3GPP TSG-RAN WG1 Meeting #101-e Tdoc R1-20xxxxx

e-Meeting, May 25th – June 5th, 2020

**Agenda Item: 8.3**

**Title: Email discussion for Study on support of reduced capability NR devices (Step 2)**

**Source: Rapporteur (Ericsson)**

**Document for: Discussion, Decision**

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# 1 Introduction

This document captures the 2nd step of the RAN1#101e email discussion [101-e-NR-RedCap-01] for the study item “Study on support of reduced capability NR devices” [1]. This email discussion focusses on high-level topics and evaluation assumptions necessary to facilitate next step’s more concrete analysis and evaluations.

The section numbering in this document follows the proposed TR skeleton [2]. The TR skeleton itself is discussed separately in email discussion [101-e-NR-RedCap-Skeleton].

# 5 Requirements

Regarding Question 1, most responses indicate that the requirements are generally sufficiently clear, but some clarifications are proposed. The proposals supported by more than one individual response are the following:

* Clarify that the reference bitrate is typical bitrate and not the cell-edge bitrate.
* Add cell-edge bit rate requirements.
* Add requirements for low-end wearables.
* Clarify that the 5-10 ms latency requirement for safety-related sensors should be considered for UEs in RRC\_CONNECTED.

Based on the proposals listed above, the following proposals can be considered.

**Proposal 1: Reference bit rate is assumed to correspond to typical (i.e. median) bit rate, not cell-edge bit rate.**

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| **Company** | **Agree (Y/N)** | **Comments** |
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**Proposal 2: There is no need to introduce new requirements on cell-edge bit rate, as cell-edge bit rates will be determined as part of the simulation assumptions.**

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**Proposal 3: The bit rates requirements indicated for smart wearable applications are assumed to correspond to high-end applications. For low-end wearables, lower bitrates can be assumed, e.g. 2-5 Mbps reference bit rate in DL and UL and 10 Mbps peak bit rate in DL and UL.**

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**Proposal 4: For safety related sensors, latency requirements apply to traffic initiated from RRC\_CONNECTED.**

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# 6 Evaluation methodology

## 6.1 Evaluation methodology for UE complexity reduction

Regarding Question 2, most responses seem to agree that the UE cost/complexity reduction evaluation methodology in TR 36.888 can be used as a starting point or baseline that can be updated to take FR1/FR2 specific aspects and technology progress into account.

**Proposal 5: Use the TR 36.888 methodology for UE cost/complexity evaluation as a starting point and determine what major updates are needed.**

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One response points out that there is no specific cost reduction target (unlike when TR 36.888 was produced) and therefore precise cost estimation may not be necessary. Some responses seem to suggest that a simplified approach with only rough cost estimates may be enough. (See also the related discussion in section 7.7 in this document.)

**Proposal 6: Since there is no specific cost reduction target, cost/complexity estimation for the combinations of different complexity reduction techniques is down prioritized for this meeting.**

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Regarding Question 3, most responses seem to agree that antenna parts should be included in the cost/complexity evaluation for FR2. Some responses list potential aspects of antenna parts or antenna-near parts, e.g. ADC/DAC, PAs, filters, beamforming network, polarization, antenna panels and antenna panel elements. A few responses want to include the antenna parts also in FR1.

Several responses propose to define separate reference modems with separate cost breakdowns for FR1 and FR2. Among the aspects that are expected to differ between FR1 and FR2 are the mentioned antenna parts and the impacts of different subcarrier spacings.

**Proposal 7: Define separate reference modems with separate cost/complexity breakdowns for FR1 and FR2.**

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**Proposal 8: Include antenna parts at least in the cost/complexity breakdown for FR2.**

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Regarding Question 4, the responses can be summarized as follows:

* **Features:** Most responses seem to agree that the reference NR device should correspond to an NR UE that supports all mandatory Rel-15 NR features including mandatory features with capability signaling. A few responses suggest including some Rel-16 features for e.g. power saving and positioning or excluding some mandatory features with capability signaling.
* **RATs:** A few responses propose that the reference device only supports one RAT, i.e. NR.
* **Bands:** Some responses propose that the reference NR devices should support a single band, whereas one response proposes that it supports multiple bands (e.g. FDD band 14 + TDD band 10).
* **Bandwidths:** Many responses propose 100 MHz for FR1 and 200 MHz for FR2. A couple of responses propose that the maximum bandwidth supported by the reference NR device should be the maximum bandwidth supported for the band, e.g. 70 MHz for FR1 FDD, 100 MHz for FR1 TDD, and 400 MHz for FR2. One response proposes that the reference NR device also supports the smaller bandwidths supported for the band.
* **Duplex modes:** One response proposes to only define reference NR devices for FR1 FDD and FR2 TDD, not for FR1 TDD, with the motivation that the cost difference between FR1 FDD and FR1 TDD can be expected to be small.
* **Antennas:** The responses mention 4Rx/2Tx, 4Rx/1Tx and 2Rx/1Tx. Some responses point to the minimum requirements in TS 38.101 and propose 4Rx/1Tx for FR1 bands {n7, n38, n41, n77, n78, n79} and 2Rx/1Tx for all other FR1/FR2 bands.
* **Power class:** A few responses propose to assume UE power class 3 (PC3).
* **Processing time:** A few responses propose to assume UE processing time capability 1.
* **Modulation:** A few responses propose that the reference NR device supports up to 64QAM in DL and UL. One of them thinks that 256QAM can also be considered in DL.
* **Access:** A couple of responses propose to clarify that access is direct DL/UL access between UE and gNB.

Furthermore, one response proposes to also define a reference NR device with 2Rx/1Tx and 20 MHz in order to have a reference NR device that matches LTE Cat-1 which was used as a reference LTE device in TR 36.888.

**Proposal 9: The reference NR device supports the following:**

* **All mandatory Rel-15 features (with or without capability signaling)**
* **Single RAT**
* **Single band**
* **Maximum bandwidth:**
  + **For FR1: 100 MHz for DL and UL**
  + **For FR2: 200 MHz for DL and UL**
* **Duplex mode:**
  + **For FR1: FD-FDD**
  + **For FR2: TDD**
* **Antennas:**
  + **For FR1 bands {n7, n38, n41, n77, n78, n79}: 4Rx/1Tx**
  + **For all other FR1/FR2 bands: 2Rx/1Tx**
* **Power class: PC3**
* **Processing time: Capability 1**
* **Modulation: QPSK to 64QAM for DL and UL**
* **Access: Direct DL/UL access between UE and gNB**

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Regarding Question 5, many responses acknowledge that there may be important benefits in terms of device size or form factor, but most responses seem to agree that there is no need to try to quantify the potential reduction in device size. Perhaps a reasonable ambition level is to mention such benefits in the TR clauses where they are most prominent, e.g. when discussing reduced number of antennas.

**Proposal 10: Potential benefits in terms of reduced device size can be mentioned where applicable in the TR (e.g. in the section on reduced number of antennas), but the SI will not aim to quantify such benefits.**

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## 6.2 Evaluation methodology for UE power saving

Regarding Question 6, responses generally agree that the power consumption model, scaling factors, and simulations assumptions from TR. 38.840 (section 8) can be reused. However, suitable parameter values (e.g., number of antennas, UE BW, modulation order, MIMO configurations) should be considered based on RedCap UE capabilities.

**Proposal 11: Reuse the power consumption models and scaling factors for FR1 and FR2 provided in TR 38.840 (sections 8.1, 8.2, 8.3).**

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**Proposal 12: The reference UE in the power saving evaluation is a RedCap UE defined by e.g. maximum UE channel bandwidth, number of Tx/Rx antennas, modulation order, PDCCH monitoring parameters and MIMO configuration. Values are FFS.**

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A few responses note that the according to the SID, the RAN1 focus for the UE power saving features should be relaxed PDCCH monitoring (number of BD and CCE limits).

**Proposal 13: The power saving evaluation in RAN1 focuses on the power saving from relaxed PDCCH monitoring (whereas the power saving for the SI objectives on Extended DRX and RRM relaxation is expected to be evaluated in RAN2).**

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Regarding Question 7, most responses agree to reuse the traffic model from TR 38.840 with proper parameters for packet size, mean inter-arrival time. One response mentions that Extended DRX parameter may need to be adjusted. Another response notes that the traffic model for connected mode can be reused.

**Proposal 14: For wearables, use the traffic model from TR 38.840 with proper modification of at least packet size and mean inter-arrival time for RedCap use cases. Values are FFS.**

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Regarding Question 8, responses generally agree to reuse traffic model from TS 22.104 for industrial wireless sensor use cases. Two responses suggest considering parameters of process monitoring use case in Table 5.2-2 from TS 22.104. One response suggests reusing the Mobile Autonomous Reporting (MAR) traffic mode in TR 45.820 with appropriate adjustment if needed.

**Proposal 15: For industrial wireless sensor use cases, use the traffic model from TS 22.104 (Table 5.2-2). For the relevant parameters such as message size and transfer interval, the values for the process monitoring use case are prioritized.**

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## 6.3 Evaluation methodology for coverage recovery

Regarding Question 9, most responses express support for using the IMT-2020 methodology. In addition, several responses prefer to align with the CE SI, e.g. to avoid duplication of work in the two parallel SIs.

The input to mail discussion [101-e-NR-Cov-Enh] concerning link budget template also indicates that most responses favour the IMT-2020 methodology.

**Proposal 16: Base the coverage analysis on the IMT-2020 self-evaluation methodology.**

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Regarding Question 10, most responses prefer to perform a complete study of all relevant DL and UL channels and/or align with the CE SI. A few responses propose that beside PDCCH/PDSCH/PUSCH/PUCCH, we should consider SSB, PRACH, message 2 PDCCH, message 2 PDSCH, message 3 PUSCH, and beam switching reliability in FR2

So far, the CE SI has not agreed on a concrete set of simulations assumptions. Based on this, two alternatives are proposed:

**Proposal 17: For coverage analysis, down select between the following options during RAN1#101e:**

1. **Align with the CE SI and perform the coverage analysis on the set of signals, channels and messages agreed to be within the scope of the CE SI.**
2. **Use a link budget approach taking all relevant DL and UL channels into account; including PSS/SSS, PBCH, PDCCH, PDSCH, PRACH, PUCCH, PUSCH, SIB1, Paging, RAR, Message-3, Message-4, and Message-5.**

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| **Company** | **Agree (Y/N)** | **Option (1/2)** | **Comments** |
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Regarding Question 11, there is support for alignment of quality targets and performance metrics with the CE SI, but several responses suggest that certain adaptations are necessary e.g. to BLER targets to accommodate a different SINR operating point compared to that assumed in the CE SI. Based on this it is suggested to await an agreement in the CE SI and continue the discussions on targeted data rates and BLER levels once that is available. In best case the CE SI will reach an agreement during the ongoing RAN1#101e meeting based on which this document can be updated.

Regarding Question 12, again, there is support for alignment of simulation assumptions with the CE SI and based on this its suggested to await an agreement in the CE SI, and hopefully resume this discussion later during RAN1#101e.

**Proposal 18: Await agreements in the CE SI regarding simulation assumptions, quality targets and performance metrics before proceeding with proposals in the RedCap SI.**

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Regarding Question 13, most responses prefer to focus on the “Hardware link budget”.

**Proposal 19: The RedCap SI determines the “Hardware link budget” following the IMT-2020 self-evaluation methodology according to the below template, where items related to the “Maximum range” have been deleted (using track changes for traceability) and the table has been adapted to support any studied signal, channel or message (not necessarily only data and control channels).**

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| **Parameter** | | **Values** | | | |
| Scenario | |  | | | |
| Frame structure | |  | | | |
| Carrier frequency (Hz) | |  | | | |
| Transmission bit rate (bit/s) | |  | |
| Target packet error rate for the required SNR in item (19a) | |  | |
| Spectral efficiency (bit/s/Hz) | |  | |
| UE speed (km/h) | |  | |
| Feeder loss (dB) | |  | |
| **Transmitter** | | | |
| (1) Number of transmit antennas. (The number shall be within the indicated range in § 8.4 of Report ITU-R M.2412-0) | |  | |
| (1bis) Number of transmit antenna ports | |  | | | |
| (2) Maximal transmit power per antenna (dBm) | |  | | | |
| (3) Total transmit power = function of (1) and (2) (dBm) (The value shall not exceed the indicated value in § 8.4 of Report ITU-R M.2412-0) | |  | | | |
| (4) Transmitter antenna gain (dBi) | |  | | |
| (5) Transmitter array gain (depends on transmitter array configurations and technologies such as adaptive beam forming, CDD (cyclic delay diversity), etc.) (dB) | |  | | |
| (6) Channel power boosting gain or loss (dB) |  | | | |
| (8) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for downlink) |  | | | |
| (9a) EIRP = (3) + (4) + (5) + (6) – (8) dBm |  | | | |
| **Receiver** | | | | |
| (10) Number of receive antennas (The number shall be within the indicated range in § 8.4 of Report ITU-R M.2412-0) |  | | | |
| (10bis) Number of receive antenna ports |  | | | |
| (11) Receiver antenna gain (dBi) |  | | | |
| (11bis) Receiver array gain (depends on transmitter array configurations and technologies such as adaptive beam forming, etc.) (dB) |  | | | |
| (12) Cable, connector, combiner, body losses, etc. (enumerate sources) (dB) (feeder loss must be included for and only for uplink) |  | | | |
| (13) Receiver noise figure (dB) |  | | | |
| (14) Thermal noise density (dBm/Hz) |  | | | |
| (15a) Receiver interference density (dBm/Hz) |  | | | |
| (16a) Total noise plus interference density = 10 log (10^(((13) + (14))/10) + 10^((15a)/10)) dBm/Hz | |  |
| (17a) Occupied channel bandwidth (for meeting the requirements of the traffic type) (Hz) | |  |
| (18a) Effective noise power = (16a) + 10 log((17a)) dBm | |  | |
| (19a) Required SNR (dB) | |  | |
| (20) Receiver implementation margin (dB) | |  | |
| (21a) H-ARQ gain (dB) | |  | |
| (22a) Receiver sensitivity = (18a) + (19a) + (20) – (21a) dBm | |  | |
| (23a) Hardware link budget = (9a) + (11) + (11bis) − (22a) dB | |  |

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Several responses would in addition like to see a maximum coupling loss (MCL) calculation added to the link budget.

**Proposal 20: Add one final row supporting the calculation of the maximum coupling loss (MCL), which is defined as the total transmitted power minus receiver sensitivity, as measured at the antenna connectors, i.e. = (3) - (22a).**

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## 6.4 Evaluation methodology for other performance impacts

Regarding Question 14, most responses agreed that the evaluation of other performance impacts (than the ones mentioned in previous sections) can focus on data rate, latency, and coexistence with legacy UEs. Some responses wanted to clarify that data rate meant peak data rate. Several responses indicated that if e.g. problems or other issues are identified, it would be good to be able to add further metrics.

**Proposal 21: The evaluation of the other performance impacts focusses on at least peak data rate, latency, and coexistence with legacy UEs. Other performance metrics are not precluded.**

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# 7 UE complexity reduction features

## 7.1 Introduction to UE complexity reduction features

Sections 7.2 through 7.6 discuss the high-level topics for the main UE complexity reduction features. Combinations of these features are discussed in section 7.7.

## 7.2 Reduced number of UE Rx/Tx antennas

Regarding Question 15, the responses indicate a clear preference for studying 1Rx/1Tx and 2Rx/1Tx implementations. Beyond this there is some limited interest in supporting additional aspects related to the antenna.

**Proposal 22: For FR1, study two antenna configurations for RedCap UEs, namely 1Rx/1Tx and 2Rx/1Tx.**

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Regarding Question 16, many responses indicate a clear preference for studying 2Rx/1Tx. In addition, several responses propose to include a study of 1Rx/1Tx.

**Proposal 23: For FR2, study two antenna configurations for RedCap UEs, namely 1Rx/1Tx and 2Rx/1Tx.**

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## 7.3 UE bandwidth reduction

Regarding Question 17, most responses support prioritizing 20 MHz UE bandwidth for FR1. A few responses are fine with considering 20 MHz UE bandwidth as the baseline, but also open to considering 10 MHz or other lower bandwidths. Several responses prefer to include both 20 MHz and 10 MHz in the study.

**Proposal 24: For FR1, down select between the following options during RAN1#101e:**

1. **Study only 20 MHz maximum UE bandwidth.**
2. **Study both 20 MHz and 10 MHz maximum UE bandwidths.**

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Regarding Question 18, many responses suggest studying both 50 MHz and 100 MHz UE bandwidth for FR2. Other proposals with support from a few responses each include study of 50 MHz only, study of 80-100 MHz only, and study of both 40-60 MHz and 80-100 MHz. Proposals with support from one response each include study of 100 MHz only, study of the range 50-100 MHz, and study of >100 MHz.

**Proposal 25: For FR2, study both 50 MHz and 100 MHz UE bandwidths.**

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## 7.4 Half-duplex FDD operation

Regarding Question 19, many responses or propose to prioritize the HD-FDD operation type that is in LTE known as Type A. Many indicate that there is no strong motivation to study HD-FDD devices with single PLL/LO due to marginal cost saving. Almost as many responses suggest both Type A and Type B are included in the study. A few responses argue that the small cost reduction of HD-FDD cannot justify the study.

**Proposal 26: Down select between the following options during RAN1#101e:**

1. **Study only HD-FDD operation Type A.**
2. **Study both HD-FDD operation Type A and Type B.**

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Many responses suggest the values of DL-to-UL and UL-to-DL guard periods should be determined by RAN4.

**Proposal 27: Let RAN4 determine the values of DL-to-UL and UL-to-DL guard periods, if needed.**

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## 7.5 Relaxed UE processing time

Regarding Question 20, most responses share the view that a more relaxed UE processing time capability in terms of N1/N2 compared to capability #1 should be studied, including impacts on latency, scheduling flexibility (e.g. cross-slot scheduling restriction), power saving, specifications (e.g. PDSCH/PUSCH TDRA tables), and dependency on PDCCH monitoring relaxation.

Some responses do not support the study, highlighting that it is unclear how much cost reduction can be attained and that the relaxation will impose a limitation on the application of low-latency use cases.

**Proposal 28: Study a more relaxed UE processing time capability in terms of N1/N2 compared to capability #1, including the impacts on latency and scheduling flexibility (at least qualitatively).**

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| **Company** | **Agree (Y/N)** | **Comments** |
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Regarding Question 21, many responses express views to study different aspects of other relaxed UE processing time. Some of them, including cross-slot scheduling, HARQ RTT relaxation, and PDCCH processing time can potentially be interpreted as being part of the proposed study on relaxed N1/N2.

Regarding CSI computation time, several responses proposed that it can be studied. It was however mentioned that there is a dependency on potential reduction of the number of UE antennas and MIMO layers.

**Proposal 29: Study relaxed CSI computation time as a complexity reduction technique through relaxed UE processing time.**

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| **Company** | **Agree (Y/N)** | **Comments** |
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## 7.6 Relaxed UE processing capability

Regarding Question 22, most responses suggest that relaxation on peak data rate via the following techniques may be beneficial and should be studied.

* Restriction on the maximum TBS size
* Maximum modulation order restriction
* Reducing the maximum number of MIMO layers

However, a few responses note that if it is desired to address all use cases using a single RedCap UE type, then the potential for cost/complexity reduction may be limited. Furthermore, a few responses point out that the studies of reduced BW and reduced number of antennas should be prioritized before considering the peak rate relaxation that would not necessarily contribute significantly to additional cost/complexity reduction.

A few responses further suggest that it may be beneficial to relax the maximum number of supported HARQ processes, while one response notes that there are no soft buffer requirements in NR, and hence it is not clear whether it is necessary or beneficial to reduce the number of HARQ processes. Furthermore, it is pointed out that a larger number of HARQ processes may be necessary to recover throughput losses in TDD or HD-FDD operations.

A few responses also note that CA support could may be beneficial for meeting the peak data rate requirements, while one response argues that CA should not be supported.

**Proposal 30:** **Study peak data rate relaxation and focus on:**

* **Restriction on the maximum TBS size**
* **Maximum modulation order restriction**
* **Reducing the maximum number of MIMO layers**

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Regarding Question 23, several responses indicate that processing capability relaxation based on CSI measurement/feedback/reporting relaxation for FR1/FR2 and beam management simplification for FR2 should be studied.

However, many responses also think that further UE processing capability relaxations are not needed or that such studies should have low priority.

**Proposal 31: Study of CSI measurement/feedback/reporting relaxation for FR1/FR2 and beam management simplification for FR2 is not prioritized.**

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| **Company** | **Agree (Y/N)** | **Comments** |
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## 7.7 Combinations of UE complexity reduction features

Regarding Question 24, several responses express a preference to postpone this discussion to e.g. first gain an understanding of the individual cost reducing techniques. Based on this it is suggested to come back to this topic at the next meeting. (See also the related discussion in section 6.1 in this document.)

**Proposal 32: Discussion on combinations of UE complexity reduction features is down prioritized till the next meeting.**

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# 8 UE power saving and battery lifetime enhancement

## 8.1 Reduced PDCCH monitoring

Regarding Question 25, several responses discuss various techniques for reducing the number of blind decodes and CCEs including reduction of: 1) the number of different DCI sizes (i.e., DCI size budget), 2) number of ALs and PDCCH candidates, 3) number of search spaces and CORESETs monitored by UE, and 4) defining BD/CCE limits per extended span gap (e.g., multi-slot). A few responses request a clarification of whether limiting the BD and CCE by configuration is not enough.

Regarding Question 26, based on the responses from the responses, the impact of BD and CCE limits reduction at least on the PDCCH blocking probability should be studied. In addition, the impact on the latency (for latency-sensitive use cases, e.g., safety-related sensors) and scheduling flexibility can be studied.

**Proposal 33: Study the impact of BD and CCE limits reduction on PDCCH blocking probability (quantitatively) and resulting impacts on latency and scheduling flexibility (at least qualitatively).**

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Regarding Question 27, there does not seem to be consensus that any other techniques for relaxed PDCCH monitoring than smaller numbers of blind decodes and CCE limits should be studied for UE power saving.

**Proposal 34: Study of other techniques for relaxed PDCCH monitoring than smaller numbers of blind decodes and CCE limits for UE power saving is not prioritized.**

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| **Company** | **Agree (Y/N)** | **Comments** |
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# 9 Other comments

Comments that do not fit in any of the previous sections of this document can be provided in this section. Note that the TR skeleton is discussed in a separate email discussion [101-e-NR-RedCap-Skeleton].

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