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

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

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

**Title: Feature lead summary #2 on reduced PDCCH monitoring**

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

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

# 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

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 8.2.1 Description of featureThe 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 $Y<3$.

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 $X>1,$ 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 YesScheme 2 NoScheme 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 $Y<3$. 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 $X>1,$ 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.
 |

## 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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 |  |
| 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 8 |
| 0.75% | 1.53% | 0.21% | 0.41% | 0.18% | 0.36% | 2.75% | 5.24% | S1 |
| 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  | - | 6.4% | - | 4.75% | - | - | - | - | S1 | Note 1, Note 3, Note 10 |
| - | 6.2% | - | 4.16% | - | - | - | - | S1 | Note 1, Note 3, 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 2, Note 12 |
| Samsung | 4.50% | 9% | 2.70% | 5.50% | 2.60% | 5.10% | 4.50% | 3.5% | S3 |  |
| 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, assumign cell center UE.Note 4: ‘S1’ represents Scheme#1, ‘S2’ represents Scheme#2, ‘S3’ represents Scheme#3Note 5: DL (50%) + UL (50%)Note 6: DL-onlyNote 7: slots "DDDU",Note 8: The blocking rate in Table 16A is assumed for corresponding cases.Note 9 : Wake-Up Signal (WUS)Note 10: TDD: DDDDDDDSUUNote 11: TDD: DDDSUDDSUUNote 12: $X=2$ |

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 |  |
| 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 |
| 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 8 |
| 0.82% | 1.63% | 0.24% | 0.47% | 0.21% | 0.41% | 2.85% | 5.70% | S1 |
| 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 | - | 6% | - | 4.13% | - | - | - | - | S1 | Note 1, Note 3, Note 10 |
| - | 4.9% | - | 4.04% | - | - | - | - | S1 | Note 1, Note 3, 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 2, Note 12 |
| Samsung | 4.50% | 6.90% | 2.70% | 4.20% | 2.50% | 3.90% | 3.50% | 5.30% | S3 |  |
| 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#3Note 5: DL (50%) + UL (50%)Note 6: DL-onlyNote 7: slots "DDDU",Note 8: The blocking rate in Table 16A is assumed for corresponding cases.Note 9 : Wake-Up Signal (WUS)Note 10: TDD: DDDDDDDSUUNote 11: TDD: DDDSUDDSUUNote 12: $X=2$ |

**Proposal 8.2.2.1-1: Incorporate the above Table 2 and Table 3 into text proposal for the Redcap TR. If not, what changes to the Tables are needed in order to add it into Redcap TR 38.875? 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 the separate Tables for Scheme 2/3 were merged into Table 2/3 for 1 and 2 Rx cases to reflect comments received in Monday Morning GTW session. Correspondingly, one new column “Scheme” is added in Table 2/3 to capture the associated scheme for each evaluation result clearly.

|  |  |  |
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| **Company** | **Y/N** | **Comments** |
| CATT | Y |  |
| LG | Y | We are okay with the tables. But, depending on the discussion on the **Proposal 8.2.1-1**, the results for Schemes 2/3 may need to be removed. |
| vivo |  | 1. For vivo simulation results, we updated the Notes to reflect the simulated scheme more accurately

Table 2: Power Saving gain, FR1, 1 Rx antennaTable 3: Power Saving gain, FR1, 2 Rx antenna1. About Note 8, we are not sure whether and how blocking rate is modelled in the power consumption evaluation? Blocking is a separate issue and is typically not considered in the power consumption evaluation.
 |

**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 key question would be how to determine the value of Xx/Yy value based on evaluation results from different companies (common for FR1 and FR2) purely for ‘observation’ section to derive representative Xx/Yy values:

* How to handle the lowest and highest value?
* How to draw observations for schemes with one or two companies results?

**Q 8.2.2.1-1: Does the draft observation above by FL can be added into text proposal for the Redcap TR 38.875 with continue discussing X/Y values? If yes, what representative Xx/Yy values can be used for different traffic models for each scheme?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| CATT | Y | The average value excluding the smallest and the largest values among companies can also be captured in the TR in order to provide more valuable information on the power saving gain. Additionally, the smallest value and largest value among companies can be the xx/yy value to provide the supplementary information on power saving gain. |
| LG | Y | Xx and Yy can be the minimum and maximum value based on evaluation results from different companies. For observations for the schemes from one or two companies, it is recommended to mention only a few companies brought this observations. |
| vivo |  | The formulation is fine but only mentioned scheme#1. We are wondering if separate observation will be proposed for scheme#2, or the intention is to have a general observation covers both schemes? |

**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. |
|  |  |

### 8.2.2.2 FR2 Results

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 2Note 6 |
| Samsung  | 6.30% | 12.70% | 4.20% | 8.30% | 3.90% | 7.60% | 6.50% | 13.10% | S1 |  |
| 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  |   | 10.62% |   | 7.94% |   |   |   |   | S1 | Note 1 Note 3Note 7 |
| ZTE | 5.76% | 11.52% | 3.55% | 7.11% | 3.09% | 6.18% |   |   | S1 | Note 1 Note 6 |
| Samsung  | 6.30% | 12.70% | 4.20% | 8.30% | 3.90% | 7.60% | 6.50% | 13.10% | S3 |  |
| 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, assumign cell center UE.Note 4: ‘S1’ represents Scheme#1, ‘S2’ represents Scheme#2, ‘S3’ represents Scheme#3Note 5: DL (50%) + UL (50%)Note 6: DL-onlyNote 7: TDD: DDDSUDDDSU |

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 2Note 6 |
| Samsung | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S1 |  |
| 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 | - | 9.73% | - | 7.80% | - | - | - | - | S1 | Note 1 Note 3 Note7 |
| ZTE | 6.01% | 12.03% | 4.03% | 8.07% | 3.64% | 7.29% | - | - | S1 | Note 1Note 6 |
| Samsung | 6.60% | 13.20% | 4.90% | 9.60% | 4.60% | 8.90% | 6.80% | 13.70% | S3 |  |
| 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#3Note 5: DL (50%) + UL (50%)Note 6: DL-onlyNote 7: TDD: DDDSUDDDSU |

**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. |

**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 |
|  |  |
|  |  |
|  |  |

## 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 optionalFR2: 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 scheduledin 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 | 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 ALsNote 3: Each UE is configured with a single ALNote 4: Reference case：2；50% BD reduction case:1Note 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 coverageNote 9: Medium coverageNote 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 | 10 | 1 | C10 | 0.20% | C13 | 0.20% | C12 | 0.20% |  |
| C1 | 15 | 1 | C10 | 1.80% | C13 | 1.80% | C12 | 1.80% |  |

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: 32 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 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 | Good coverage |
| C1 | 4 | 2 | C7 | 0.0008 | C10 | 0.0008 | C9 | 0.0062 | Good coverage |
| C1 | 6 | 2 | C7 | 0.003 | C10 | 0.0049 | C9 | 0.0134 | Good coverage |
| C1 | 8 | 2 | C7 | 0.007 | C10 | 0.0112 | C9 | 0.0226 | Good coverage |
| C1 | 2 | 2 | C7 | 0 | C10 | 0 | C9 | 0.0006 | Good coverage |
| C1 | 4 | 2 | C7 | 0.0003 | C10 | 0.0005 | C9 | 0.0029 | Good coverage |
| C1 | 6 | 2 | C7 | 0.0015 | C10 | 0.0025 | C9 | 0.0067 | Good coverage |
| C1 | 8 | 2 | C7 | 0.0037 | C10 | 0.0061 | C9 | 0.0118 | Good coverage |
| C1 | 2 | 2 | C7 | 0 | C10 | 0 | C9 | 0.0004 | Good coverage |
| C1 | 4 | 2 | C7 | 0.0003 | C10 | 0.0004 | C9 | 0.0022 | Good coverage |
| C1 | 6 | 2 | C7 | 0.0008 | C10 | 0.0016 | C9 | 0.0046 | Good coverage |
| C1 | 8 | 2 | C7 | 0.0024 | C10 | 0.004 | C9 | 0.0084 | Good coverage |
| C2 | 2 | 2 | C8 | 0 | C10 | 0.0076 | C9 | 0.0202 | Med coverage  |
| C2 | 4 | 2 | C8 | 0.0248 | C10 | 0.0428 | C9 | 0.0901 | Med coverage  |
| C2 | 6 | 2 | C8 | 0.1023 | C10 | 0.1114 | C9 | 0.1691 | Med coverage  |
| C2 | 8 | 2 | C8 | 0.1823 | C10 | 0.1888 | C9 | 0.2453 | Med coverage  |
| C3 | 2 | 2 | C9 | 0 | C10 | 0.0003 | C9 | 0.0003 | Poor coverage  |
| C3 | 4 | 2 | C9 | 0.2358 | C10 | 0.2432 | C9 | 0.2661 | Poor coverage  |
| C3 | 6 | 2 | C9 | 0.3939 | C10 | 0.395 | C9 | 0.4155 | Poor coverage  |
| C3 | 8 | 2 | C9 | 0.4895 | C10 | 0.4918 | C9 | 0.515 | Poor coverage  |

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:1Note 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 above1. 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.
 |

**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.  |
|  |  |

#### **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 2, 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 2, 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 2, 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 2: Analog BeamformingNote 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 coverageNote 6: Medium coverageNote 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. |

**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 |
|  |  |
|  |  |

### 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 |
|  |  |

## 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.  |
|  |  |
|  |  |

## 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 S2For 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.  |

# 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 [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] | ~~15~~ 16 |
| 2 | vivo[6], Fraunhofer HHI[26],  | 2 |
| 3 | NEC[16] ,Samsung[17], Lenovo [19] CATT[8] | ~~3~~ 4 |
| 4 (Remain same as in Rel-15/16) | Futurewei [3], Nokia [13], MTK [22], LG[12] | ~~3~~ 4 |

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# 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.