assuming only UEs in the same beam can be simultaneously scheduled, the impact of BD reduction on the blocking probability is negligible. |
| Intel | Same comment as in Q8.2.3.1-1 |
| DOCOMO | P4, P5, P6 |
| OPPO | Similar as comments for FR1. |
| ZTE,sanechips | The observations should be captured similar as FR1. High level views should be considered, instead of some raw results based on each company. |

### 8.2.3.2 Latency and Scheduling flexibility

The latency impacts were studied in [2,6] with following observations:

* P1 [2]: Reduction of BD and CCE limits increases PDCCH blocking probability as well as latency. Moreover, it restricts scheduling flexibility and efficient multiplexing for scheduling multiple UEs.
* P2 [6]: The latency increase caused by BD reduction is negligible.

**Q 8.2.3.2-1: Which of the listed (P1, P2) can be incorporated into text proposal in the Redcap TR for the potential latency and scheduling flexibility performance impacts? If none of them, what is suggested to be captured in the latency and scheduling flexibility analysis section in TR?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| CATT | P1 |
| LG | P1 |
| vivo | P2. Due to the long DRX cycle associated with the simulated traffic model, the additional latency impact due to different PDCCH monitoring cases is marginal. For PDCCH blocking and scheduling flexibility, they are more suitable for the previous section 8.2.3.1 |
| Huawei, HiSilicon | We also have an observation in [4], which could be the P3:   * Observation 6: When BD reduction with the same DCI size budget is considered, the number of outage UEs would be increased due to the higher PDCCH blocking rate.   We think we should distinguish the reduction of BD into:   1. BD reduction by reducing DCI size budget; 2. BD reduction with the same DCI size budget;   Based on our results in Table 9, the following is suggested to be captured:  BD reduction by reducing DCI size budget shall not impact the latency and scheduling flexibility and when BD reduction with the same DCI size budget is considered, the number of outage UEs would be increased due to the higher PDCCH blocking rate. |
| Panasonic | P1 |
| Sharp | P2 |
| Samsung | P2. Latency can be negligible for RedCap use cases. |
| Nokia | P1 |
| Qualcomm | None of the two seems to capture the overall picture. We propose to add the following based on our evaluation study of PDCCH blocking probability by BD reduction   * Pn [24]: Scheduling flexibility impact by BD reduction depends on multiple factors at least including BW, AL distribution, channel condition, number of ALs per UE, number of UEs that need to be scheduled. |
| MediaTek | P1 |
| InterDigital | P1 |
| Fraunhofer | P1 |
| Futurewei | More discussion is needed before concluding this aspect: if BDs are reduced, all other things being the same (scheme 1a in question 1), P1 is appropriate. However, other schemes (e.g., reducing the number of DCI sizes to monitor) do not affect performance, but may have other impact to study (e.g., what is the impact of reducing the number of DCI sizes).  The QC suggestion could be a good starting point for a top level observation but then, more details should be provided to quantify the impact of each listed parameter |
| Ericsson | P1 should be captured, but not P2. |
| Intel | More discussion is needed before such as observations can be captured. In our analysis, scheduling flexibility loss due to BD reduction up to 50% was minimal at least for the agreed configurations. Below is our observation, copied here for reference:  **Observation 5: For AL distribution [0.5, 0.4, 0.05, 0.03, 0.02], scheduling flexibility is not compromised for 30kHz, 2OS CORESET configuration and only minimally impacted for 15kHz 3OS CORESET, when BD numbers are reduced by half.** |
| DOCOMO | P1 |
| Lenovo, Motorola Mobility | P2. Considering relaxed latency requirements (e.g. 5-10ms, <100ms, < 500ms) for RedCap UEs, a small increase of latency related to PDCCH blocking shouldn’t be a concern. |
| OPPO | P2 |
| ZTE,sanechips | We think P1 and P2 can be applied for different cases according to companies’ simulation scenarios, and both of them should be counted.  Therefore, Combine P1 and P2 as following.  In some cases, reduction of BD and CCE limits increases PDCCH blocking probability as well as latency. Moreover, it restricts scheduling flexibility and efficient multiplexing for scheduling multiple UEs(P1)  In some other cases, the latency increase caused by BD reduction is negligible (P2). |

## 8.2.4 Analysis of coexistence with legacy UEs

Several contributions [2, 7] analyzed potential coexistence issues with legacy UEs caused by reduced PDCCH monitoring. The specification impact analysis based on papers were listed below:

* C1 [2]: The potential impacts on legacy UEs, in terms of PDCCH blocking probability, when coexisting with RedCap UEs depend on the scheduling strategy and system parameters. If legacy UEs are prioritized over RedCap UEs in the gNB scheduling, we do not expect any coexistence impact on the legacy UEs.
* C2 [7]: The coexistence impacts from reducing BD and CCE limits can be mitigated by gNB configuration.

**Q 8.2.4-1: Does the list above (C1, C2) can be incorporated into text proposal in the Redcap TR for the coexistence impacts that need to be considered? If not, please explain why? what other aspects need to be added?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| LG | C1 can be incorporated but further study is needed. For coverage recovery, RedCap UEs’ PDCCHs tend to be on higher ALs, and legacy UEs in poor coverage cannot avoid impact. RedCap UEs may be fine with relaxed latency requirement, but, it should be clarified. |
| vivo | There should be no impact to legacy UEs as BD are not reduced for legacy UEs. |
| Huawei, HiSilicon | We think C2 is reasonable observation. |
| Panasonic | FFS |
| Sharp | C1 and C2 |
| Samsung | No. The PDCCH blocking probability for legacy UEs is impacted by the number of UEs served per cell. It doesn’t matter the coexistence UE is RedCap UE or legacy UE. The reduced PDCCH monitoring capability of RedCap won’t cause any coexistence issue for legacy UEs. |
| Nokia | C1 and C2 |
| Qualcomm | C1 is obvious for legacy UE. It would be equally important if proponent of C1 [2] can clarify how RedCap UEs are impacted if legacy UEs are always prioritized.  It is unclear what does C2 really mean. It is better if proponent of C2 [7] can present some details about whether the impact is to legacy UE or to RedCap UE and how gNB can mitigate the impact by configuration. |
| MediaTek | C1 |
| InterDigital | It is not clear why leagcy UEs are impacted by reduced PDCCH monitoring of RedCap UEs. |
| Futurewei | Both observations are acceptable |
| Ericsson | C1 and C2 should be captured. |
| Intel | It seems this topic received limited attention in this meeting. More discussion is needed. |
| DOCOMO | No. Reduced PDCCH monitoring does not have impact on coexistence with legacy UEs |
| Lenovo, Motorola Mobility | C1 |
| OPPO | Both |
| ZTE,sanechips | C1 and C2. |

## 8.2.5 Analysis of specification impacts

Several contributions [2,7] also point out the specification impacts from the reduced PDCCH monitoring.

* S1 [2]: If the network assist BD reduction and UE power saving using existing configurations without any specified restriction for RedCap, specification changes are not required.
* S2 [2]: If a specific set of number of PDCCH candidates needs to be hardcoded for RedCap, there will be a specification impact.
* S3 [7]: The specification impacts by reducing the BDs and CCEs may be mainly on the RRC parameters, DCI design or the UE behaviors related to blind decoding.

**Q 8.2.5-1: Which of list above (S1, S2, S3) capture the most important specifications impacts that need to be considered for reduced PDCCH monitoring? If none, what other aspects need to be added?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| CATT | Y |  |
| LG | Y | S1, S2 |
| vivo | N | For scheme #1, agree with S2  For scheme #2, the spec impact would be the specification of supported PDCCH monitoring span gap (i.e. X) and potentially multi-slot scheduling from a single monitoring span. |
| Huawei, HiSilicon | N | In our view, BD limit, DCI size budget and DCI format design shall be impacted. |
| Panasonic | Y | S1 and S2. |
| Sharp | Y | S2 and S3 |
| Samsung | Y | Both S2 and S3 are possible. It depends on what type of power saving schemes (in Section 8.2.1 we support eventually. |
| Nokia | Y | S1 and S2 |
| Qualcomm | Y | For S1, it is unclear how UE can be guaranteed that actual BD number is reduced by network without any change to specification. If there is not any specification impact, then even eMBB may use the network assisted BD reduction. S1 should not be captured.  S2 can be captured. But it can be changed from “If a specific set of number of PDCCH candidates” to “a specific set of “reduced” number”. This is because Rel-15 BD limit is also a specific set of number of PDCCH candidates.  For S3, it is a very broad conclusion. Would be better to further clarify by proponent ([7]) the specification change is for adaptive PDCCH monitoring configuration, PDCCH overhead reduction (i.e., by using less PDCCH for scheduling) or DCI size reduction etc. or all of them. Then it can be captured.  For the table in “12. Conclusion”, please also add Qualcomm to the companies supporting scheme 3. |
| MediaTek | Y | S1 and S2 |
| InterDigital | Y | S2 and S3 |
| FUTUREWEI |  | S1 as written is too strong, but could be reworded as:  S4 If the network assist BD reduction and UE power saving using existing configurations without any specified restriction for RedCap, only limited specification changes are ~~not~~ required |
| Ericsson | Y | S1 and S2 should be captured. |
| Intel |  | We think specification impact can be discussed together with the methods for reducing BD numbers, Section 8.2.1 |
| DOCOMO | Y | S1, S2 |
| Lenovo, Motorola Mobility | Y | S2, S3 |
| OPPO | N | The specification impact can be discussed further. |
| ZTE,sanechips | Y | S2 and S3. The details can be clarified according to the discussion of Proposal 8.2.1-1 |

# 12. Conclusion

The following table summarizes companies’ proposals to further study the power saving scheme(s) to reduce PDCCH power consumption:

|  |  |  |
| --- | --- | --- |
| Scheme Index | Supportive Companies | # of companies |
| 1 | Huawei&HiSilicon [4], vivo [6], ZTE [7], Intel [10], Spreadtrum [15], NEC[16] , Samsung[17], OPPO [18], Lenovo [19], Sharp[20], Apple [21], Qualcomm [24], InterDigital[25], WILUS [27], Sequans [28], CATT[8], Fraunhofer [26], CMCC[11] | 19 |
| 2 | vivo[6] | 1 |
| 3 | NEC[16] ,Samsung[17], Lenovo [19] CATT[8], InterDigital, Fraunhofer [26] | 6 |
| 4 (Remain same as in Rel-15/16) | Futurewei [3], Nokia [13], MTK [22], LG[12], Ericsson [2], DOCOMO [23] | 6 |

# References

1. 3GPP TR 38.875 Study on support of reduced capability NR devices (Rel-17)
2. [R1-2007530](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007530.zip) Reduced PDCCH monitoring for RedCap Ericsson
3. [R1-2007535](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007535.zip) Power savings for RedCap UEs FUTUREWEI
4. [R1-2007597](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007597.zip) Power saving for reduced capability devices Huawei, HiSilicon
5. [R1-2007625](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007625.zip) Discussion on PDCCH monitoring reduction for RedCap UEs Panasonic
6. [R1-2007669](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007669.zip) Reduced PDCCH monitoring for Reduced Capability NR devices vivo, Guangdong Genius
7. [R1-2007716](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007716.zip) Consideration on reduced PDCCH monitoring ZTE
8. [R1-2007863](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007863.zip) Discussion on PDCCH monitoring reduction CATT
9. [R1-2007888](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007888.zip) Reduced PDCCH monitoring TCL Communication Ltd.
10. [R1-2007948](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2007948.zip) On reduced PDCCH monitoring for RedCap UEs Intel Corporation
11. [R1-2008017](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008017.zip) Discussion on PDCCH monitoring reduction CMCC
12. [R1-2008049](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008049.zip) Discussion on PDCCH monitoring for reduced capability NR devices LG Electronics
13. [R1-2008069](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008069.zip) Reduced PDCCH monitoring Nokia, Nokia Shanghai Bell
14. [R1-2008085](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008085.zip) Discussion on reduced PDCCH monitoring for reduced capability device Xiaomi
15. [R1-2008105](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008105.zip) Discussion on reduced PDCCH monitoring Spreadtrum Communications
16. [R1-2008115](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008115.zip) Reduced PDCCH monitoring for REDCAP NR devices NEC
17. [R1-2008171](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008171.zip) Reduced PDCCH monitoring Samsung
18. [R1-2008261](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008261.zip) Solutions of reduced PDCCH monitoring OPPO
19. [R1-2008336](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008336.zip) PDCCH monitoring at reduced capability UE Lenovo, Motorola Mobility
20. [R1-2008395](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008395.zip) Reduced PDCCH Monitoring for RedCap Devices Sharp
21. [R1-2008470](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008470.zip) Reduced PDCCH Monitoring for RedCap Devices Apple
22. [R1-2008511](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008511.zip) Discussion on reduced PDCCH monitoring for NR RedCap UEs MediaTek Inc.
23. [R1-2008552](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008552.zip) Discussion on reduced PDCCH monitoring for RedCap NTT DOCOMO, INC.
24. [R1-2008621](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008621.zip) PDCCH Monitoring Reduction and Power Saving for RedCap Devices Qualcomm Incorporated
25. [R1-2008685](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008685.zip) Reduced PDCCH monitoring for reduced capability NR devices InterDigital, Inc.
26. [R1-2008712](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008712.zip) Reduced PDCCH Monitoring for RedCap UEs Fraunhofer HHI, Fraunhofer IIS
27. [R1-2008727](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008727.zip) Discussion on PDCCH monitoring for RedCap UE WILUS Inc.
28. [R1-2008739](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_103\Docs\R1-2008739.zip) Reduced PDCCH monitoring for RedCap UE Sequans Communications
29. [R1-2007482](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_102-e/Docs/R1-2007482.zip) FL summary on initial collection of RedCap evaluation results Moderator (Ericsson, Apple, Qualcomm)

# Annex: Previous Agreements

## **RAN1 #101 e-meeting**

*Agreements:*

* Study the impact of BD and CCE limits reduction on power saving and PDCCH blocking probability (quantitatively) and impacts on latency and scheduling flexibility (at least qualitatively).

*Agreements:*

* Study the impact of BD and CCE limits reduction on power saving and PDCCH blocking probability (quantitatively) and resulting impacts on latency and scheduling flexibility (at least qualitatively).
* Reuse the power consumption models and scaling factors for FR1 and FR2 provided in TR 38.840 (sections 8.1.1, 8.1.2, 8.1.3) as appropriate.
* For evaluation of UE power saving, for wearables, use the traffic models FTP model 3 and VoIP from TR 38.840 to characterize the wearables service types including IM, VoIP, heartbeat, etc. with proper modification of at least packet size and mean inter-arrival time. Values are FFS.
* For evaluation of UE power saving, for industrial wireless sensor use cases, use a traffic model based on the service performance requirements for the process monitoring use case in TS 22.104 Table 5.2-2. At least 64 bytes UL message (plus headers, e.g. MAC, RLC, etc.) transmitted periodically with a periodicity 100 ms should be considered (other values are encouraged).

## **RAN1 #102 e-meeting**

Agreements:

* Use the VoIP traffic model from TR 38.840 as baseline. Other VoIP traffic models are not precluded and companies to report if other VoIP traffic models are assumed in evaluation.

Agreements:

For power saving evaluation of RedCap UEs:

* Reuse the Instant message traffic model from TR 38.840 as baseline. Other ~~Instant~~ traffic models based on FTP model 3 are not precluded and companies to report the mean inter-arrival time and packet size if other ~~instant~~ traffic models are assumed in evaluation.
* FFS: ‘heartbeat’ traffic model

Agreements:

* The scaling factor ‘0.7’ is used for 2 Rx to 1Rx power scaling for power reduction related evaluation.
* For evaluation, the power scaling for PDCCH candidate reduction defined in TR 38.840 is reused for Redcap UEs.
* For power consumption evaluation, the DRX configurations of Instant message and VoIP in TR 38.840 are reused.
* Discussion on reduced maximum number of configurable CORESET technique for power saving is deprioritized in the Redcap power saving sub-agenda
* For power consumption evaluation, use FTP-3 model with 100 Bytes packet size and 60s mean inter-arrival time as baseline for ‘heartbeat’ traffic.
* For power consumption evaluation, reuse the following DRX configuration defined in TS 38.840 for ‘heartbeat’ traffic model:
* C-DRX cycle 640 msec, inactivity timer {200, 80} msec
* FR1 On duration: 10 msec
* FR2 On duration: 5 msec

Agreements: For the PDCCH blocking rate evaluation, at least the following parameters are assumed as baseline:

|  |  |
| --- | --- |
| Parameters | Assumptions |
| Number of candidates for each AL | Each company to report. |
| SCS/BW | FR1: 30KHz/20MHz   * 15kHz/20MHz is optional   FR2: 120KHz/[100]MHz |
| CORESET duration | 2 symbols, with 3 symbols optional |
| Delay toleration (Slot) | 1 (1: implies that PDCCH is blocked if it can’t be scheduled in the given slot), with 2 optional |
| Aggregation level Distribution | Companies to report (including the necessary UE channel conditions and deployment scenario(s) for the aggregation level distribution) |

Agreements: For Redcap power consumption evaluation:

* Note that 2RX is assumed

|  |  |
| --- | --- |
| Power State | Alt.4a |
| Deep Sleep (PDS) | 0.8 |
| Light Sleep (PLS) | 18 |
| Micro sleep (PMS) | 31 |
| PDCCH-only (PPDCCH) | 50 for same-slot scheduling,  40 for cross-slot scheduling |
| PDCCH + PDSCH (PPDCCH+PDSCH) | 120 |
| PDSCH-only (PPDSCH) | 112 |
| SSB/CSI-RS proc. (PSSB) | 50 |
| Intra-frequency RRM measurement (Pintra) | ·        [60]Note4 (synchronous case, N=8, measurement only)  ·        [80]Note4 (combined measurement and search) |
| Inter-frequency RRM measurement (Pinter) | [60]Note4 (neighbor cell search power per freq. layer)  ·       [~~150~~80] Note4 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer |

Working assumption:

Adopting the following rule for power determination

* Rule 1: ‘Micro sleep’ power of 1 Rx is [0.8]x2 Rx ‘Micro sleep’ power
* Rule 2: For both 1 Rx and 2 Rx configuration,
* P(α) = max (Micro-sleep, α ∙ Pt + (1 – α) ∙ 0.7Pt))
* Pt is the PDCCH-only power for same slot and cross-slot scheduling cases.

**Conclusion**: It is up to each company to report the power consumption modeling for 3-symbols CORESET configuration and reduced number of non-overlapped CCEs.