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Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on support of reduced capability NR devices
(Release 17)

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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

can indicates that something is possible

cannot indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

1 Scope

This document captures the findings from the study item "Study on support of reduced capability NR devices" [2].

The study includes identification and study of potential UE complexity reduction techniques and UE power saving and battery lifetime enhancements for reduced capability UEs in applicable use cases, functionality that will enable the performance degradation of such complexity reduction to be mitigated or limited, principles for how to define and constrain such reduced capabilities, and functionality that will allow devices with reduced capabilities to be explicitly identifiable to networks and networks operators and allow operators to restrict their access if desired.

The scope of the study includes support for all FR1/FR2 bands for FDD and TDD and coexistence with Rel-15/16 UEs. This study focuses on SA mode and single connectivity. The scope of the study does not include LPWA use cases.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP RP-201677: "Revised SID on support of reduced capability NR devices".

[3] 3GPP R1-2009293: "FL summary on RedCap evaluation results".

[4] 3GPP TR 36.888: "Study on provision of low-cost Machine-Type Communications (MTC) User Equipments (UEs) based on LTE".

[5] 3GPP TR 38.830: "Study on NR coverage enhancements".

[6] 3GPP TR 38.840: "Study on User Equipment (UE) power saving in NR".

[7] 3GPP R1-070674: "LTE physical layer framework for performance verification", Orange, China Mobile, KPN, NTT DoCoMo, Sprint, T-Mobile, Vodafone, Telecom Italia.

[8] 3GPP R2-2009116: "Further considerations for eDRX", MediaTek.

[9] 3GPP R2-2009620: "RedCap power saving enhancements", Ericsson.

[10] 3GPP R2-2100459: "TP for TR 38875 on evaluation for RRM relaxation", vivo, Guangdong Genius.

[11] 3GPP R2-2101257: "RRM measurement relaxation for RedCap UE", Huawei, HiSilicon.

[12] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

RedCap UE: For convenience only, a RedCap UE refers to an NR UE with reduced capabilities with details described herein.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

<ABBREVIATION> <Expansion>

4 Introduction

The usage scenarios that have been identified for 5G are *enhanced mobile broadband* (eMBB), *massive machine-type communication* (mMTC), and *Ultra-Reliable and Low Latency communication* (URLLC). Yet another identified area is *time sensitive communication* (TSC). In particular, mMTC, URLLC and TSC are associated with novel IoT use cases that are targeted in vertical industries. It is envisaged that eMBB, mMTC, URLLC and TSC use cases may all need to be supported in the same network.

In the 3GPP study on "*self-evaluation towards IMT-2020 submission*" it was confirmed that NB-IoT and LTE-MTC (a.k.a. eMTC) fulfil the IMT-2020 requirements for mMTC and can be certified as 5G technologies. For URLLC support, URLLC features were introduced in Release 15 for both LTE and NR, and NR URLLC is further enhanced in Release 16 within the enhanced URLLC (eURLLC) and Industrial IoT work items. Rel-16 also introduced support for Time-Sensitive Networking (TSN) and 5G integration for TSC use cases.

1. One important objective of 5G is to enable connected industries. 5G connectivity can serve as catalyst for next wave of industrial transformation and digitalization, which improve flexibility, enhance productivity and efficiency, reduce maintenance cost, and improve operational safety. Devices in such environment include e.g. pressure sensors, humidity sensors, thermometers, motion sensors, accelerometers, actuators, etc. It is desirable to connect these sensors and actuators to 5G radio access and core networks. The massive industrial wireless sensor network (IWSN) use cases and requirements described in TR 22.804, TS 22.104, TR 22.832 and TS 22.261 include not only URLLC services with very high requirements, but also relatively low-end services with the requirement of small device form factors, and/or being completely wireless with a battery life of several years. The requirements for these services are higher than LPWA (i.e. LTE-MTC/NB-IoT) but lower than URLLC and eMBB.

2. Similar to connected industries, 5G connectivity can serve as catalyst for the next wave smart city innovations. As an example, TR 22.804 describes smart city use case and requirements for that. The smart city vertical covers data collection and processing to more efficiently monitor and control city resources, and to provide services to city residents. Especially, the deployment of surveillance cameras is an essential part of the smart city but also of factories and industries.

3. Finally, wearables use case includes smart watches, rings, eHealth related devices, and medical monitoring devices etc. One characteristic for the use case is that the device is small in size.

As a baseline, the requirements for these three use cases are:

Generic requirements:

- Device complexity: Main motivation for the new device type is to lower the device cost and complexity as compared to high-end eMBB and URLLC devices of Rel-15/Rel-16. This is especially the case for industrial sensors.
- Device size: Requirement for most use cases is that the standard enables a device design with compact form factor.
- Deployment scenarios: System should support all FR1/FR2 bands for FDD and TDD.

Use case specific requirements:

1. Industrial wireless sensors: Reference use cases and requirements are described in TR 22.832 and TS 22.104: Communication service availability is 99.99% and end-to-end latency less than 100 ms. The reference bit rate is less than 2 Mbps (potentially asymmetric e.g. UL heavy traffic) for all use cases and the device is stationary. The battery should last at least few years. For safety related sensors, latency requirement is lower, 5-10 ms (TR 22.804)
2. Video Surveillance: As described in TR 22.804, reference economic video bitrate would be 2-4 Mbps, latency < 500 ms, reliability 99%-99.9%. High-end video e.g. for farming would require 7.5-25 Mbps. It is noted that traffic pattern is dominated by UL transmissions.
3. Wearables: Reference bitrate for smart wearable application can be 5-50 Mbps in DL and 2-5 Mbps in UL and peak bit rate of the device higher, up to 150 Mbps for downlink and up to 50 Mbps for uplink. Battery of the device should last multiple days (up to 1-2 weeks).

The intention is to study a UE feature and parameter list with lower end capabilities, relative to Release 16 eMBB and URLLC NR to serve the three use cases mentioned above.

5 Study objectives

The study includes the following objectives:

1) Identify and study potential UE complexity reduction features, including [RAN1, RAN2]:
   - Potential features:
     - Reduced number of UE RX/TX antennas
     - UE bandwidth reduction
     - Half-duplex FDD
     - Relaxed UE processing time
     - Relaxed UE processing capability
   - Notes:
     - Rel-15 SSB bandwidth should be reused and L1 changes minimized.
     - The work defined above should not overlap with LPWA use cases.
     - The lowest data rate and bandwidth capability considered should be no less than an LTE Category 1bis modem.
   - The study includes evaluations of the impact to coverage, network capacity and spectral efficiency.
2) Study UE power saving and battery lifetime enhancement for reduced capability UEs in applicable use cases (e.g. delay tolerant) [RAN2, RAN1]:
   - Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits [RAN1].
   - Extended DRX for RRC Inactive and/or Idle [RAN2]

- RRM relaxation for stationary devices [RAN2]

3) Study functionality that will enable the performance degradation of such complexity reduction to be mitigated or limited, including [RAN1]:
   - Coverage recovery to compensate for potential coverage reduction due to the device complexity reduction.
     - For FR1, coverage analysis for wearables can include consideration of potential reduced antenna efficiency due to device size limitations as part of the antenna gains. The extent of additional recovery of coverage loss due to reduced antenna efficiency is to be limited to 3 dB.
   - The study includes evaluations of the impact to network capacity and spectral efficiency.
   - Note: Potential overlap with the Coverage Enhancement SI [5] is discussed and resolved in RAN plenary.
4) Study standardization framework and principles for how to define and constrain such reduced capabilities – considering definition of a limited set of one or more device types and considering how to ensure those device types are only used for the intended use cases [RAN2, RAN1].
5) Study functionality that will allow devices with reduced capabilities to be explicitly identifiable to networks and network operators, and allow operators to restrict their access, if desired [RAN2, RAN1].

Additional notes:

- Coexistence with Rel-15 and Rel-16 UE should be ensured.
- This SI should focus on SA mode and single connectivity.

6 Evaluation methodology

6.1 Evaluation methodology for UE complexity reduction

For cost/complexity evaluation of UE complexity reduction techniques, the methodology used in TR 36.888 [4] was used as a starting point.

Reference NR devices were defined as follows for FR1 FDD, FR1 TDD and FR2, respectively.

- All mandatory Rel-15 features (with or without capability signaling)
- Single RAT
- Operation in a single band at a time
- Maximum bandwidth:
  - For FR1: 100 MHz for DL and UL
  - For FR2: 200 MHz for DL and UL
- Antennas:
  - For FR1 FDD: 2Rx/1Tx
  - For FR1 TDD: 4Rx/1Tx
  - For FR2: 2Rx/1Tx
- Power class: PC3
- Processing time: Capability 1
- Modulation:
  - For FR1: support 256QAM for DL and 64QAM for UL

  - For FR2: support 64QAM for DL and 64QAM for UL
- Access: Direct DL/UL access between UE and gNB

Detailed cost breakdown for the reference NR devices according to Table 6.1-1 was assumed in the study. The RF-to-baseband cost ratio was assumed to be 40:60 for an FR1 UE and 50:50 for an FR2 UE.

The study considered impacts on cost/complexity reduction from the studied UE complexity reduction techniques for a UE that supports multiple RF bands through operation in a single band at a time, where it was assumed that support of multiple RF bands may affect the RF cost but not the baseband cost significantly.

NOTE: This study assesses, from a 3GPP standpoint, the technical feasibility of reduced-capability NR devices for industrial wireless sensors, video surveillance and wearables use cases. Given that factors outside 3GPP responsibility influence the cost of a modem/device, this study item (and this study report) cannot guarantee, or be used as a guarantee, that such modem/device will be low-cost in the market.

Table 6.1-1: Detailed cost breakdown for the reference NR devices

Functional block	FR1 FDD (2Rx)	FR1 TDD (4Rx)	FR2
RF			
Antenna array for FR2			~33%
Power amplifier	~25%	~25%	~18%
Filters	~10%	~15%	~8%
RF transceiver (including LNAs, mixer, and local oscillator)	~45%	~55%	~41%
Duplexer / Switch	~20%	~5%	~0%
Baseband			
ADC / DAC	~10%	~9%	~4%
FFT/IFFT	~4%	~4%	~4%
Post-FFT data buffering	~10%	~10%	~11%
Receiver processing block	~24%	~29%	~24%
LDPC decoding	~10%	~9%	~9%
HARQ buffer	~14%	~12%	~11%
DL control processing & decoder	~5%	~4%	~5%
Synchronization / cell search block	~9%	~9%	~7%
UL processing block	~5%	~5%	~7%
MIMO specific processing blocks	~9%	~9%	~18%

6.2 Evaluation methodology for UE power saving

UE power consumption model for UE power saving evaluation:

The power states and relative power consumption values in Table 6.2-1 are adopted for the study of UE power saving.

Table 6.2-1: UE power consumption model for FR1

Power State	Relative power
Deep Sleep (P_{DS})	0.8
Light Sleep (P_{LS})	18
Micro sleep (P_{MS})	31
PDCCH-only (P_{PDCCH})	50 for same-slot scheduling, 40 for cross-slot scheduling
PDCCH + PDSCH ($P_{PDCCH+PDSCH}$)	120

PDSCH-only (P_{PDSCH})	112
SSB/CSI-RS proc. (P_{SSB})	50
Intra-frequency RRM measurement (P_{intra})	[60] (synchronous case, N=8, measurement only) [80] (combined measurement and search)
Inter-frequency RRM measurement (P_{inter})	[60] (neighbor cell search power per freq. layer) [80] (measurement only per freq. layer) Micro sleep power assumed for switch in/out a freq. layer
Note: 2 Rx is assumed	

In addition to the assumptions in Table 6.2-1, the following additional assumptions are considered for UE power saving evaluations:

- The scaling factor '0.7' is used for 2 Rx to 1Rx power scaling.
- The power scaling for PDCCH candidate reduction defined in TR 38.840 [6] is reused for RedCap UEs.
- For FR2, the power consumption model in TR 38.840 [6] is reused.

The following rules for power determination are adopted as working assumption for power saving evaluations:

- 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, $P(\alpha) = \max(\text{Micro-sleep}, \alpha \cdot Pt + (1 - \alpha) \cdot 0.7Pt)$, where Pt is the PDCCH-only power for same slot and cross-slot scheduling cases

Traffic model used for UE power saving evaluation:

For instant messaging, Heartbeat and VoIP application, the following traffic models and DRX configuration in Table 6.2-2 and Table 6.2-3 are used as baseline for evaluations.

Table 6.2-2: Baseline traffic models

	Instant messaging	**Heartbeat**	**VoIP**
Model	FTP model 3	FTP model 3	As defined in R1-070674 [7]. Assume max two packets bundled.
Packet size	0.1 Mbytes	100 Bytes	
Mean inter-arrival time	2 seconds	60 seconds	
DRX setting	Period = 320 ms Inactivity timer = 80 ms FR1 'On' duration: 10 ms FR2 'On' duration: 5 ms	C-DRX cycle 640 ms Inactivity timer {200, 80} ms FR1 'On' duration: 10 ms FR2 'On' duration: 5 ms	Period = 40 ms Inactivity timer = 10 ms FR1 'On' duration: 4 ms FR2 'On' duration: 2 ms
Comments	Above values are taken from clause 8.2 of TR 38.840 [6].		Above values are taken from clause 8.2 of TR 38.840 [6].

Table 6.2-3: Main parameters of the VoIP traffic model (from R1-070674 [7])

Parameter	**Characterization**
Codec	RTP AMR 12.2, Source rate 12.2 kbps
Encoder frame length	20 ms
Voice activity factor (VAF)	50% (c=0.01, d=0.99)
SID payload	Modelled 15 bytes (5 bytes + header) SID packet every 160 ms during silence

Protocol Overhead with compressed header	10 bits + padding (RTP-pre-header) 4 byte (RTP/UDP/IP) 2 byte (RLC/security) 16 bits (CRC)
Total voice payload on air interface	40 bytes (AMR 12.2)

For capturing the observations on power saving results in clause 8.2.2, the following methodology is used:

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

PDCCH blocking rate evaluation:

The baseline parameters used for the evaluations of PDCCH blocking rate (blocking probability) evaluations is given in Table 6.2-4.

Table 6.2-4: Baseline parameters for the PDCCH blocking rate evaluation

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

The aggregation level (AL) distributions in Table 6.2-5 are used by different sources for PDCCH blocking rate evaluations.

Table 6.2-5: 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 (A1): [0.5, 0.4, 0.05, 0.03, 0.02], assuming majority of the UEs are in is good coverage - Configuration 2 (A2): [0.1, 0.2, 0.4, 0.2, 0.1]: Majority of the UEs are in medium coverage - Configuration 3 (A3): [0.05, 0.05, 0.2, 0.3, 0.4]: Majority of the UEs are in poor coverage - Configuration 4 (A4): [0.3 0.5 0.1 0.06 0.04] - Configuration 5 (A5): [0.4 0.45 0.08 0.04 0.03] - Configuration 6 (A6): [0.2 0.55 0.14 0.06 0.05] - Configuration 7 (A7): [0.4 0.3 0.2 0.05 0.05]

Note: the results for A2/A3 may not represent a typical case, e.g., because of the assumptions of unfavourable channel conditions.

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In addition, the set of number of PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6 are also used by different sources for evaluations.

Table 6.2-6: 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]
Note: For the cases where the number of PDCCH candidates per AL is more than 8, multiple overlapping search space sets are allowed.			

For capturing the observations on PDCCH blocking rate in clause 8.2.3, the following methodology is used:

- For each of the simultaneously scheduled UE numbers denoting as '*N*' (1<*N*<=10)
  - Step 1: Determine a single average/mean value *Average_a_N(i)* based on values reported by each company '*i*' with existing Rel-15/16 schemes for DCI transmission

$$Average\_a(i)\_N = \sum_{j=1}^{M} a1(i)\_N/M$$

  for company '*j*'. '*M*' represents the number of configurations that are simulated by company '*j*' for '*N*' simultaneously scheduled UEs in a slot.

  - Step 2: Determine a single average/mean value *Average_a_N* by averaging the values from different companies for a sperate observation, excluding the smallest and the largest values of *Average_a(i)_N* among companies if number of source companies > 3

$$Average\_a\_N = \sum_{i=1}^{K} Average\_a\_N(i)/K$$

  where '*K*' denotes the number of source companies that simulated a same observation configuration (e.g. '*N*=2' in Table B.1-1) after excluding the smallest and largest value.

  - Step-3: Reuse the same approach to derive the *Average_b_N* for Case 2 and Case 3 with approximately 25% and 50% BD reduction (see Annex B).

- Step-4: Determine the absolute increase and relative increase as follows:
  - *X_N*% = [*Average_b_N* - *Average_a_N*].
  - *Y_N*% = [(*Average_b_N* - *Average_a_N*)/ *Average_a_N*]
- Step-5: Capture the PDCCH blocking rate impact based on the following template:
  - For FR1 with AL distribution configuration A1 in Table 6.2-5 with '*N*' simultaneously scheduled UE in a slot, it was observed that the PDCCH blocking rate is increased *X_N*% from [*Average_a_N*] which corresponds to *Y_N*% increase relative to [*Average_a_N]*.

6.3 Evaluation methodology for coverage recovery

Coverage recovery evaluation is based on link budget evaluations.

The channels and messages used in link budget evaluations include PDCCH, PDSCH, PUCCH, and PUSCH. The initial access related channels, such as PBCH, PRACH, Msg2, Msg3, Msg4 and PDCCH scheduling Msg2/4 are also included.

The impact of small form factor is considered for all the uplink and downlink channels. To reflect such an impact, a 3dB loss of antenna gain is included in link budget calculation for the FR1 bands.

The assumptions in the Rel-17 Coverage Enhancement SI regarding link budget template and antenna array gain are reused [5]. Furthermore, the Rel-17 Coverage Enhancement SI assumptions on gNB antenna configuration, # gNB Tx and Rx chains, channel model and delay spread are reused, with the revision or addition shown in Table 6.3-1.

Table 6.3-1: Assumptions used for coverage recovery evaluation

Parameters	FR1 values	FR2 values
Channel model	TDL-C	TDL-A CDL-A(optional)
Delay spread	300ns	30ns
UE velocity	3 km/h	3 km/h
Antenna correlation	Low	Low
# gNB Tx chains	2 or 4	2
# gNB Rx chains	2 or 4	2

For coverage evaluation, the assumptions for the reference NR UEs and RedCap UEs are shown in Table 6.3-2 and 6.3-3, respectively.

Table 6.3-2: Assumptions for reference NR UE

Parameters	FR1 values	FR2 values
# UE Tx chains	1	1
# UE Rx chains	Urban: 4 and Rural: 2	2
UE bandwidth	Urban: 100 MHz (273 PRBs, 30 kHz SCS) Rural: 20 MHz (106 PRBs, 15 kHz SCS)	100 MHz (66 PRBs, 120 kHz SCS)

Table 6.3-3: Assumptions for RedCap UE

Parameters	FR1 values	FR2 values
# UE Tx chains	1	1
# UE Rx chains	1 or 2	1 or 2
UE bandwidth	Urban: 20 MHz (51 PRBs, 30 kHz SCS) Rural: 20 MHz (106 PRBs, 15 kHz SCS)	50 MHz (32 PRBs, 120 kHz SCS) or 100 MHz (66 PRBs, 120 kHz SCS)

The assumptions for channel specific parameters are also based on reusing the Rel-17 Coverage Enhancement SI agreements [5], with the revision or addition described below.

The target data rates for RedCap UEs are:

- FR1 Rural: 1 Mbps on DL and 100kbps in UL
- FR1 Urban: 2 Mbps on DL and 1Mbps in UL (Note: The 2Mbps target data rate in downlink is the scaled value of the 10Mbps in the Rel-17 Coverage Enhancement SI by a factor of 0.2)
- FR2: 25Mbps on DL and 5 Mbps in UL (for bandwidth options 50MHz and 100MHz)

The TBS, PRB, and MCS of PDSCH (except for Msg2) and PUSCH for the RedCap UE are based on the agreed target data rates or message sizes and reported by sourcing companies. For Msg2, the assumptions listed in Table 6.3-4 were adopted.

Table 6.3-4: Assumptions for Msg2

Parameters	Values
PRBs/TBS/MCS	MCS is fixed to zero. Companies to report the used number of PRBs and corresponding TBS value
PDSCH duration	12 OS
DMRS configuration	Type 1, 3 DMRS symbol, no multiplexing with data
Waveform	CP-OFDM
HARQ configuration	No retransmission

Note: the TBS scaling is not precluded in the table entry "PRBs/TBS/MCS"

For the channel(s) affected by complexity reduction, the following methodology is used to determine the target performance for coverage recovery

- Step 1: Obtain the link budget performance of the channel based on link budget evaluation
- Step 2: Obtain the target performance requirement for RedCap UEs within a deployment scenario
- Step 3: Find the coverage recovery value for the channel if the link budget performance is worse than the target performance requirement

For step 2, the study considered two options for determining the target performance for coverage recovery.

- Option 1: The target performance requirement for each channel is identified by a target MPL within a reasonable deployment.
- Option 3: The target performance requirement for each channel is identified by the link budget of the bottleneck channel(s) for the reference NR UE within the same deployment scenario. The "bottleneck channel(s)" are the physical channel(s) that have the lowest MIL.

Eventually, the adopted methodology is based on Option 3 and a single coverage recovery target based on the same bottleneck channel is used for initial access channels and non-initial access channels of RedCap UE. The coverage recovery target for each channel of RedCap UE corresponds to the link budget of the bottleneck channel(s) for the reference NR UE within the same deployment scenario, where the reference UE is a Rel-15/16 NR UE with mandatory features only. Each sourcing company reports sourcing-company-specific observations of the amount of compensation for each channel by comparing the link budget with that of the bottleneck channel for the reference NR UE, where the amount of compensation for each channel is the difference between the link budget of the channel for RedCap UE and the link budget of the bottleneck channel for the reference UE. A representative value of the amount of compensation is derived by taking the mean value (in dB domain) from the compensation values from all sourcing companies, including both negative and non-negative values based on the following adjustments.

- Excluding the highest & the lowest values when the number of samples is more than 3.
- If the number of samples used to compute a representative value is less than 4 for each scenario, this representative value is not used for bottleneck identification.

The representative value of a channel is used for identifying whether the channel needs coverage recovery, and coverage recovery is not needed if the representative value of a channel is larger than or equal to zero.

6.4 Evaluation methodology for network capacity and spectral efficiency

For the evaluations of the impact to network capacity and spectral efficiency, system-level simulation (SLS) have been used and the assumptions in TR 38.802, Table A.2.1-1 are used as the baseline. Additionally, the scenarios and assumptions described in the table below were agreed for alignment purpose. The same assumptions were adopted by some sourcing companies for SLS.

Table 6.4-1: Assumptions for alignment purpose for system-level simulation

Parameters	FR1 values	FR2 values
Layout	Single layer Macro layer: Hex. Grid	Single layer Indoor floor: (12BSs per 120m x 50m) Candidate TRP numbers: 3, 6, 12
Inter-BS distance	500m	20m
Scenario and frequency	Dense Urban: 2.6 GHz (TDD) (primary choice) 4 GHz (TDD) (secondary choice) Other scenarios (e.g. Rural 700MHz) are not precluded.	Indoor: 28 GHz (TDD)
Frame structure for TDD	For 2.6 GHz: DDDDDDDSUU (S: 6D:4G:4U) For 4 GHz: DDDSUDDSUU (S: 10D:2G:2U)	DDDSU (S: 10D:2G:2U)
Channel model	3D-UMa	5GCM office
UE distribution	20% Outdoor in cars: 30km/h, 80% Indoor in houses: 3km/h	100% Indoor: 3km/h
Traffic model	Full buffer (Optional) Non-full buffer traffic, e.g. FTP traffic model 3 for the reference NR UEs and the IM traffic model from TR 38.840 [6] for RedCap UEs	
Traffic load	Full buffer traffic (Optional): 10 users per cell including both RedCap and reference NR UEs Non-full buffer traffic: Low (e.g. <30%) and medium (e.g. 30%-50%) loading (resource utilization)	
Percentage of RedCap UEs among total number of UEs Note: Other UEs are the reference NR UEs	Full buffer traffic (Optional): 0, 20%, 50% (i.e. 0, 2 or 5 RedCap UEs per cell), 100% (as applicable) Non-full buffer traffic: 0, 25%, 50%, 100% (optional, as applicable)	

For UE complexity reduction features for evaluation, at least 1Rx and 2Rx are considered for RedCap UEs. In addition, 20MHz, max 64QAM in DL and max 16QAM in UL are used for FR1, whereas 100MHz, max 16QAM in DL and max 16QAM in UL are used for FR2. Other UE complexity reduction feature combinations may also be considered. For the reference eMBB UE, 4Rx for FR1 TDD and 2Rx for FR2 were assumed.

The total system bandwidth in the SLS can be 100 MHz for both FR1 and FR2 (aligned with the LLS assumption). In FR1, the scheduled bandwidths for eMBB and RedCap UEs can be up to 100 MHz and 20 MHz, respectively. In FR2, the scheduled bandwidths for eMBB UEs can be up to 100 MHz, and up to 100 MHz or 50 MHz for RedCap UEs.

The spectral efficiency (SE) definition for the non-full buffer traffic is given by:

SE (bps/Hz) = cell average throughput (Mbps) / (cell bandwidth (MHz) * RU)

7 UE complexity reduction features

7.1 Introduction to UE complexity reduction features

The following UE complexity reduction techniques have been studied:

- Reduced number of UE Rx branches
- UE bandwidth reduction
- Half-duplex FDD operation
- Relaxed UE processing time
- Relaxed maximum number of MIMO layers
- Relaxed maximum modulation order

The evaluation results for each one of the studied individual UE complexity reduction techniques are captured in clauses 7.2 through 7.7, respectively. The properties of combinations of different individual UE complexity reduction techniques are described in clause 7.8. Recommendations based on the evaluations are captured in clause 13.

The following UE complexity reduction techniques for higher layers have been discussed in RAN2:

- Reduction of the maximum number of DRBs which UE needs to mandatorily support.
- Reduction of L2 buffer size. According to the calculation in TS 38.306, with peak data rate reductions, L2 buffer requirements for RedCap UEs are implicitly reduced accordingly. Benefits and feasibility of further reduction requires evaluation in normative phase if it is to be considered.
- SN in PDCP and RLC is 18-bits, and the size could be reduced depending on which features RedCap UEs support, if a clear benefit in such reduction is identified.
- The gain of relaxing RRC processing delay requirements was not studied and requires further evaluation in normative phase if it is to be considered.

These UE complexity reduction techniques for higher layers have not been explicit objectives during the study and would require further evaluation during the normative phase if they are to be considered.

7.2 Reduced number of UE Rx/Tx antennas

7.2.1 Description of feature

The antenna configurations for RedCap UEs that were considered in the study are:

- For FR1: 1Rx/1Tx and 2Rx/1Tx
- For FR2: 1Rx/1Tx and 2 Rx/1Tx

The evaluation of cost/complexity reduction has been performed with respect to a reference NR UE. The reference NR UE has the following antenna configuration:

- For FR1 FDD: 2Rx/1Tx
- For FR1 TDD: 4Rx/1Tx
- For FR2: 2Rx/1Tx

7.2.2 Analysis of UE complexity reduction

When the number of UE Rx branches is reduced, the maximum number of DL MIMO layers is reduced correspondingly. For study purposes, two sets of evaluation results are presented below. The first set concerns the estimated cost reduction from reducing the number of Rx branches without taking the reduced maximum number of downlink MIMO layers into account, whereas the second set considers both the reduced number of Rx branches and the corresponding reduction of the maximum number of DL MIMO layers.

The estimated cost for a device with reduced number of UE Rx branches without taking reduced number of downlink MIMO layers into consideration, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.2.2-1. As can be seen in the last row for the total cost, the average estimated cost reduction achieved by reducing the number of UE Rx branches are as follows:

- FR1 FDD (2Rx → 1Rx): ~26%
- FR1 TDD (4Rx → 2Rx): ~31%
- FR1 TDD (4Rx → 1Rx): ~46%
- FR2 TDD (2Rx → 1Rx): ~31%

By comparing Table 7.2.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:

- RF: Antenna array (only FR2)
- RF: Filters
- RF: Transceiver (including LNAs, mixer, and local oscillator)
- Baseband: ADC/DAC
- Baseband: FFT/IFFT
- Baseband: Post-FFT data buffering
- Baseband: Receiver processing block
- Baseband: Synchronization/cell search block

Furthermore, all sourcing companies indicated that the RF cost savings (but not the baseband cost savings) from reducing the number of UE Rx branches accumulate across supported bands in both FR1 and FR2.

The reduction of number of UE Rx branches, relative to that of the reference NR device, may be beneficial in terms of reducing the device size in FR1. It is unclear whether the reduction of number of UE Rx branches, relative to that of the reference NR device, may be beneficial in terms of reducing the device size in FR2. This does not imply that a non-RedCap NR UE cannot be used in a compact or small form factor in FR1 or FR2.

Table 7.2.2-1: Estimated relative device cost for reduced number of UE Rx branches

Reduced number of UE Rx branches	**FR1 FDD (2Rx → 1Rx)**	**FR1 TDD (4Rx → 2Rx)**	**FR1 TDD (4Rx → 1Rx)**	**FR2 TDD (2Rx → 1Rx)**
RF: Antenna array	-	-	-	18.2%
RF: Power amplifier	25.0%	25.0%	25.0%	18.0%
RF: Filters	4.8%	7.6%	3.9%	4.3%
RF: Transceiver (including LNAs, mixer, and local oscillator)	25.3%	30.4%	17.8%	23.7%
RF: Duplexer / Switch	19.6%	4.9%	4.9%	0.0%
RF: Total relative cost	**74.7%**	**67.9%**	**51.6%**	**64.2%**
BB: ADC / DAC	6.4%	5.2%	3.4%	2.4%
BB: FFT/IFFT	2.3%	2.2%	1.3%	2.2%
BB: Post-FFT data buffering	5.6%	5.3%	3.0%	6.0%
BB: Receiver processing block	13.7%	15.7%	9.0%	13.3%
BB: LDPC decoding	9.7%	8.7%	8.6%	8.6%
BB: HARQ buffer	13.6%	11.6%	11.4%	10.5%
BB: DL control processing & decoder	4.9%	4.0%	3.9%	4.9%

BB: Synchronization / cell search block	5.1%	4.8%	2.7%	3.8%
BB: UL processing block	5.0%	5.0%	5.0%	7.0%
BB: MIMO specific processing blocks	8.2%	7.9%	7.3%	15.8%
BB: Total relative cost	**74.4%**	**70.4%**	**55.7%**	**74.5%**
RF+BB: Total relative cost	**74.5%**	**69.4%**	**54.0%**	**69.4%**

The estimated cost for a device with reduced number of UE Rx branches and a corresponding reduction of the number of downlink MIMO layers, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.2.2-2. As can be seen in the last row for the total cost, the average estimated cost reduction achieved by reducing the number of UE Rx branches and MIMO layers are as follows:

- FR1 FDD (2Rx → 1Rx): ~37%
- FR1 TDD (4Rx → 2Rx): ~40%
- FR1 TDD (4Rx → 1Rx): ~60%
- FR2 TDD (2Rx → 1Rx): ~40%

By comparing Table 7.2.2-2 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:

- RF: Antenna array (only FR2)
- RF: Filters
- RF: Transceiver (including LNAs, mixer, and local oscillator)
- Baseband: ADC/DAC
- Baseband: FFT/IFFT
- Baseband: Post-FFT data buffering
- Baseband: Receiver processing block
- Baseband: LDPC decoding
- Baseband: HARQ buffer
- Baseband: Synchronization/cell search block
- Baseband: MIMO specific processing blocks

Furthermore, all sourcing companies indicated that the RF cost savings (but not the baseband cost savings) from reducing the number of UE Rx branches accumulate across supported bands in both FR1 and FR2, whereas the cost savings from reducing the number of downlink MIMO layers do not.

Table 7.2.2-2: Estimated relative device cost for reduced number of UE Rx branches and a corresponding reduction of the supported maximum number of MIMO layers

Reduced number of UE Rx branches and MIMO layers	**FR1 FDD (2Rx → 1Rx)**	**FR1 TDD (4Rx → 2Rx)**	**FR1 TDD (4Rx → 1Rx)**	**FR2 TDD (2Rx → 1Rx)**
RF: Antenna array	-	-	-	18.7%
RF: Power amplifier	25.0%	25.0%	25.0%	18.0%
RF: Filters	5.2%	7.6%	4.0%	4.4%
RF: Transceiver (including LNAs, mixer, and local oscillator)	24.6%	30.4%	17.4%	23.8%
RF: Duplexer / Switch	19.5%	4.9%	4.8%	0.0%
RF: Total relative cost	**74.2%**	**68.0%**	**51.3%**	**64.9%**
BB: ADC / DAC	5.9%	5.0%	3.1%	2.3%
BB: FFT/IFFT	2.1%	2.1%	1.1%	2.1%
BB: Post-FFT data buffering	5.0%	5.0%	2.5%	5.5%
BB: Receiver processing block	12.1%	14.6%	7.5%	12.1%
BB: LDPC decoding	5.0%	4.5%	2.3%	4.5%
BB: HARQ buffer	7.2%	6.1%	3.1%	5.7%

BB: DL control processing & decoder	5.0%	4.0%	4.0%	5.0%
BB: Synchronization / cell search block	4.5%	4.5%	2.3%	3.5%
BB: UL processing block	5.0%	5.0%	5.0%	7.0%
BB: MIMO specific processing blocks	4.1%	4.5%	2.0%	8.0%
BB: Total relative cost	**55.9%**	**55.4%**	**33.0%**	**55.7%**
RF+BB: Total relative cost	**63.2%**	**60.4%**	**40.3%**	**60.3%**

7.2.3 Analysis of performance impacts

Coverage:

In general, degradation of downlink performance is expected when reducing the number of Rx branches, which may affect the coverage. The amount of degradation depends on the number of Rx branches. Quantitative evaluation results are provided in clause 9.

Network capacity and spectral efficiency:

A loss in network capacity and spectral efficiency is expected when reducing the number of UE Rx branches. The magnitude of the loss depends on the proportion of RedCap UEs, the traffic characteristics, as well as on the number of Rx branches. Quantitative evaluation results are provided in clause 12.

Data rate:

Reducing the number of Rx branches at the UE will lower the downlink peak data rate. This is due to the reduction in number of downlink MIMO layers that can be supported when the number of Rx branches is reduced.

- Reduction from 2 Rx branches to 1 Rx branch decreases the downlink peak rate by ~50%.
- Reduction from 4 Rx branches to 2 Rx branches decreases the downlink peak rate by ~50%.
- Reduction from 4 Rx branches to 1 Rx branch decreases the downlink peak rate by ~75%.

Despite this reduction in peak data rate, a UE with reduced number of Rx branches and downlink MIMO layers will be able to sufficiently fulfil the peak data rate requirements for the RedCap use cases. For peak rate impacts from other combinations of UE complexity reduction techniques, see clause 7.8.3.

Latency and reliability:

Reducing the number of UE Rx branches has limited impact on the latency in most cases. However, if the UE is near the cell edge, the latency can increase. Nevertheless, the latency requirements of RedCap use cases can be sufficiently fulfilled, in both FR1 and FR2.

The reliability requirements for the RedCap use cases can still be fulfilled with reduced number of UE Rx branches. However, in some cases, the reliability can only be maintained at the cost of downlink spectral efficiency loss.

Power consumption:

The instantaneous power consumption in the RF and the baseband modules of the UE is expected to be reduced due to the use of fewer RF chains and the reduction in the complexity of multi-antenna processing. However, downlink reception time may be longer for large payloads due to reduced spectral efficiency.

PDCCH blocking rate:

In order to compensate for the performance degradation resulting from a reduced number of UE Rx branches, higher aggregation levels may need to be used. This can lead to increase in PDCCH blocking rate if the amount of PDCCH resources is not increased.

7.2.4 Analysis of coexistence with legacy UEs

In general, RedCap UEs with reduced number of Rx branches can coexist with legacy UEs. However, the presence of RedCap UEs with reduced number of Rx branches may impact the performance for legacy UEs if some broadcast channels are used for both legacy UEs and RedCap UEs. This is because, if there is no early indication of RedCap UE, both legacy UEs and RedCap UEs will be treated the same by the network, which may lead to conservative treatment of all UEs.

If higher PDCCH aggregation levels are used for RedCap UEs, the PDCCH blocking rate for legacy UEs may be increased if they share the same CORESET.

7.2.5 Analysis of specification impacts

For reduced number of Rx branches, work in RAN4 may be required to define new receiver characteristics, demodulation performance requirements, and requirements relating to CSI reporting, RF, RRM, and other procedures, such as cell handover or (re)selection, radio link management and beam management. RAN4 may also need to evaluate and specify new minimum numbers of Rx branches for RedCap UEs in different bands. Impacts on RAN4 specifications may also extend beyond the mentioned aspects.

Additionally, to address the performance and coexistence impacts identified in clauses 7.2.3 and 7.2.4, specification work in other working groups than RAN4 may be needed.

7.3 UE bandwidth reduction

7.3.1 Description of feature

In the study, the main UE bandwidth reduction options considered are:

- For FR1: 20 MHz
- For FR2: 50 MHz or 100 MHz

The study uses a legacy NR UE as a reference. The evaluation of cost/complexity reduction is with respect to a reference UE with maximum bandwidth capability shown below.

- For FR1: 100 MHz for DL and UL
- For FR2: 200 MHz for DL and UL

For the baseline UE bandwidth capability of RedCap UEs, the same maximum UE bandwidth in a band applies to both RF and baseband. It is also primarily assumed that this maximum UE bandwidth applies to both data and control channels and that this maximum UE bandwidth is assumed for both DL and UL. A few contributions analysed other mixes of bandwidths.

7.3.2 Analysis of UE complexity reduction

The estimated cost for a device with reduced maximum UE bandwidth, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.3.2-1. As can be seen in the last row for the total cost, the average estimated cost reduction achieved by reducing the UE bandwidth from 100 MHz to 20 MHz is ~32% for FR1 FDD and ~33% for FR1 TDD. For FR2, the average estimated cost reduction achieved by reducing the UE bandwidth from 200 MHz to 100 MHz and 50 MHz is ~16% and ~23%, respectively.

By comparing Table 7.3.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:

- Baseband: ADC/DAC
- Baseband: FFT/IFFT
- Baseband: Post-FFT data buffering
- Baseband: Receiver processing block
- Baseband: LDPC decoding
- Baseband: HARQ buffer

Although the results from most sourcing companies do not show PA cost reduction from bandwidth reduction, some sourcing companies indicate that PA cost can be reduced due to Tx bandwidth reduction from 100 MHz to 20 MHz in FR1.

Furthermore, ~75% of sourcing companies indicated that the cost savings do not accumulate across supported bands.

Table 7.3.2-1: Estimated relative device cost for reduced maximum UE bandwidth

Reduced UE bandwidth	FR1 FDD	FR1 TDD	FR2 (200 MHz → 100 MHz)	FR2 (200 MHz → 50 MHz)
RF: Antenna array	-	-	33.0%	33.0%
RF: Power amplifier	24.1%	23.8%	17.9%	17.8%
RF: Filters	10.0%	14.7%	8.0%	8.0%
RF: Transceiver (including LNAs, mixer, and local oscillator)	43.7%	53.0%	40.6%	40.3%
RF: Duplexer / Switch	20.0%	5.0%	0.0%	0.0%
RF: Total relative cost	**97.7%**	**96.4%**	**99.5%**	**99.0%**
BB: ADC / DAC	2.8%	2.0%	2.0%	1.0%
BB: FFT/IFFT	1.1%	1.1%	1.9%	0.9%
BB: Post-FFT data buffering	2.3%	2.1%	5.6%	2.8%
BB: Receiver processing block	9.1%	9.9%	14.2%	9.1%
BB: LDPC decoding	3.8%	3.5%	5.4%	3.8%
BB: HARQ buffer	4.2%	3.3%	6.0%	3.5%
BB: DL control processing & decoder	4.5%	3.7%	4.7%	4.5%
BB: Synchronization / cell search block	9.0%	9.0%	7.0%	7.0%
BB: UL processing block	3.4%	3.7%	5.6%	4.9%
BB: MIMO specific processing blocks	8.2%	8.4%	17.0%	16.5%
BB: Total relative cost	**48.4%**	**46.7%**	**69.4%**	**54.0%**
RF+BB: Total relative cost	**68.1%**	**66.6%**	**84.4%**	**76.5%**

7.3.3 Analysis of performance impacts

Coverage:

The impact of reduced bandwidth on the coverage of downlink and uplink channels would not be large, although a small loss may be observed due to reduced frequency diversity.

For PDCCH coverage, one important aspect is whether the larger aggregation levels (AL), e.g. 8 and 16, can be supported after bandwidth reduction. In FR1, UE bandwidth 20 MHz is enough for supporting AL 16 for any CORESET#0 configuration. In FR2, UE bandwidth 100 MHz is also enough for supporting AL 16 for any CORESET#0 configuration. However, reducing the UE bandwidth to 50 MHz in FR2 will have impact on PDCCH coverage when CORESET#0 is configured to have 69.12 MHz bandwidth. The loss is assessed to be ~1.5-3.0 dB. Reducing the UE bandwidth to 50 MHz will have impact on PBCH coverage if the SSB is configured with 240 kHz SCS. The loss is assessed to be within 1 dB. Furthermore, reducing the UE bandwidth to 50 MHz may also impact the coverage of initial access messages if CORESET#0 is configured to have 69.12 MHz bandwidth.

Network capacity and spectral efficiency:

Bandwidth reduction in FR1 will not have a significant impact on capacity and spectral efficiency, although there may be some minor degradation due to the loss in frequency selective scheduling gain.

Bandwidth reduction in FR2 may be associated with more noticeable loss in capacity and spectral efficiency if analog beamforming is being used. In this case, the loss will be larger for 50 MHz UE bandwidth than for 100 MHz UE bandwidth.

Data rate:

Bandwidth reduction results in a reduction in the achievable peak data rate. However, all the bandwidth options (20 MHz in FR1, and 50 MHz or 100 MHz in FR2) considered in the RedCap study are enough for meeting the peak data rate requirements for the RedCap use cases, at least when the bandwidth reduction is not combined with other UE complexity reduction techniques, except in some TDD configurations. For peak rate impacts from combinations of UE complexity reduction techniques, see clause 7.8.3.

Latency and reliability:

All the latency and reliability requirements for the RedCap use cases can be satisfied by all the bandwidth options (20 MHz in FR1, and 50 MHz or 100 MHz in FR2)

In FR2, UE bandwidth reduction may result in a longer SSB/SIB1 acquisition time for certain configurations for SSB/CORESET multiplexing patterns 2 and 3. To minimize the SSB/SIB1 acquisition time, it may be beneficial to support an FR2 RedCap UE bandwidth of 100 MHz.

PDCCH blocking rate:

If CORESET is configured according to the RedCap UE capability and shared by both RedCap and non-RedCap UEs, this may result in increased PDCCH blocking rate. In that case, the impact of an FR2 RedCap UE bandwidth of 50 MHz would be greater than for 100 MHz.

7.3.4 Analysis of coexistence with legacy UEs

In general, UE bandwidth options such as 20 MHz for FR1 UEs and 100 MHz for FR2 UEs achieve good coexistence performance with legacy UEs.

- The 20 MHz bandwidth option for FR1 UEs allows a RedCap UE to reuse existing procedures for acquiring SSB, SIB1, other SIBs, RAR and Msg4.
- The 100 MHz bandwidth option for FR2 UEs achieves the same coexistence benefits, except that for certain configurations for SSB/CORESET multiplexing patterns 2 and 3, the UE needs to acquire SSB and SIB1 in a sequential manner. However, the sequential SSB/SIB1 acquisition for a RedCap UE does not cause any performance degradation to legacy UEs.
- The 50 MHz bandwidth option for FR2 UEs would result in coverage loss for PDCCH reception in CORESET#0 if CORESET#0 is configured to 69.12 MHz. In such cases, if coverage recovery is needed for PDCCH, PDCCH capacity of CORESET#0 may be affected, and this will have impact on legacy UEs. Furthermore, if early RedCap UE identification is not provided, supporting 50-MHz RedCap UEs requires the gNB to schedule the PDSCH of SIBs, RAR, and Msg4 within 50 MHz bandwidth. Such scheduling restrictions will have an impact on legacy UEs.

If RedCap and eMBB UEs share the same initial BWP in downlink and uplink for initial access procedure, and the number of RedCap UEs in the network is large, gNB may need to use some means (e.g. access control) to avoid congestion due to high load or configuration restriction (e.g. for RACH occasions).

7.3.5 Analysis of specification impacts

At least the UE bandwidth reduction options 20 MHz in FR1 and 100 MHz in FR2 are expected to have small specification impacts. With proper configurations of RRC parameters and support of early indication of RedCap UE, the network may be able to support RedCap UE bandwidth reduction with minor or no additional specification changes.

However, to address the performance and coexistence impacts identified in clauses 7.3.3 and 7.3.4, specification work would be needed.

7.4 Half-duplex FDD operation

7.4.1 Description of feature

Half-duplex operation allows the UE to receive and transmit on different frequencies, but not at the same time. Half-duplex mode allows for removing a duplexer and instead use a switch and an additional filter.

The RedCap study includes both HD-FDD operation Type A and Type B, as defined in LTE, where study of Type A is prioritized.

7.4.2 Analysis of UE complexity reduction

The estimated cost for an HD-FDD only device, relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.4.2-1.

- For Type A HD-FDD, a high proportion of the cost saving occurs because the duplexer can be replaced with a switch and a lowpass filter.
- For Type B HD-FDD, uplink and downlink can share one local oscillator, therefore, some additional saving on RF transceiver can be obtained.

By comparing Table 7.4.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributor of the cost reduction is the duplexer/switch block. Depending on the implementation, as indicated by some sourcing companies, removing the duplexer may also reduce the insertion loss in both the Rx and Tx chains and as a result, the PA power can be reduced, and the LNA sensitivity requirement can be relaxed which allows for potential UE complexity reduction.

As can be seen in the last row for the total cost, the average estimated cost reduction achieved by Type A and Type B HD-FDD is approximately ~7% and ~10%, respectively.

Furthermore, all sourcing companies indicated that the RF cost savings (but not the baseband cost savings) accumulate across supported bands.

It is unclear whether the HD-FDD operation may be beneficial in terms of reducing the device size in FR1 FDD.

Table 7.4.2-1: Estimated relative device cost for an HD-FDD device

Half-duplex FDD operation	HD-FDD operation (Type A)	HD-FDD operation (Type B)
RF: Antenna array	-	-
RF: Power amplifier	24.1%	23.9%
RF: Filters	10.6%	10.7%
RF: Transceiver (including LNAs, mixer, and local oscillator)	44.4%	37.8%
RF: Duplexer / Switch	4.8%	4.9%
RF: Total relative cost	**83.9%**	**77.3%**
BB: ADC / DAC	10.0%	10.0%
BB: FFT/IFFT	3.8%	3.7%
BB: Post-FFT data buffering	9.9%	9.9%
BB: Receiver processing block	24.0%	24.0%
BB: LDPC decoding	10.0%	10.0%
BB: HARQ buffer	14.0%	14.0%
BB: DL control processing & decoder	4.8%	4.8%
BB: Synchronization / cell search block	9.0%	9.0%
BB: UL processing block	4.8%	4.8%
BB: MIMO specific processing blocks	9.0%	9.0%
BB: Total relative cost	**99.4%**	**99.2%**
RF+BB: Total relative cost	**93.2%**	**90.4%**

7.4.3 Analysis of performance impacts

Coverage:

If there are no stringent requirements on latency and data rate, then HD-FDD will not result in coverage loss, otherwise a coverage loss can be expected.

Network capacity and spectral efficiency:

HD-FDD operation has minor impact on spectral efficiency and capacity.

Data rate:

There is minor impact from HD-FDD operation on instantaneous data rates for uplink or downlink, but similarly to TDD, HD-FDD reduces user throughput compared to FD-FDD, especially in case of simultaneous downlink and uplink traffic, and it may be challenging to meet the peak data rate requirements in downlink and uplink simultaneously. For peak rate impacts from other combinations of UE complexity reduction techniques, see clause 7.8.3.

Latency and reliability:

HD-FDD introduces longer latency than FD-HDD, especially in case of simultaneous downlink and uplink traffic, but the latency and reliability requirements of RedCap use cases can still be fulfilled at least for one direction (downlink or uplink).

Power consumption:

The lower insertion loss of an HD-FDD UE may enable a higher power efficiency in the transmit chain and reduce power consumption. Furthermore, compared to the reference NR modem, half-duplex operation means some components can work in a reduced power state until required. However, on the other hand, HD-FDD may have a negative impact on UE average power consumption because the UE will be active for a longer time before being able to return to a lower power light sleep or deep sleep state. The impact on power consumption of HD-FDD depends on implementation and traffic characteristics.

PDCCH blocking rate:

HD-FDD operation may potentially reduce the available PDCCH monitoring occasions when the UE is transmitting rather than receiving.

7.4.4 Analysis of coexistence with legacy UEs

Introducing HD-FDD operation might make gNB scheduling more complicated. The impact due to the support for HD-FDD Type B operation is greater than for Type A.

For initial access, supporting HD-FDD Type B operation might have a potential impact on the RACH procedure in that longer time gaps between messages might be needed. One example is the switching time from PRACH to Msg2. Supporting HD-FDD Type B operation may cause a longer switching time from PRACH to Msg2 to be used for all UEs, if the RedCap UEs are not identified in Msg1. This is not an issue for Type A due to its faster UL-to-DL switching capability.

7.4.5 Analysis of specification impacts

Introducing support for HD-FDD operation may have the following impacts on RAN1 specifications.

- Specifying DL-to-UL and UL-to-DL switching time
- Specifying how the UE handles DL/UL collision

Depending on the detailed solution, it may or may not be possible to reuse existing RAN1 specification for non-full-duplex operation for support of HD-FDD operation type A (but not for type B).

Additionally, HD-FDD support also has the following impacts on RAN4 specifications.

- Specifying applicable bands
- Specifying performance requirements such as reference sensitivity and RRM

7.5 Relaxed UE processing time

7.5.1 Description of feature

In the RedCap study item, relaxed UE processing time is considered in terms of more relaxed N_1 and N_2 values (as defined in TS 38.214) compared to those of UE processing time capability 1. In the study, for the purpose of evaluation, the relaxed UE processing time in terms of N_1 and N_2 are assumed to be doubled compared to those of capability 1, i.e.,

- N_1 = 16, 20, 34, and 40 symbols for 15, 30, 60, and 120 kHz SCS (assuming only front-loaded DMRS)
- N_2 = 20, 24, 46, and 72 symbols for 15, 30, 60, and 120 kHz SCS

In the study, for the purpose of evaluation, relaxed CSI computation time was also considered, assuming doubled Z and Z' compared to the values defined in TS 38.214 clause 5.4.

7.5.2 Analysis of UE complexity reduction

Relaxed UE processing time in terms of N_1 and N_2:

The estimated cost for a device with relaxed UE processing time in terms of N_1 and N_2 (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.5.2-1. As can be seen in the last row for the total cost, the average estimated cost reduction is ~6% for FR1 FDD, ~6% for FR1 TDD, and ~6% for FR2 TDD.

Relaxed UE processing time in terms of N_1 and N_2 potentially reduces UE complexity by allowing a longer time for the processing of PDCCH and PDSCH and preparing PUSCH and PUCCH. By comparing Table 7.5.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the cost of the following functional blocks can be reduced:

- Baseband: Receiver processing block
- Baseband: LDPC decoding
- Baseband: DL control processing & decoder
- Baseband: UL processing block

Whether the relaxed UE processing time in terms of N_1 and N_2 may reduce the cost/complexity in the 'DL control processing & decoder' block depends on the UE implementation.

Furthermore, all sourcing companies indicated that these cost savings do not accumulate across supported bands.

Table 7.5.2-1: Estimated relative device cost for relaxed UE processing time in terms of N_1 and N_2

Relaxed processing time (doubled N1 and N2)	FR1 FDD	FR1 TDD	FR2 TDD
RF: Antenna array	-	-	33.0%
RF: Power amplifier	25.0%	25.0%	18.0%
RF: Filters	10.0%	14.7%	8.0%
RF: Transceiver (including LNAs, mixer, and local oscillator)	45.0%	54.3%	41.0%
RF: Duplexer / Switch	20.0%	6.0%	0.0%
RF: Total relative cost	**100.0%**	**100.0%**	**100.0%**
BB: ADC / DAC	10.0%	9.0%	4.0%
BB: FFT/IFFT	4.0%	4.0%	4.0%
BB: Post-FFT data buffering	10.0%	10.0%	11.0%
BB: Receiver processing block	20.3%	24.6%	19.5%
BB: LDPC decoding	6.6%	5.9%	5.9%
BB: HARQ buffer	14.0%	12.0%	11.0%
BB: DL control processing & decoder	4.1%	3.3%	4.0%
BB: Synchronization / cell search block	9.0%	9.0%	7.0%
BB: UL processing block	3.7%	3.6%	5.0%
BB: MIMO specific processing blocks	8.8%	8.8%	17.5%
BB: Total relative cost	**90.5%**	**90.1%**	**88.9%**
RF+BB: Total relative cost	**94.3%**	**94.1%**	**94.4%**

Relaxed UE processing time in terms of CSI computation time:

One source provided estimates of the cost for a device with relaxed UE processing time in terms of CSI computation time (see evaluation methodology described in clause 6.1) as summarized in Table 7.5.2-2. As can be seen in the last row for the total cost, the estimated cost reduction is ~5% for FR1 FDD, ~4.5% for FR1 TDD, and ~6% for FR2 TDD. The cost reduction gain is estimated without combination with relaxation in terms of N_1 and N_2.

Table 7.5.2-2: Estimated relative device cost for relaxed UE processing time in terms of CSI computation time

Relaxed processing time (doubled Z and Z')	FR1 FDD	FR1 TDD	FR2 TDD
RF: Antenna array	-	-	33.0%

RF: Power amplifier	25.0%	25.0%	18.0%
RF: Filters	10.0%	15.0%	8.0%
RF: Transceiver (including LNAs, mixer, and local oscillator)	45.0%	55.0%	40.2%
RF: Duplexer / Switch	20.0%	5.0%	0.0%
RF: Total relative cost	**100.0%**	**100.0%**	**99.2%**
BB: ADC / DAC	10.0%	9.0%	4.0%
BB: FFT/IFFT	4.0%	4.0%	4.0%
BB: Post-FFT data buffering	10.0%	10.0%	11.0%
BB: Receiver processing block	24.0%	29.0%	24.0%
BB: LDPC decoding	10.0%	9.0%	9.0%
BB: HARQ buffer	14.0%	12.0%	11.0%
BB: DL control processing & decoder	2.5%	2.0%	2.5%
BB: Synchronization / cell search block	9.0%	9.0%	7.0%
BB: UL processing block	4.0%	4.0%	5.6%
BB: MIMO specific processing blocks	4.5%	4.5%	9.0%
BB: Total relative cost	**92.0%**	**92.5%**	**87.1%**
RF+BB: Total relative cost	**95.2%**	**95.5%**	**93.6%**

7.5.3 Analysis of performance impacts

Coverage:

No coverage impact is expected from a more relaxed UE processing time in terms of N_1 and N_2.

Network capacity and spectral efficiency:

Depending on the gNB scheduler implementation, there may be no or minor impact on network capacity or spectral efficiency from a more relaxed UE processing time in terms of N_1 and N_2.

Data rate:

No impact on instantaneous peak data rate is expected from a more relaxed UE processing time in terms of N_1 and N_2, but the UE throughput may be reduced if the HARQ round trip time is extended. The throughput requirements identified for the RedCap use cases are still expected to be fulfilled.

Latency and reliability:

Relaxed UE processing time in terms of N_1 and N_2 has impact on latency. For downlink transmission, relaxed N_1 value impacts how fast HARQ-ACK feedback can be sent after the reception of PDSCH. For uplink transmission, relaxed N2 value impacts how fast PUSCH can be scheduled with respect to the UL grant. How significant the impact on latency is depends on use cases and scheduled number of retransmissions.

Power consumption:

Relaxed UE processing time in terms of N_1 and N_2 may allow for processing with lower clock frequency and lower voltage which may help reducing the UE power consumption. The impact on power consumption of relaxed UE processing time depends on implementation and traffic characteristics.

7.5.4 Analysis of coexistence with legacy UEs

In scenarios where RedCap UEs coexist with legacy UEs, relaxed UE processing time capability in terms of N_1 and N_2 may for RedCap UEs increase the complexity for the scheduling.

The relaxed UE processing time capability in terms of N_1 and N_2 may cause potential coexistence issues with legacy UEs during initial access if early identification of RedCap UEs prior to Msg2 scheduling is not supported or conservative scheduling is not possible. If gNB schedules all UEs according to relaxed timing relationships for RedCap UEs, legacy UEs may experience an increase in control plane latency.

7.5.5 Analysis of specification impacts

A new UE processing time capability needs to be defined if relaxed UE processing time in terms of N_1 and N_2 is introduced. New values of N_1 and N_2, as well as how the PDSCH processing time and PUSCH preparation time are determined by N_1 and N_2, need to be defined.

Depending on the degree of relaxation of the N_1 and N_2 values, specification details on scheduling timing related to the default TDRA tables and HARQ-ACK timing range may also need to be updated.

7.6 Relaxed maximum number of MIMO layers

7.6.1 Description of feature

In the study, the following relaxation options for maximum number of DL MIMO layers were studied and evaluated:

- For FR1 FDD: 1 MIMO layer
- For FR1 TDD: 1 and 2 MIMO layers
- For FR2: 1 MIMO layer

The study uses a legacy NR UE as a reference. The evaluation of cost/complexity reduction is with respect to a reference UE with the maximum number of DL MIMO layers support shown below.

- For FR1 FDD: 2 MIMO layers
- For FR1 TDD: 4 MIMO layers
- For FR2: 2 MIMO layers

It is primarily assumed that this maximum number of MIMO layers applies to DL data channel only.

7.6.2 Analysis of UE complexity reduction

The estimated cost for a device with relaxed maximum number of MIMO layers (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.6.2-1. As can be seen in the last row for the total cost, the average estimated cost reduction achieved by relaxing the maximum number of MIMO layers from 2 to 1 layer is ~12% for FR1 FDD, from 4 to 2 layer is ~11% for FR1 TDD, from 4 to 1 layer is ~17% for FR1 TDD, and from 2 to 1 layer is ~11% for FR2.

By comparing Table 7.6.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:

- Baseband: Receiver processing block
- Baseband: LDPC decoding
- Baseband: HARQ buffer
- Baseband: MIMO specific processing block

Furthermore, all sourcing companies indicated that these cost savings do not accumulate across supported bands. Finally, it can be noted that for an FR1 UE supporting multiple bands, the baseband cost/complexity reduction may be limited by the case with the highest maximum number of MIMO layers among the supported bands.

Table 7.6.2-1: Estimated relative device cost for relaxed maximum number of MIMO layers

Relaxed maximum number of MIMO layers	**FR1 FDD (2 → 1 layer)**	**FR1 TDD (4 → 2 layers)**	**FR1 TDD (4 → 1 layer)**	**FR2 (2 → 1 layer)**
RF: Antenna array	-	-	-	33.0%
RF: Power amplifier	25.0%	25.0%	25.0%	18.0%
RF: Filters	10.0%	15.0%	15.0%	8.0%
RF: Transceiver (including LNAs, mixer, and local oscillator)	45.0%	55.0%	55.0%	41.0%
RF: Duplexer / Switch	20.0%	5.0%	5.0%	0.0%
RF: Total relative cost	**100.0%**	**100.0%**	**100.0%**	**100.0%**
BB: ADC / DAC	10.0%	9.0%	9.0%	4.0%
BB: FFT/IFFT	3.9%	4.0%	4.0%	4.0%
BB: Post-FFT data buffering	9.8%	10.0%	10.0%	11.0%
BB: Receiver processing block	19.7%	24.4%	22.3%	19.9%
BB: LDPC decoding	5.2%	4.6%	2.4%	4.7%

BB: HARQ buffer	7.2%	6.1%	3.3%	5.7%
BB: DL control processing & decoder	4.9%	4.0%	4.0%	5.0%
BB: Synchronization / cell search block	8.8%	9.0%	9.0%	7.0%
BB: UL processing block	5.0%	5.0%	5.0%	7.0%
BB: MIMO specific processing blocks	4.8%	5.0%	3.0%	9.5%
BB: Total relative cost	**79.3%**	**81.1%**	**71.9%**	**77.8%**
RF+BB: Total relative cost	**87.6%**	**88.7%**	**83.2%**	**88.9%**

7.6.3 Analysis of performance impacts

Coverage:

Reducing the maximum number of MIMO layers does not impact the coverage.

Network capacity and spectral efficiency:

Since reducing the maximum number of MIMO layers reduces the peak data rate, it degrades the network capacity and spectral efficiency. Especially, the reduction of maximum number of MIMO layers mainly degrades the spectral efficiency for UEs in good channel conditions.

Data rate:

Reducing the maximum number of downlink MIMO layers will lower the downlink peak data rate.

- Reduction from 2 layers to 1 layer decreases the downlink peak rate by ~50%.
- Reduction from 4 layers to 2 layers decreases the downlink peak rate by ~50%.
- Reduction from 4 layers to 1 layer decreases the downlink peak rate by ~75%.

Despite this reduction in peak data rate, the UE with reduced number of downlink MIMO layers will be able to sufficiently fulfil the peak data rate requirements for the RedCap uses cases. For peak rate impacts from combinations of UE complexity reduction techniques, see clause 7.8.3.

Latency and reliability:

Reducing the number of MIMO layers does not impact the latency and reliability significantly. The reduction of the maximum number of MIMO layers is only expected to affect the achievable latency for UEs in good channel conditions. The latency requirements of most RedCap use cases can still be sufficiently fulfilled.

7.6.4 Analysis of coexistence with legacy UEs

There is no significant coexistence impact from reduction of the maximum number of MIMO layers for RedCap UEs.

7.6.5 Analysis of specification impacts

The specification impact from reduction of the maximum number of MIMO layers for RedCap UEs is small.

7.7 Relaxed maximum modulation order

7.7.1 Description of feature

Relaxation of maximum mandatory modulation orders reduces complexity through reducing the amount of RF and baseband processing required.

In the study, the main options for relaxation of maximum mandatory modulation orders considered are:

- UL:
  - FR1: 16QAM instead of 64QAM

  - FR2: 16QAM instead of 64QAM
- DL
  - FR1: 64QAM instead of 256QAM
  - FR2: 16QAM instead of 64QAM

The study uses a legacy NR UE as a reference. The evaluation of cost/complexity reduction is with respect to a reference UE with the maximum modulation orders shown below.

- UL:
  - FR1: 64QAM
  - FR2: 64QAM
- DL
  - FR1: 256QAM
  - FR2: 64QAM

It is primarily assumed that these maximum modulation orders apply to data channels only.

7.7.2 Analysis of UE complexity reduction

The estimated cost for a device with relaxed maximum modulation order (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], is summarized in Table 7.7.2-1 and Table 7.7.2-2.

Relaxed maximum uplink modulation order:

As can be seen in the last row for the total cost in Table 7.7.2-1, the average estimated cost reduction achieved by relaxing the maximum uplink modulation order from 64QAM to 16QAM is ~2% for FR1 FDD, FR1 TDD, and FR2.

By comparing Table 7.7.2-1 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:

- RF: Power amplifier
- RF: Transceiver
- Baseband: ADC/DAC
- Baseband: UL processing block

Furthermore, ~50% of sourcing companies indicated that the RF cost savings (but not the baseband cost savings) accumulate across supported bands.

Table 7.7.2-1: Estimated relative device cost for relaxed maximum uplink modulation order

Relaxed maximum UL modulation order	FR1 FDD (64QAM → 16QAM)	FR1 TDD (64QAM → 16QAM)	FR2 (64QAM → 16QAM)
RF: Antenna array	-	-	33.0%
RF: Power amplifier	22.7%	22.7%	16.5%
RF: Filters	10.0%	10.0%	8.0%
RF: Transceiver (including LNAs, mixer, and local oscillator)	44.4%	44.4%	40.4%
RF: Duplexer / Switch	20.0%	20.0%	0.0%
RF: Total relative cost	**97.1%**	**97.1%**	**97.9%**
BB: ADC / DAC	9.1%	9.1%	3.6%
BB: FFT/IFFT	4.0%	4.0%	4.0%
BB: Post-FFT data buffering	10.0%	10.0%	11.0%
BB: Receiver processing block	24.0%	24.0%	24.0%
BB: LDPC decoding	10.0%	10.0%	9.0%
BB: HARQ buffer	13.9%	13.9%	10.9%
BB: DL control processing & decoder	5.0%	5.0%	5.0%

BB: Synchronization / cell search block	9.0%	9.0%	7.0%
BB: UL processing block	4.2%	4.2%	5.8%
BB: MIMO specific processing blocks	9.0%	9.0%	18.0%
BB: Total relative cost	**98.3%**	**98.3%**	**98.4%**
RF+BB: Total relative cost	**97.8%**	**97.8%**	**98.1%**

Relaxed maximum downlink modulation order:

From Table 7.7.2-2, the average estimated cost reduction achieved by relaxing the maximum downlink modulation order from 256QAM to 64QAM is ~6% for both FR1 FDD and TDD bands. For FR2, the average estimated cost reduction achieved by relaxing the maximum DL modulation order from 64QAM to 16QAM is ~6%.

By comparing Table 7.7.2-2 with the reference NR device cost breakdown in clause 6.1, it can be observed that the main contributors of the cost reduction are the following functional blocks:

- RF: Transceiver
- Baseband: ADC/DAC
- Baseband: Receiver processing block
- Baseband: LDPC decoding
- Baseband: HARQ buffer

Furthermore, more than 70% of sourcing companies indicated that these cost savings do not accumulate across supported bands.

Table 7.7.2-2: Estimated relative device cost for relaxed maximum downlink modulation order

Relaxed maximum DL modulation order	**FR1 FDD (256QAM → 64QAM)**	**FR1 TDD (256QAM → 64QAM)**	**FR2 (64QAM → 16QAM)**
RF: Antenna array	-	-	33.0%
RF: Power amplifier	25.0%	24.6%	18.0%
RF: Filters	10.0%	14.9%	8.0%
RF: Transceiver (including LNAs, mixer, and local oscillator)	42.8%	51.8%	38.8%
RF: Duplexer / Switch	20.0%	5.0%	0.0%
RF: Total	**97.8%**	**96.2%**	**97.8%**
BB: ADC / DAC	9.0%	8.0%	3.6%
BB: FFT/IFFT	4.0%	4.0%	4.0%
BB: Post-FFT data buffering	9.4%	9.4%	10.1%
BB: Receiver processing block	23.0%	27.8%	22.7%
BB: LDPC decoding	7.6%	6.8%	6.3%
BB: HARQ buffer	11.0%	9.3%	8.1%
BB: DL control processing & decoder	5.0%	4.0%	5.0%
BB: Synchronization / cell search block	9.0%	9.0%	7.0%
BB: UL processing block	5.0%	5.0%	7.0%
BB: MIMO specific processing blocks	8.7%	8.7%	17.3%
BB: Total	**91.8%**	**92.1%**	**91.0%**
RF+BB: Total	**94.2%**	**93.7%**	**94.4%**

7.7.3 Analysis of performance impacts

Coverage:

Relaxation of maximum mandatory modulation orders does not impact the coverage.

Network capacity and spectral efficiency:

Relaxation of maximum mandatory modulation orders will reduce spectral efficiency due to reduced peak data rate. Quantitative evaluation results are provided in clause 12.

Data rate:

Reducing the maximum modulation orders will lower the downlink peak data rate.

- Reduction from 256QAM to 64QAM decreases the downlink peak rate by ~25%.
- Reduction from 64QAM to 16QAM decreases the downlink peak rate by ~33%.

Despite this reduction in peak data rate, the UE will be able to sufficiently fulfil the peak data rate requirements for the RedCap uses cases. For peak rate impacts from combinations of UE complexity reduction techniques, see clause 7.8.3.

Latency and reliability:

Relaxing the maximum modulation orders may increase the latency slightly. Nevertheless, all the latency and reliability requirements for the RedCap use cases can be satisfied by all the studied options for relaxed maximum modulation orders.

Power consumption:

Relaxation of maximum modulation orders can reduce power consumption of the RF and baseband modules marginally during transmission and reception.

7.7.4 Analysis of coexistence with legacy UEs

Relaxing the maximum modulation orders for RedCap UEs will have no significant impacts on coexistence with legacy UEs.

7.7.5 Analysis of specification impacts

The specification impact from relaxed maximum modulation orders for RedCap UEs is small, assuming that no performance optimizations are introduced.

7.8 Combinations of UE complexity reduction features

7.8.1 Description of feature combinations

The evaluation results for the studied individual UE complexity reduction techniques are captured in clauses 7.2 through 7.7. In this clause, the properties of combinations of different individual UE complexity reduction techniques are described.

7.8.2 Analysis of UE complexity reduction

The estimated costs and estimated cost reductions for devices employing one or more of the UE complexity reduction techniques (see descriptions in clauses 7.2 through 7.7), relative to the reference NR device (see evaluation methodology described in clause 6.1) and averaged over the results provided by the sourcing companies [3], are summarized in Table 7.8.2-1 for FR1 FDD, Table 7.8.2-2 for FR1 TDD, and Table 7.8.2-3 for FR2.

Table 7.8.2-1: Estimated relative device cost and estimated relative device cost reduction for UE complexity reduction technique(s) for FR1 FDD

FR1 FDD UE complexity reduction technique(s)	RF cost metric	BB cost metric	Total cost metric	RF reduction	BB reduction	Total reduction
20 MHz (instead of 100 MHz)	97.7%	48.4%	68.1%	2.3%	51.6%	31.9%
1 layer (instead of 2 layers)	100.0%	79.3%	87.6%	0.0%	20.7%	12.4%
1 layer, 1 Rx (instead of 2 layers, 2 Rx)	74.2%	55.9%	63.2%	25.8%	44.1%	36.8%
HD-FDD type A (instead of FD-FDD)	83.9%	99.4%	93.2%	16.1%	0.6%	6.8%
HD-FDD type B (instead of FD-FDD)	77.3%	99.2%	90.4%	22.7%	0.8%	9.6%
Double N_1 and N_2	100.0%	90.5%	94.3%	0.0%	9.5%	5.7%
DL 64QAM (instead of DL 256QAM)	97.8%	91.8%	94.2%	2.2%	8.2%	5.8%
UL 16QAM (instead of UL 64QAM)	97.1%	98.3%	97.8%	2.9%	1.7%	2.2%
20 MHz, 1 layer, 1 Rx	67.5%	25.8%	42.5%	32.5%	74.2%	57.5%
20 MHz, 1 layer, 1 Rx, HD-FDD type A	53.2%	25.6%	36.6%	46.8%	74.4%	63.4%

20 MHz, 1 layer, 1 Rx, DL 64QAM, UL 16QAM	64.2%	24.3%	40.2%	35.8%	75.7%	59.8%
20 MHz, 1 layer, 1 Rx, double N_1 and N_2	67.5%	22.9%	40.7%	32.5%	77.1%	59.3%
20 MHz, 1 layer, 1 Rx, DL 64QAM, UL 16QAM, double N_1 and N_2	64.6%	21.7%	38.9%	35.4%	78.3%	61.1%
20 MHz, 1 layer, 1 Rx, DL 64QAM, UL 16QAM, HD-FDD type A, double N_1 and N_2	50.2%	21.4%	32.9%	49.8%	78.6%	67.1%
20 MHz, 2 layers, 2 Rx, HD-FDD type A	81.3%	46.0%	60.1%	18.8%	54.0%	39.9%
20 MHz, 2 layers, 2 Rx, double N_1 and N_2	97.6%	42.6%	64.6%	2.4%	57.4%	35.4%

Table 7.8.2-2: Estimated relative device cost and estimated relative device cost reduction for UE complexity reduction technique(s) for FR1 TDD

FR1 TDD UE complexity reduction technique(s)	RF cost metric	BB cost metric	Total cost metric	RF reduction	BB reduction	Total reduction
20 MHz (instead of 100 MHz)	96.4%	46.7%	66.6%	3.6%	53.3%	33.4%
2 layers (instead of 4 layers)	100.0%	81.1%	88.7%	0.0%	18.9%	11.3%
1 layer (instead of 4 layers)	100.0%	71.9%	83.2%	0.0%	28.1%	16.8%
2 layers, 2 Rx (instead of 4 layers, 4 Rx)	68.0%	55.4%	60.4%	32.0%	44.6%	39.6%
1 layer, 1 Rx (instead of 4 layers, 4 Rx)	51.3%	33.0%	40.3%	48.7%	67.0%	59.7%
Double N_1 and N_2	100.0%	90.1%	94.1%	0.0%	9.9%	5.9%
DL 64QAM (instead of DL 256QAM)	96.2%	92.1%	93.7%	3.8%	7.9%	6.3%
UL 16QAM (instead of UL 64QAM)	96.9%	98.4%	97.8%	3.1%	1.6%	2.2%
20 MHz, 1 layer, 1 Rx	50.6%	18.6%	31.4%	49.4%	81.4%	68.6%
20 MHz, 1 layer, 1 Rx, DL 64QAM, UL 16QAM	47.1%	17.5%	29.3%	52.9%	82.5%	70.7%
20 MHz, 1 layer, 1 Rx, double N_1 and N_2	50.6%	16.2%	30.0%	49.4%	83.8%	70.0%
20 MHz, 1 layer, 1 Rx, DL 64QAM, UL 16QAM, double N_1 and N_2	47.1%	15.3%	28.1%	52.9%	84.7%	71.9%
20 MHz, 2 layers, 2 Rx	66.8%	27.8%	43.4%	33.3%	72.2%	56.6%
20 MHz, 2 layers, 2 Rx, DL 64QAM, UL 16QAM	61.8%	26.1%	40.4%	38.2%	73.9%	59.6%
20 MHz, 2 layers, 2 Rx, double N_1 and N_2	66.8%	24.9%	41.7%	33.3%	75.1%	58.3%
20 MHz, 2 layers, 2 Rx, DL 64QAM, UL 16QAM, double N_1 and N_2	61.8%	23.7%	38.9%	38.2%	76.3%	61.1%

Table 7.8.2-3: Estimated relative device cost and estimated relative device cost reduction for UE complexity reduction technique(s) for FR2

FR2 UE complexity reduction technique(s)	RF cost metric	BB cost metric	Total cost metric	RF reduction	BB reduction	Total reduction
100 MHz (instead of 200 MHz)	99.5%	69.4%	84.4%	0.5%	30.6%	15.6%
50 MHz (instead of 200 MHz)	99.0%	54.0%	76.5%	1.0%	46.0%	23.5%
1 layer (instead of 2 layers)	100.0%	77.8%	88.9%	0.0%	22.2%	11.1%
1 layer, 1 Rx (instead of 2 layers, 2 Rx)	64.9%	55.7%	60.3%	35.1%	44.3%	39.7%
Double N_1 and N_2	100.0%	88.9%	94.4%	0.0%	11.1%	5.6%
DL 16QAM (instead of DL 64QAM)	97.8%	91.0%	94.4%	2.2%	9.0%	5.6%
UL 16QAM (instead of UL 64QAM)	97.9%	98.4%	98.1%	2.2%	1.6%	1.9%
100 MHz, 1 layer, 1 Rx	64.8%	40.3%	52.5%	35.2%	59.7%	47.5%
100 MHz, 1 layer, 1 Rx, DL 16QAM, UL 16QAM	61.6%	37.0%	49.3%	38.4%	63.0%	50.7%
100 MHz, 1 layer, 1 Rx, double N_1 and N_2	64.4%	35.5%	50.0%	35.6%	64.5%	50.0%
100 MHz, 1 layer, 1 Rx, DL 16QAM, UL 16QAM, double N_1 and N_2	61.6%	32.9%	47.2%	38.4%	67.1%	52.8%
100 MHz, 2 layers, 2 Rx, DL 16QAM, UL 16QAM	95.2%	63.8%	79.5%	4.8%	36.2%	20.5%
100 MHz, 2 layers, 2 Rx, double N_1 and N_2	99.4%	62.4%	80.9%	0.6%	37.6%	19.1%
100 MHz, 2 layers, 2 Rx, DL 16QAM, UL 16QAM, double N_1 and N_2	95.2%	57.8%	76.5%	4.8%	42.2%	23.5%

7.8.3 Analysis of performance impacts

Peak data rate:

Reducing the maximum number of downlink MIMO layers (with or without reducing the number of Rx branches) will lower the downlink peak data rate.

- Reduction from 2 layers to 1 layer decreases the downlink peak rate by ~50%.
- Reduction from 4 layers to 2 layers decreases the downlink peak rate by ~50%.
- Reduction from 4 layers to 1 layer decreases the downlink peak rate by ~75%.

Reducing the maximum UE bandwidth will lower the downlink peak data rate.

- Reduction from 100 MHz to 20 MHz decreases the downlink peak rate by ~80%.
- Reduction from 200 MHz to 100 MHz decreases the downlink peak rate by ~50%.
- Reduction from 200 MHz to 50 MHz decreases the downlink peak rate by ~75%.

Reducing the maximum modulation orders will lower the peak data rate.

- Reduction from 256QAM to 64QAM decreases the peak rate by ~25%.
- Reduction from 64QAM to 16QAM decreases the peak rate by ~33%.

Other performance impacts:

For impacts on coverage, network capacity, spectral efficiency, data rate, latency, reliability, power consumption and PDCCH blocking rate from each UE complexity reduction technique, refer to clauses 7.2 through 7.7.

Quantitative evaluation results for coverage, network capacity and spectral efficiency are provided in clauses 9 and Annex D.

7.8.4 Analysis of coexistence with legacy UEs

For coexistence impacts from each UE complexity reduction technique, refer to clauses 7.2 through 7.7.

7.8.5 Analysis of specification impacts

For specification impacts from each UE complexity reduction technique, refer to clauses 7.2 through 7.7.

8 UE power saving features

8.1 Introduction to UE power saving features

The following UE power saving techniques have been studied:

- Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits
- Extended DRX for RRC Inactive and/or Idle
- RRM relaxation for stationary devices

The outcomes of the studies of these techniques are captured in clauses 8.2 through 8.4, respectively, and summarized in clause 13.

In addition, RAN2 has studied the impact of introducing RedCap UEs on UE power consumption in general and has observed that power consumption of RedCap UEs may be impacted because of paging false alarm and unnecessary SIB1 reading. Paging false alarm and unnecessary SIB1 reading are not specific to RedCap UEs and are discussed in Rel-17 Power Saving WI. Enhancements introduced by Rel-17 Power Saving WI should also be applicable to RedCap UEs.

8.2 Reduced PDCCH monitoring

8.2.1 Description of feature

Scheme #1: Reduced maximum number of Blind Decoding (BD) per slot in connected mode:

In Rel-15 and Rel-16 NR, the number of BDs per slot is configurable up to the limits defined for different SCS configurations, as summarized in 8.2.1-1. Scheme #1 reduces the maximum number of BDs in a slot. In Rel-15 and Rel-16 specifications, the total number of different DCI sizes configured to monitor is up to 4 with up to 3 different DCI sizes with C-RNTI. Two alternatives were studied under Scheme #1, which includes reduced maximum number of BDs per slot with additionally reduced DCI size budget (Alt.1a) and reduced maximum number of BDs per slot without reduced DCI size budget (Alt.1b).

Table 8.2.1-1: Blind decoding 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 gap to X slots (X>1) in connected mode:

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 extend the minimum separation between two consecutive PDCCH monitoring occasions, spans or slots with configured PDCCH candidates to be X slots, where X>1.

Scheme #3: Dynamic adaptation of PDCCH BD parameters in connected mode:

In Rel-15/16, the parameters of PDCCH monitoring is configured by RRC signalling on a per search space set basis. Scheme #3 is to dynamically adapt PDCCH BD parameters e.g. maximum number of PDCCH candidates per PDCCH monitoring occasion and minimum time separation between two consecutive PDCCH monitoring occasions

8.2.2 Analysis of UE power saving

UE power saving for FR1:

The UE power saving evaluation results for FR1 from [3] are summarized in Tables A.1-1 through A.1-4 in Annex A.1.

12 sources (Vivo, Ericsson, Qualcomm, CATT, Spreadtrum, Oppo, Huawei/HiSilicon, Apple, Futurewei, Intel, ZTE, InterDigital) reported the evaluation results of power saving gain for FR1 with same-slot scheduling for the 1 Rx antenna case. The following is observed for the 1 Rx antenna case:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.32%~5.7%} and {0.59%~11.4%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 2.81% and 5.82%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~3.40%} and {0.02%~6.80%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain by reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.56% and 3.25%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~3.20%} and {0.02%~6.40%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.33% and 2.92%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.90%~3.88%} and {1.82%~6.48%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 2.59% and 4.74%, respectively.

13 sources (Vivo, Ericsson, Qualcomm, Nokia, CATT, Spreadtrum, Oppo, Huawei/HiSilicon, Apple, Futurewei, Intel, ZTE, InterDigital) reported the evaluation results of power saving gain for FR1 with same-slot scheduling for 2 Rx antennas cases. The following is observed for the 2 Rx antennas case:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.44%~6.20%} and {0.82%~12.30%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 3.05% and 6.59%.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~4.10%} and {0.03%~8.20%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.65% and 3.72%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~3.90%} and {0.02%~7.80%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.49% and 3.42%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {1.16%~4.60%} and {2.32%~7.20%}. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 2.85% and 5.66%, respectively.

8 sources (Vivo, Ericsson, Samsung, Qualcomm, Oppo, Apple, ZTE, MediaTek) reported the evaluation results of power saving gain for FR1 with cross-slot scheduling for the 1 Rx antenna and 2 Rx antennas cases. The following is observed for the 1 Rx antenna case:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.30%~4.5%} and {0.36%~9%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 2.58% and 4.26%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~2.7%} and {0.01%~5.5%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing 36 PDCCH blind decoding by 25% and 50% are approximately 1.66% and 2.48%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~2.6%} and {0.01%~5.1%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.60% and 2.34%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.87%~4.5%} and {1.39%~7%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 2.29% and 3.20%, respectively.

For the 2 Rx case (with cross-slot scheduling), the observations are as follows:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.36%~4.69%} and {0.67%~9.38%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 3.08% and 5.7%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~2.9%} and {0.02%~5.7%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.95% and 3.51%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.01%~2.5%} and {0.02%~4.94%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 1.69% and 3.21%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50%, the power saving gains are in the range of approximately {0.83%~3.5%} and {1.65%~6.07%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 36) by 25% and 50% are approximately 2.28% and 4.45%, respectively.

In general, it is expected that the power saving gain by BD reduction for cross-slot scheduling is less than that of the same-slot scheduling. Also, in general, it is expected that the power saving gain by BD reduction for 1 Rx case is less than that of the 2 Rx case.

UE power saving for FR2:

The UE power saving evaluation results for FR2 from [3] are summarized in Tables A.2-1 through A.2-4 in Annex A.2.

6 sources (Ericsson, CATT, Spreadtrum, Futurewei, Intel, ZTE) reported the evaluation results of power saving gain for FR2 with same-slot scheduling for the 1 Rx antenna and 2 Rx antennas cases. The following is observed for the 1 Rx antenna case:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.77%~6.6%} and {1.43%~13.1%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 4.20% and 8.60%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.03%~4.30%} and {0.06%~8.60%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain by reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 1.72% and 3.69%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.03%~4%} and {0.05%~7.9%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 1.28% and 2.58%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {2.52%~5%} and {4.66%~9.4%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 3.81% and 7.43%, respectively.

For the 2 Rx case (with same-slot scheduling), the observations are as follows:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {1.04%~6.8%} and {1.92%~13.6%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 4.52% and 8.98%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.04%~4.90%} and {0.08%~11.90%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain by reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 2.13% and 4.14%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.04%~4.6%} and {0.07%~9.2%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 1.99% and 3.88%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {3.10%~5.5%} and {5.74%~10.5%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 4.27% and 8.27%, respectively.

4 sources (Ericsson, Samsung, ZTE, MediaTek) reported the evaluation results of power saving gain for FR2 with cross-slot scheduling for the 1 Rx antenna and 2 Rx antennas cases. The following is observed for the 1 Rx antenna case:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.55%~6.30%} and {1.03%~12.7%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 3.19% and 6.17%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.02%~4.20%} and {0.04%~8.30%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain by reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 1.30% and 2.60%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.02%~3.9%} and {0.04%~7.6%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 1.24% and 2.48%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {1.94%~6.5%} and {3.6%~13.1%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 3.27% and 6.33%, respectively.

For the 2 Rx case (with cross-slot scheduling), the observations are as follows:

- For the instant message traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.75%~6.6%} and {1.4%~13.20%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 3.43% and 6.59%, respectively.

- For the heartbeat traffic model with 200ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.03%~4.90%} and {0.06%~9.60%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain by reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 1.05% and 2.11%, respectively.

- For the heartbeat traffic model with 80ms inactivity timer configuration, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {0.03%~4.6%} and {0.05%~8.9%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 0.92% and 1.84%, respectively.

- For the VoIP traffic model, with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50%, the power saving gains are in the range of approximately {1.97%~6.8%} and {3.95%~13.7%}, respectively. With excluding the smallest and the largest values among sources, the mean value of power saving gain with reducing maximum PDCCH blind decoding (i.e. 20) by 25% and 50% are approximately 3.38% and 6.52%, respectively.

In general, it is expected that the power saving gain by BD reduction for cross-slot scheduling is less than that of the same-slot scheduling. Also, in general, it is expected that the power saving gain by BD reduction for 1 Rx case is less than that of the 2 Rx case.

8.2.3 Analysis of performance impacts

PDCCH blocking rate vector format:

Each observation below for PDCCH blocking rate impact based on the evaluation results in [3] is formulated using the vector format: *<N, A%, [z1%, x1%, y1%], [z2%, x2%, y2%]>*, which represents the following: With *N* simultaneously scheduled UEs in a slot and *z1%* reduction in maximum PDCCH blind decoding, the PDCCH blocking rate is increased approximately *x1%* from *A%*, which corresponds to *y1%* increase relative to *A%*. With *N* simultaneously scheduled UEs in a slot and *z2%* reduction in maximum PDCCH blind decoding, the PDCCH blocking rate is increased approximately *x2%* from *A%*, which corresponds to *y2%* increase relative to *A%*.

PDCCH blocking rate for FR1:

Evaluation results of PDCCH blocking rate were reported for FR1 with AL distribution configuration 'A1' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4. Based on Table B.1-1, the observations from these evaluation results are summarized as follows:

- 10 sources (Vivo, Ericsson, Qualcomm, Nokia, Huawei/HiSilicon, InterDigital, Intel, ZTE, Samsung, Futurewei) reported the following evaluation results:
  - < 2, 1.63%, [25%, 0.39%, 23.9%], [50%, 0.77%, 47.11%] >
  - < 3, 2.70%, [25%, 0.71%, 30.85%], [50%, 1.28%, 47.26%] >
  - < 4, 3.22%, [25%, 0.99%, 30.85%], [50%, 4.35%, 135.32%] >
  - < 5, 4.07%, [25%, 1.98%, 48.68%], [50%, 6.81%, 167.16%] >
  - < 6, 4.84%, [25%, 2.25%, 48.68%], [50%, 9.70%, 200.54%] >
  - < 7, 5.34%, [25%, 6.36%, 119.24%], [50%, 15.8%, 296%] >
  - < 8, 9.81%, [25%, 4.54%, 46.24%], [50%, 16.21%, 165.24%] >
  - < 9, 7.32%, [25%, 7.79%, 106.43%], [50%, 19.59%, 267.74%] >
  - < 10, 10.39%, [25%, 11.84%, 113.99%], [50%, 17.71%, 170.45%] >

Evaluation results of PDCCH blocking rate were reported for FR1 with configuration 'A2' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4. Based on Table B.1-2, the observations from these evaluation results are summarized as follows:

- 5 sources (Ericsson, Qualcomm, Nokia, ZTE, Samsung) reported the following evaluation results:
  - < 2, 6.6%, [25%, 0.1%, 1.52%], [50%, 1.63%, 24.62%] >
  - < 3, 13.15%, [25%, 0.18%, 1.33%], [50%, 3.95%, 30.04%] >
  - < 4, 20.18%, [25%, 0.3%, 1.49%], [50%, 3.33%, 16.48%] >
  - < 6, 36.53%, [25%, 1.03%, 2.83%], [50%, 4.37%, 11.95%] >
- 3 sources (Qualcomm, Nokia Samsung) reported the following evaluation results:
  - < 5, 37.32%, [25%, 1.58%, 4.24%], [50%, 8.95%, 23.98%] >
  - < 7, 47.38%, [25%, 2.33%, 4.92%], [50%, 8.67%, 18.29%] >
- 3 sources (Qualcomm, ZTE Samsung) reported the following evaluation results:

    - <8, 33.58%, [25%, 2.68%, 7.99%], [50%, 10.30%, 30.67%]>

- 2 sources (Qualcomm, Samsung) reported the following evaluation results:

    - <9, 29.55%, [25%, 3.95%, 13.37%], [50%, 13.58%, 45.94%]>

    - <10, 33.75%, [25%, 3.98%, 11.78%], [50%, 13.43%, 39.78%]>

Evaluation results of PDCCH blocking rate were reported for FR1 with configuration 'A3' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4. Based on Table B.1-3, the observations from these evaluation results are summarized as follows:

- 3 sources (Qualcomm, Samsung), ZTE or Ericsson) reported the following evaluation results:

    - <2, 16.73%, [25%, 2.78%, 16.63%], [50%, 4.88%, 29.18%]>

    - <3, 27.90%, [25%, 4.47%, 16.01%], [50%, 8.08%, 28.97%]>

    - <4, 36.47%, [25%, 4.6%, 12.61%], [50%, 9.07%, 24.86%]>

- 2 sources (Qualcomm, Samsung) reported the following evaluation results:

    - <5, 33.9%, [25%, 7.33%, 21.61%], [50%, 12.75%, 37.61%]>

- 4 sources (Qualcomm, Samsung), ZTE, Ericsson) reported the following evaluation results:

    - <6, 63.88%, [25%, 0.62%, 0.98%], [50%, 2.2%, 3.44%]>

- 2 sources (Qualcomm, Samsung) reported the following evaluation results:

    - <7, 44.62%, [25%, 6.38%, 14.42%], [50%, 12.7%, 28.73%]>

    - <9, 52.75%, [25%, 4.35%, 8.25%], [50%, 10.15%, 19.24%]>

    - <10, 56.35%, [25%, 2.85%, 5.06%], [50%, 9.12%, 16.19%]>

- 2 sources (Qualcomm, ZTE) reported the following evaluation results:

    - <8, 56.65%, [25%, 3.42%, 6.03%], [50%, 8.43%, 14.89%]>

1 source (Huawei/HiSilicon) reported the following evaluation results of PDCCH blocking rate for FR1 with baseline evaluation parameters in Table 6.2-4 and configuration 'A4' in Table 6.2-5 (the results are available in Table B.1-4):

- <5, 12.3%, [25%, 1.5%, 12.20%], [50%, 4%, 32.52%]>

- <10, 29.4%, [25%, 4.5%, 15.31%], [50%, 4.9%, 16.67%]>

1 source ([Panasonic]) reported the following evaluation results of PDCCH blocking rate for FR1 with baseline evaluation parameters in Table 6.2-4 and configuration 'A7' in Table 6.2-5 (the results are available in Table B.1-4):

- <4, 5.93%, [25%, 1.1%, 18.55%], [50%, 8%, 134.91%]>

- <6, 10.1%, [25%, 3.6%, 35.64%], [50%, 13.1%, 129.7 %]>

1 source (Vivo) reported the evaluation results of PDCCH blocking rate for FR1 with configuration 'A1' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4 except 15kHz SCS and 20MHz (the results are available in Table B.1-5).

- <2, 0%, [25%, 1.36%, N/A], [50%, 1.17%, N/A]>

- <3, 0.56%, [25%, 1.58%, 284.14%], [50%, 1.76%, 314.29%]>

- <4, 1.31%, [25%, 1.63%, 124.43%], [50%, 2.04%, 155.73%]>

- <5, 1.9%, [25%, 1.83%, 96.32%], [50%, 2.24%, 117.89%]>

Evaluation results of PDCCH blocking rate were reported for FR1 with configuration 'A1' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4 except the following: 15kHz SCS/20 MHz BW and 3-symbols CORESET duration. Based on Table B.1-6, the observations from these evaluation results are summarized as follows:

- 3 sources (Vivo, Nokia, Intel) reported the following evaluation results:
  - <2, 0%, [25%, 0.3%, N/A], [50%, 0.3%, N/A]>
  - <3, 0.67%, [25%, 0.6%, 89.55%], [50%, 1.13%, 167.91%]>
  - <4, 0.88%, [25%, 0.88%, 100%], [50%, 1.88%, 213.64%]>
  - <5, 2.54%, [25%, 2.34%, 92.13%], [50%, 4.37%, 172.05%]>
- 1 source (Nokia) reported the following evaluation results with using C2 in Table 6.2-6 as number of PDCCH candidates for AL [1,2,4,8,16]
  - <6, 10%, [25%, 2%, 20%], [50%, 6%, 60%]>
  - <7, 12.50%, [25%, 2%, 16%], [50%, 7%, 56%]>
- 2 sources (Nokia, Intel) reported the evaluation result:
  - <8, 9.04%, [25%, 2%, 22.14%], [25%, 6.61%, 73.10%]>
- 1 source (Intel) reported the following evaluation results with using C10 in Table 6.2-6 as number of PDCCH candidates for AL [1,2,4,8,16]:
  - <10, 0.2%, [25%, 0%, 0%], [50%, 0.4%, 200%]>
  - <15, 1.8%, [25%, 0%, 0%], [50%, 0.7%, 38.89%]>

1 source (ZTE) reported the evaluation results of PDCCH blocking rate for FR1 with configuration A1/A2/A3 in Table 6.2-5 and baseline evaluation parameters in Table 6.2-4 except the following parameters: 15kHz SCS/20 MHz BW and 1/2/3 slots delay tolerance. The results are available in Table B.1-7.

- The following was observed for AL distribution configuration 'A1' with 1 slot delay tolerance:
  - <2, 0%, [25%, 0%, N/A], [50%, 0.14%, N/A]>
  - <4, 0.08%, [25%, 0.08%, 0%], [50%, 0.54%, 675%]>
  - <6, 0.3%, [25%, 0.19%, 63.33%], [50%, 1.04%, 347%]>
  - <8, 0.7%, [25%, 0.42%, 60%], [50%, 1.56%, 223%]>
- The following was observed for AL distribution configuration 'A1' with 2 slots delay tolerance:
  - <2, 0%, [25%, 0%, N/A], [50%, 0.06%, N/A]>
  - <4, 0.03%, [25%, 0.02%, 66.67%], [50%, 0.26%, 867%]>
  - <6, 0.15%, [25%, 0.10%, 66.67%], [50%, 0.52%, 347%]>
  - <8, 0.37%, [25%, 0.24%, 64.86%], [50%,0.81%, 219%]>
- The following was observed for AL distribution configuration 'A1' with 3 slots delay tolerance:
  - <2, 0%, [25%, 0%, N/A], [50%, 0.04%, N/A]>
  - <4, 0.03%, [25%, 0.01%, 33.33%], [50%, 0.19%, 633%]>
  - <6, 0.08%, [25%, 0.08%, 100%], [50%, 0.38%, 475%]>
  - <8, 0.24%, [25%, 0.16%, 66.67%], [50%, 0.60%, 250%]>
- The following was observed for AL distribution configuration 'A2':

    - <2, 0%, [25%, 0.76%, N/A], [50%, 2.02%, N/A]>
    - <4, 2.48%, [25%, 1.80%, 72.58%], [50%, 6.53%, 263%]>
    - <6, 10.23%, [25%, 0.91%, 8.9%], [50%, 6.68%, 65.30%]>
    - <8, 18.23%, [25%, 0.65%, 3.57%], [50%, 6.30%, 34.56%]>
- The following was observed for AL distribution configuration 'A3':
    - <2, 0%, [25%, 0.03%, N/A], [50%, 0.03%, N/A]>
    - <4, 23.58%, [25%, 0.74%, 3.14%], [50%, 3.03%, 12.85%]>
    - <6, 39.39%, [25%, 0.11%, 0.28%], [50%, 2.16%, 5.48%]>
    - <8, 48.95%, [25%, 0.23%, 0.47%], [50%, 2.55%, 5.21%]>

1 source (Vivo) reported the evaluation results of PDCCH blocking rate for FR1 with configuration A1 in Table 6.2-5 and baseline evaluation parameters in Table 6.2-4 except 3-symbols CORESET duration is assumed. From Table B.1-8, the following was observed:

- <2, 0.67%, [25%, 0.91%, 135%], [50%, 0.81%, 120.9%]>
- <3, 1.62%, [25%, 1.33%, 82%], [50%, 1.51%, 93.21%]>
- <4, 2.34%, [25%, 2.05%, 87.6%], [50%, 2.46%, 105.13%]>
- <5, 3.35%, [25%, 2.39%, 71.3%], [50%, 2.46%, 73.43%]>

1 source (Huawei/HiSilicon) reported the evaluation results of PDCCH blocking rate for FR1 with configuration A1/A4/A5/A6 in Table 6.2-5 and baseline evaluation parameters in Table 6.2-4 except 60-bits DCI payload size (not including CRC) is assumed for A5 and A6. The following was observed with 50% BD reduction by reducing the monitored DCI sizes from 2 to 1:

- For configuration A1(results in Table B.1-1 with "Note 4"):
    - <5, 6.07%, [50%, 0%, 0%]>,
    - <10, 17.3%, [50%, 0%, 0%]>
- For configuration A4 (results in Table B.1-4 with "Note 4"):
    - <5, 12.3%, [50%, 0%, 0%]>,
    - <10, 29.4%, [50%, 0%, 0%]>
- For configuration A5 (results in Table B.1-9 with "Note 1"):
    - <5, 8.6%, [50%, 0%, 0%]>,
    - <10, 23.20%, [50%, 0%, 0%]>
- For configuration A6 (results in Table B.1-9 with "Note 1"):
    - < 5, 14.5%, [50%, 0%, 0%]>,
    - <10, 33.70%, [50%, 0%, 0%]>

1 source (Samsung) reported the evaluation results of PDCCH blocking rate for FR1 with configuration A1/A2/A3 in Table 6.2-5 and baseline evaluation parameters in Table 6.2-4 with UE group scheduling and PDCCH dropping based on predefined CCE AL priority order.

- The following was observed for configuration A1:
    - With UE group scheduling (results in Table B.1-1 with "Note 6"):
        - <2, 0%, [25%, 0%, N/A], [50%, 0%, N/A]>,

        - <3, 0%, [25%, 0%, N/A], [50%, 0%, N/A]>,
        - <4, 0%, [25%, 0%, N/A], [50%, 0%, N/A]>,
        - <5, 0%, [25%, 0%, N/A], [50%, 2%, N/A]>,
        - <6, 0%, [25%, 0%, N/A], [50%, 2%, N/A]>,
        - <7, 0%, [25%, 1%, N/A], [50%, 7%, N/A]>,
        - <8, 0%, [25%, 1%, N/A], [50%, 7%, N/A]>,
        - <9, 0%, [25%, 3%, N/A], [50%, 13%, N/A]>,
        - <10, 0%, [25%, 3%, N/A], [50%, 13%, N/A]>
    - With PDCCH dropping based on predefined CCE AL priority order [1,2,4,8,16] (results in Table B.1-1 with "Note 7"):
        - <2, 0%, [25%, 0%, N/A], [50%, 8%, N/A]>,
        - <3, 0%, [25%, 0%, N/A], [50%, 14%, N/A]>,
        - <4, 0%, [25%, 1%, N/A], [50%, 19%, N/A]>,
        - <5, 0%, [25%, 1%, N/A], [50%, 22%, N/A]>,
        - <6, 1%, [25%, 1%, 100%], [50%, 24%, 2400%]>,
        - <7, 2%, [25%, 1%, 50%], [50%, 26%, 1300%]>,
        - <8, 3%, [25%, 2%, 67%], [50%, 28%, 933%]>,
        - <9, 6%, [25%, 1%, 17%], [50%, 28%, 467%]>
        - <10, 8%, [25%, 2%, 25%], [50%, 30%, 375%]>
- The following was observed for configuration A2:
    - With UE group scheduling (results in Table B.1-2 with "Note 6"):
        - <2, 0%, [25%, 0%, N/A], [50%, 0%, N/A]>,
        - <3, 0%, [25%, 2.6%, N/A], [50%, 3%, N/A]>,
        - <4, 0%, [25%, 2.6%, N/A], [50%, 3%, N/A]>,
        - <5, 0%, [25%, 4.6%, N/A], [50%, 7%, N/A]>,
        - <6, 0%, [25%, 4.6%, N/A], [50%, 7%, N/A]>,
        - <7, 1%, [25%, 6.3%, 630%], [50%, 11%, 1100%]>,
        - <8, 1%, [25%, 6.3%, 630%], [50%, 11%, 1100%]>,
        - <9, 2%, [25%, 10.4%, 520%], [50%, 16%, 800%]>,
        - <10, 2%, [25%, 10.4%, 520%], [50%, 16%, 800%]>
    - With PDCCH dropping based on predefined CCE AL priority order [1,2,4,8,16] (results in Table B.1-2 with "Note 7"):
        - <2, 0%, [25%, 1%, N/A], [50%, 3%, N/A]>,
        - <3, 0%, [25%, 1%, N/A], [50%, 6%, N/A]>,
        - <4, 1%, [25%, 1%, 100%], [50%, 8%, 800%]>,
        - <5, 2%, [25%, 1%, 50%], [50%, 9%, 450%>,

    - <6, 3%, [25%, 2%, 67%], [50%, 12%, 400%]>,
    - <7, 5%, [25%, 2%, 40%], [50%, 13%, 260%]>,
    - <8, 8%, [25%, 2%, 25%], [50%, 14%, 175%]>,
    - <9, 11%, [25%, 2%, 18%], [50%, 14%, 127%]>
    - <10, 15%, [25%, 1%, 7%], [50%, 14%, 93%]>
- The following was observed for configuration A3:
  - With UE group scheduling (results in Table B.1-3 with "Note 6"):
    - <2, 0%, [25%, 0%, N/A], [50%, 0%, N/A]>,
    - <3, 0%, [25%, 1%, N/A], [50%, 12%, N/A]>,
    - <4, 0%, [25%, 1%, N/A], [50%, 12%, N/A]>,
    - <5, 3%, [25%, -2%, -67%], [50%, 19%, 633%]>,
    - <6, 3%, [25%, -2, -67%], [50%, 19%, 633%]>,
    - <7, 7%, [25%, -4%, -57%], [50%, 23%,329%]>,
    - <8, 7%, [25%, -4%, -57%], [50%, 23%, 329%]>,
    - <9, 12%, [25%, -7%, -58%], [50%, 24%, 200%]>,
    - <10, 12%, [25%, -7%, -58%], [50%, 24%, 200%]>
  - With PDCCH dropping based on predefined CCE AL priority order [1,2,4,8,16] (results in Table B.1-3 with "Note 7"):
    - <2, 0%, [25%, 0%, N/A], [50%, 0%, N/A]>,
    - <3, 3%, [25%, 0%, 0%], [50%, 1%, 33%]>,
    - <4, 7%, [25%, 1%, 14%], [50%, 1%, 14%]>,
    - <5, 12%, [25%, 1%, 8%], [50%, 1%, 8%]>,
    - <6, 17%, [25%, 1%, 6%], [50%, 1%, 6%]>,
    - <7, 22%, [25%, 1%, 5%], [50%, 2%, 9%]>,
    - <8, 28%, [25%,0%, 0%], [50%, 2%, 7%]>,
    - <9, 33%, [25%, 1%, 3%], [50%, 2%, 6%]>
    - <10, 38%, [25%, 0%, 0%], [50%, 2%, 5%]>

PDCCH blocking rate for FR2:

Evaluation results of PDCCH blocking rate were reported for FR2 with configuration 'A1' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4. The results are available in Table B.2-1.

- 4 sources (Ericsson, Qualcomm, Nokia, Samsung) reported the following evaluation results:
  - <2, 0.07%, [25%, 2.07%, 3100%], [50%, 4.93%, 7400%]>
  - <3, 1%, [25%, 3.07%, 307%], [50%, 7.47%, 747%]>
  - <4, 2.7%, [25%, 4.93%, 183%], [50%, 13.43%, 498%]>
  - <5, 7%, [25%, 9%, 129%], [50%, 21.5%, 307%]>

  - <6, 7.13%, [25%, 6.7%, 94%], [50%, 20.30%, 285%]>
  - <7, 15.50%, [25%, 14.5%, 94%], [50%, 36.5%, 235%]>
  - <8, 15.70%, [25%, 12.57%, 80%], [50%, 34.47%, 220%]>
  - <10, 17.20%, [25%, 12.3%, 72%], [50%, 26.75%, 156%]>
- 1 source (Samsung) reported the following evaluation results:
  - <9, 22%, [25%, 20%, 91%], [50%, 33%, 150%]>
- 1 source (Qualcomm) reported the following evaluation results:
  - <12, 12.7%, [25%, 3.9%, 31%], [50%, 20.80%, 164%]>
  - <14, 17.70%, [25%, 3.8%, 21%], [50%, 20.30%, 115%]>
  - <16, 22.90%, [25%, 3.6%, 16%], [50%, 18.80%, 82%]>
  - <18, 28.20%, [25%, 3.2%, 11%], [50%, 17.20%, 61%]>
  - <20, 33.50%, [25%, 2.6%, 8%], [50%, 15.20%, 45%]>

4 sources (Ericsson, Qualcomm, ZTE, Samsung) reported the following evaluation results of PDCCH blocking rate for FR2 with configuration 'A2' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4 (the results are available in Table B.2-2):

- <2, 9.2%, [25%, 10.73%, 117%], [50%, 22.36%, 243%]>
- <3, 17.07%, [25%, 9.7%, 57%], [50%, 18.03%,106%]>
- <4, 23.83%, [25%, 8.8%, 37%], [50%, 20.83%, 87%]>
- <5, 27.95%, [25%, 11%, 39%], [50%, 20.8%, 74%]>
- <6, 35.78%, [25%, 6.45%, 18%], [50%, 15.06%, 42%]>
- <7, 37.40%, [25%, 8.8%, 24%], [50%, 18.25%, 49%]>
- <8, 45.07%, [25%, 6.03%,13%], [50%, 14.70%, 33%]>
- <9, 45%, [25%, 7.35%, 16%], [50%, 15.65%, 35%]>
- <10, 48.25%, [25%, 6.8%, 14%], [50%, 14.55%, 30%]>

3 sources (Ericsson, Qualcomm, Samsung) reported the following evaluation results of PDCCH blocking rate for FR2 with configuration 'A3' in Table 6.2-5 and the baseline evaluation parameters in Table 6.2-4 (the results are available in Table B.2-3):

- <2, 18.10%, [25%, 8.75%, 48%], [50%, 22.45%, 124%]>
- <3, 35.40%, [25%, 6.6%, 19%], [50%, 15.40%,44%]>
- <4, 40.4%, [25%, 8.05%, 20%], [50%, 18.85%, 47%]>
- <5, 47.55%, [25%, 7.65%, 16%], [50%, 17.6%, 37%]>
- <6, 56.5%, [25%, 5.13%, 9%], [50%, 11.77%, 21%]>
- <7, 57.95%, [25%, 6.25%, 11%], [50%, 14.2%, 25%]>
- <8, 61.6%, [25%, 5.75%,9%], [50%, 13.15%, 21%]>
- <9, 64.35%, [25%, 5.25%, 8%], [50%, 12.20%, 19%]>
- <10, 66.85%, [25%, 5.2%, 8%], [50%, 11.2%, 17%]>

1 source (Samsung) reported the evaluation results of PDCCH blocking rate for FR2 with configuration A1/A2/A3 in Table 6.2-5, baseline evaluation parameters in Table 6.2-4, and with UE group scheduling or PDCCH dropping based on predefined CCE AL priority order.

- The following was observed for A1:
  - With UE group scheduling (results in Table B.2-1with "Note 3"):
    - <2, 0%, [25%, 5%, N/A], [50%, 8%, N/A]>,
    - <3, 0%, [25%, 5%, N/A], [50%, 8%, N/A]>,
    - <4, 0%, [25%, 5%, N/A], [50%, 8%, N/A]>,
    - <5, 0%, [25%, 7%, N/A], [50%, 14%, N/A]>,
    - <6, 0%, [25%, 7%, N/A], [50%, 14%, N/A]>,
    - <7, 1%, [25%, 11%, 1100%], [50%, 21%, 2100%]>,
    - <8, 1%, [25%, 11%, 1100%], [50%, 21%, 2100%]>,
    - <9, 3%, [25%, 15%, 500%], [50%, 28%, 933%]>,
    - <10, 3%, [25%, 15%, 500%], [50%, 28%, 933%]>
  - With PDCCH dropping based on predefined CCE AL priority order [1,2,4,8,16] (results in Table B.2-1 with "Note 4"):
    - <2, 0%, [25%, 10%, N/A], [50%, 18%, N/A]>,
    - <3, 0%, [25%, 10%, N/A], [50%, 24%, N/A]>,
    - <4, 1%, [25%, 10%, 1000%], [50%, 28%, 2800%]>,
    - <5, 3%, [25%, 10%, 333%], [50%, 29%, 967%]>,
    - <6, 7%, [25%, 9%, 129%], [50%, 29%, 414%]>,
    - <7, 11%, [25%, 9%, 82%], [50%, 30%, 273%]>,
    - <8, 16%, [25%, 9%, 56%], [50%, 28%,175%]>,
    - <9, 22%, [25%, 8%, 36%], [50%, 27%, 123%]>
    - <10, 26%, [25%, 9%, 35%], [50%, 26%,100%]>
- The following was observed for A2:
  - With UE group scheduling (results in Table B.2-2 with "Note 3"):
    - <2, 0%, [25%, 40%, N/A], [50%, 61%, N/A]>,
    - <3, 11%, [25%, 31%, 282%], [50%, 50%, 455%]>,
    - <4, 11%, [25%, 31%, 282%], [50%, 50%, 455%]>,
    - <5, 19%, [25%, 26%, 137%], [50%, 42%, 221%]>,
    - <6, 19%, [25%, 26%, 137%], [50%, 42%, 221%]>,
    - <7, 25%, [25%, 22%, 88%], [50%, 37%, 148%]>,
    - <8, 25%, [25%, 22%, 88%], [50%, 37%, 148%]>,
    - <9, 30%, [25%, 20%, 67%], [50%, 33%, 110%]>,
    - <10, 30%, [25%, 20%, 67%], [50%, 33%, 110%]>

    - With PDCCH dropping based on predefined CCE AL priority order [1,2,4,8,16] (results in Table B.2-2 with "Note 4"):
        - <2, 11%, [25%, 0%, 0%], [50%, 19%, 173%]>,
        - <3, 19%, [25%, 0%, 0%], [50%, 19%, 100%]>,
        - <4, 25%, [25%, 2%, 8%], [50%, 18%, 72%]>,
        - <5, 30%, [25%, 2%, 7%], [50%, 18%, 60%]>,
        - <6, 35%, [25%, 2%, 6%], [50%, 17%, 49%]>,
        - <7, 39%, [25%, 2%, 5%], [50%, 16%, 41%]>,
        - <8, 43%, [25%, 2%, 5%], [50%, 15%,35%]>,
        - <9, 46%, [25%, 3%, 7%], [50%, 15%, 33%]>
        - <10, 49%, [25%, 4%, 8%], [50%, 14%, 29%]>
- The following was observed for A3:
    - With UE group scheduling (results in Table B.2-3 with "Note 3"):
        - <2, 0%, [25%, 20%, N/A], [50%, 49%, N/A]>,
        - <3, 15%, [25%, 17%, 113%], [50%, 43%, 287%]>,
        - <4, 15%, [25%, 17%, 113%], [50%, 43%, 287%]>,
        - <5, 25%, [25%, 17%, 68%], [50%, 39%, 156%]>,
        - <6, 25%, [25%, 17%, 68%], [50%, 39%, 156%]>,
        - <7, 34%, [25%, 15%, 44%], [50%, 34%, 100%]>,
        - <8, 34%, [25%, 15%, 44%], [50%, 34%, 100%]>,
        - <9, 41%, [25%, 14%, 34%], [50%, 31%, 76%]>,
        - <10, 41%, [25%, 14%, 34%], [50%, 31%, 76%]>
    - With PDCCH dropping based on predefined CCE AL priority order [1,2,4,8,16] (results in Table B.2-3 with "Note 4"):
        - <2, 14%, [25%, 1%, 7%], [50%, 5%, 36%]>,
        - <3, 26%, [25%, 0%, 0%], [50%, 5%, 19%]>,
        - <4, 34%, [25%, 1%, 3%], [50%, 6%, 18%]>,
        - <5, 41%, [25%, 1%, 2%], [50%, 6%, 15%]>,
        - <6, 47%, [25%, 1%, 2%], [50%, 5%, 11%]>,
        - <7, 52%, [25%, 0%, 0%], [50%, 5%, 10%]>,
        - <8, 56%, [25%, 0%, 0%], [50%, 5%, 9%]>,
        - <9, 59%, [25%, 1%, 2%], [50%, 5%, 8%]>
        - <10, 62%, [25%, 1%, 2%], [50%, 5%, 8%]>

Latency and scheduling flexibility:

The latency impact due to BD reduction may largely depend on PDCCH blocking rate performance impact. If the PDCCH blocking rate is increased by BD reduction, the average latency is expected to be increased; Otherwise, BD reduction has no impact on the latency.

Scheduling flexibility may or may not be impacted by BD reduction depending on multiple factors at least including BW, Subcarrier Spacing (SCS), CORESET size, AL distribution, channel condition, number of ALs per UE, number of UEs that need to be simultaneously scheduled, DCI size budget reduction, etc.

8.2.4 Analysis of coexistence with legacy UEs

The potential impacts on legacy UEs, in terms of PDCCH blocking rate, when coexisting with RedCap UEs in a shared CORESET depend on the scheduling strategy and system parameters. Depending on the network implementation, if legacy UEs are prioritized over RedCap UEs, there is no coexistence impact on the legacy UEs at the cost of increased latency at the RedCap UE side.

8.2.5 Analysis of specification impacts

For reduced PDCCH monitoring, the following specification impacts are foreseen:

- Depending on the considered techniques, for scheme with reducing maximum number of PDCCH candidates, specification impact may include reducing the limit on maximum number of PDCCH candidates.

- For extending the PDCCH monitoring gap to X slots (X>1), the minimum separation between two consecutive PDCCH monitoring occasions, spans or slots configured with PDCCH candidates is increased from 1 slot to X>1 slots and X needs to be specified.

- For dynamic adaptation of PDCCH BD parameters in connected mode, specification impacts may include mechanisms used to dynamically adapt PDCCH BD parameters e.g., maximum number of BDs per PDCCH monitoring occasion, span or slot and minimum time separation between two consecutive PDCCH monitoring occasions, spans or slots configured with PDCCH candidates.

- The existing Rel-15/Rel-16 PDCCH monitoring configuration can still be used to configure the BD candidates and PDCCH monitoring gap. Additional specification impacts may include one or more of following: reducing DCI size budget, modification to DCI size alignment rule, DCI format design (including single PDSCH scheduling and multiple PDSCHs scheduling), modification to PDCCH candidates dropping rule, to minimize the PDCCH blocking rate impact and network restriction.

8.3 Extended DRX for RRC Inactive and/or Idle

8.3.1 Description of feature

In LTE connected to EPC, the UE may be configured with an extended DRX (eDRX) cycle. The UE may operate in eDRX only if the UE is configured by NAS and the cell indicates support for eDRX in System Information (note that there is no System Information indication for NB-IoT). In RRC_IDLE, the eDRX cycle has the maximum value of 2621.44 seconds (43.69 minutes). For NB-IoT the maximum value of eDRX cycle is 10485.76 seconds (2.91 hours). Hyper SFN (H-SFN) is broadcasted in System Information and incremented by one when SFN wraps around. The Paging Hyperframe (PH) refers to the H-SFN in which the UE starts to monitor for paging during a Paging Time Window (PTW), see e.g. [12].

RAN2 has studied the following topics related to extended DRX for RRC_IDLE and RRC_INACTIVE:

- Analysis of UE power saving

- Analysis of upper and lower bound of extended DRX cycles

- Analysis of mechanisms for extended DRX

8.3.2 Analysis of UE power saving

Annex E.1 lists power saving results and analysis from two sources for extended DRX in RRC_IDLE and RRC_INACTIVE.

In summary, one source finds that an eDRX cycle of 10485.76 seconds (2.91 hours) can result in power saving between 34-80 % for a high SINR case and between 56-91 % for a low SINR using an RRC_IDLE DRX cycle (with equal PTW length) from 2.56 seconds down to 320 ms. One source provides a plot of possible UE battery lifetime against eDRX cycle length. The battery lifetime for a UE with a 2-minute eDRX cycle compared to the same device with 10.24 seconds eDRX cycle is shown to result in between 0.38 – 340 % improvements for RRC_IDLE and 1-419 % improvements for RRC_INACTIVE, respectively. The evaluation has been performed for various use cases and inter-arrival times from 100 ms up to 5 minutes.

From RAN2 perspective, extended DRX is beneficial for UE power consumption and can be specified and configured for RedCap UEs so that eDRX cycles can be used in RRC_IDLE and in RRC_INACTIVE states.

RAN2 sees a benefit extending the eDRX cycle in RRC_INACTIVE beyond 10.24 seconds for RedCap UEs for the following reasons:

- It is very beneficial to have eDRX cycles >10.24 seconds in RRC_INACTIVE to effectively support the use of Rel-17 SDT (small data transmission) e.g. for use cases with periodic uplink data with periodicity > 10.24 seconds. TS 22.104 provides such use cases, e.g. some industrial wireless sensors need to transfer small packets and have strict battery lifetime requirements, while not being sensitive to DL traffic delay.
- Based on the results in Annex E.1, there is a clear power saving gain vs eDRX in RRC_IDLE at least for eDRX cycles in the range from 10.24 seconds up to couple of minutes, where the UE in eDRX in RRC_INACTIVE additionally benefits from less signaling. Based on these results, lifetime of several years would not be achievable in some cases (e.g. 1-minute inter-arrival time) if only RRC_IDLE can be used, because of the signaling overhead.
- Signaling reduction is an additional benefit from network point of view – there is need for less RRC signaling.

The potential issues with eDRX extension beyond 10.24 seconds for RRC_INACTIVE are:

- Impact on CN procedures (e.g. NAS retransmission), thus SA2/CT1 must be consulted on the feasibility.
- Potential handling of different eDRX cycles > 10.24 seconds and/or PTWs, one for IDLE and the other for INACTIVE.
- It needs to be studied which node decides and configures the eDRX cycle for RRC_INACTIVE.

SA2/CT1 must be consulted on the feasibility prior to the introduction of eDRX cycles longer than 10.24 seconds in RRC_INACTIVE.

8.3.3 Analysis of upper and lower bound of extended DRX cycles

For the upper bound, the eDRX cycle should support up to 10485.76 seconds, since the upper limit of the H-SFN (10 bits) already is 10485.76 seconds, and 5GC already supports eDRX values up to 10485.76 seconds for NB-IoT and LTE-MTC connected to 5GC. Although little power saving gain has been observed beyond 2621.44 seconds (simulation results show that the gain is saturated at around 40 minutes, see Annex E), there is no reason to artificially limit the range without technical concern, e.g., unless RAN4 indicates such eDRX value requires UE to perform RRM on serving cell outside PTW.

Shorter values than 5.12 seconds for the DRX cycles, such as 2.56 seconds, have also been studied. For the lower bound of the eDRX cycle, one motivation to support down to 2.56 seconds is that at least some RedCap UEs should be able to support the reception of emergency broadcast services (e.g. ETWS primary notification) within the required delay budget of 4 seconds while still saving power. This is not possible with 5.12 seconds eDRX cycle lengths. However, other solutions exist allowing RedCap UEs to receive emergency broadcast services without requiring eDRX to support lower cycle values than legacy LTE (5.12 seconds), while also saving power:

- **Solution 1**: For RedCap UEs, if the NAS configures the UE with a 2.56 seconds DRX UE-specific paging cycle, the RedCap UE follows this DRX cycle even when the RAN paging cycle or default paging cycle is shorter.

- **Solution 2**: gNB can configure 2.56 seconds default broadcasted DRX cycle for those RedCap UEs that need to receive emergency broadcast services and a shorter UE-specific RAN paging cycle can be configured for UEs with tighter latency requirements (e.g. smartphones).

Solution 1 is similar to supporting eDRX cycle of 2.56 seconds in that the UE does not need to follow shorter RAN or default paging cycle, and therefore has the same pros/cons: it enables a mix of smartphones and RedCap UEs in the network, with an appropriate paging cycle configured for each of them. However, these solutions (solution 1 and eDRX with 2.56 seconds cycle) assume such RedCap UEs do not need to monitor gNB configured default broadcasted paging (and UE-specific RAN paging) cycles, thus resulting in network not being able to reach such RedCap UEs by using default broadcasted paging cycles and/or UE-specific RAN paging cycles. This may result e.g. in a potential risk of UE missing SI change indicator. Specifically, solution 1 requires a different way to determine the UE DRX cycle for RedCap UEs in both the UE and the gNB.

Solution 2 is consistent with the LTE solution, but a default broadcasted DRX value of 2.56 seconds is expected not to be widely used, e.g. in existing deployments supporting smartphones, requiring changes to the paging cycle in existing deployments and configuration of a UE-specific paging cycle for each UE intended to follow a shorter paging cycle.

Other solutions also exist that do not consider the power saving aspects for UEs receiving emergency broadcast services. For example, a simple solution is that RedCap UEs that need to receive emergency broadcast services do not request to be configured with eDRX, and no specific handling/configuration is required for those UEs. However, such RedCap UEs do not benefit from any specific eDRX power saving. Alternately, a RedCap UE could request an eDRX configuration while still monitoring for ETWS and CMAS in between the paging occasions.

8.3.4 Analysis of mechanisms for extended DRX

If extension of the eDRX cycles beyond 10.24 seconds is specified, a feasible extension mechanism is expected to be similar to what is specified for LTE. This mechanism would include the use of H-SFN, PH and PTW, see e.g. [12].

For RedCap UEs in RRC_IDLE or RRC_INACTIVE, if the eDRX cycle is less than or equal to 10.24 seconds, the paging monitoring configuration does not use PTW and PH.

Specifically, for the case when the eDRX cycle equals 10.24 seconds, the pros and cons of not using PTW and PH are as follows:

Pros:

- Allows UEs that do not need long eDRX cycles (> 10.24 seconds) to reuse NR Rel-16 DRX implementation without additional development work and without a need for an explicit capability signalling.
- NR already supports 10.24 seconds interval in C-DRX without using PTW and PH.
- For RRC_INACTIVE, the same solution was adopted for LTE-MTC connected to 5GC.

Cons:

- Different solution from LTE for eDRX cycle = 10.24 seconds in RRC_IDLE.
- Will impact 5GC and RAN2 will need to consult SA2/CT1 on the feasibility.
- UE cannot have multiple opportunities to receive its paging during an eDRX cycle.

The following solutions can be considered for PTW and eDRX cycle configuration for RRC_IDLE and RRC_INACTIVE:

- A common PTW and eDRX cycle.
- A common PTW but with different eDRX cycle.
- A common eDRX cycle but with different PTW length.
- Different eDRX cycle and different PTW length.

Two options should be considered for the deciding node for the eDRX configuration for RRC_INACTIVE:

Option 1: CN decides the eDRX parameters for RRC_INACTIVE.

- CN has better insight on the UE traffic profile.
- Better for addressing potential core network impacts.
- CN is responsible for eDRX in RRC_IDLE (and UE needs to monitor for CN paging also in RRC_INACTIVE).
- If RAN2 agrees to consider a common PTW and eDRX cycle configuration, CN based eDRX configuration can be supported with minimum impact to specifications where RAN follows the CN configured cycle. This common configuration can additionally be justified by its simplicity and less expected impacts to other WGs.

Option 2: RAN decides the eDRX parameters for RRC_INACTIVE

- It provides more flexibility to the RAN node in the configuration of the eDRX parameters.
- It allows RAN to configure different eDRX cycle for RRC INACTIVE.
- In Rel-16 LTE-MTC connected to 5GC, NR-RAN chooses and configures the final eDRX cycle for RRC_INACTIVE (configuration is possible up to 10.24 seconds), based on idle mode eDRX cycle as provided by the AMF.

8.4 RRM relaxation for stationary devices

8.4.1 Description of feature

The study includes an objective on RRM relaxation for stationary RedCap UEs. RAN2 recommends that irrespective of RRC state, it is under network control whether to enable or disable RRM relaxation functionality for RedCap UEs.

RAN2 has studied different types of classification of potential RedCap UEs' mobility states, e.g. possibility to introduce a stationary mobility state. Considering the mobility of a RedCap UE, the stationarity property would not be limited to fixed or immobile UEs, but UEs which are considered stationary can also have low mobility, i.e., be slightly moving. In addition, another mobility option for "confined mobility" has been studied (see details in Enhancement 6 of triggering criterion in 8.4.1.1).

RAN2 has studied different enhancements to triggering RRM measurement relaxation and potential RRM relaxation methods for RRC_IDLE, RRC_INACTIVE and RRC_CONNECTED. RRM relaxation for neighboring cell measurements for RRC_IDLE and RRC_INACTIVE is discussed in clause 8.4.2 and RRM relaxation for neighboring cells for RRC_CONNECTED in clause 8.4.3.

8.4.2 RRM relaxation in RRC_IDLE and RRC_INACTIVE

Rel-16 NR RRM relaxation procedures are taken as a baseline to study further enhancements of neighbour cell RRM relaxation for RedCap UEs in RRC_IDLE and RRC_INACTIVE.

For triggering neighbour cell RRM relaxation for RedCap UEs in RRC_IDLE and RRC_INACTIVE, based on Rel-16 triggering criterion, the following triggering enhancements can be considered (other solutions are not precluded):

- **Enhancement 1**: Introduce additional $S_{searchDeltaP\_stationary}$ threshold to support 2-level speed evaluation (i.e. stationary and low mobility), for example:
  - Stationary: $(Srxlev_{Ref} – Srxlev) < S_{SearchDeltaP\_stationary}$
  - Low mobility: $S_{SearchDeltaP\_stationary} <= (Srxlev_{Ref} – Srxlev) < S_{SearchDeltaP\_low\_mobility}$

  Pros:

  - From specification point of view, it is simple and straightforward enhancement based on Rel-16 mechanism.
  - It supports 2 levels speed evaluation (i.e. stationary and low mobility), so it provides flexibility of designing different RRM relaxation levels for different mobility scenarios.

Cons:

- Unclear whether UE's mobility level can be accurately determined because channel or link (RSRP/RSRQ) may change even if UE is purely stationary, thus it may not be a reliable way to distinguish between truly stationary and low mobility UE.

- **Enhancement 2**: Introduce additional $T_{SearchDeltaP\_stationary}$ to support 2-level speed evaluation (i.e. stationary and low mobility).

  Pros:

  - From specification point of view, it is simple and straightforward enhancement based on Rel-16 mechanism.
  - It supports 2 levels speed evaluation (i.e. stationary and low mobility), so it provides flexibility of designing different RRM relaxation levels for different mobility scenarios.

  Cons:

  - Unclear whether UE's mobility level can be accurately determined.

Note: There can be synergies if Enhancement 1 is combined with Enhancement 2.

- **Enhancement 3**: Take into account changes in beam measurements in serving cell when evaluating the mobility status of UE, e.g. based on the number of beam changes, the beam can be the best beam or all beams exceeding a threshold, for example:

  Stationary:

  - number of beam changes < N1 or
  - no beam change and ($Srxlev_{Ref}$ – Srxlev) < $S_{SearchDeltaP\_stationary}$

  Low mobility:

  - number of beam changes < N2 or
  - $S_{SearchDeltaP\_stationary}$ <= ($Srxlev_{Ref}$ – Srxlev) < $S_{SearchDeltaP\_low\_mobility}$

  Pros:

  - Using beam level measurement results can assess UE's movement more accurately than cell measurement, because UE may move among beams but without changing the cell level results.
  - Potentially good for detecting "circular motion" around base station.

  Cons:

  - Unclear whether UE's mobility level can be accurately determined.
  - Beam level measurement results may fluctuate more than cell-level results, so it might cause misjudgement.

- **Enhancement 4:** UE determines its stationary property based on subscription information (e.g. USIM).

  Pros:

  - It is simpler and faster than evaluating the quality of serving cell.

  Cons:

  - Only applicable to limited scenarios, e.g. fixed-location devices.
  - Channel or link (RSRP/RSRQ) may change (e.g. may be low) even if UE is fixed-location, RRM relaxation only depends on fixed-location information may impact the performance if the UE is located at cell edge.

- **Enhancement 5:** Introduce an additional $S_{searchDeltaP\_correction}$ threshold and configure the UE to use it if only it detects that it observes higher received signal power variation that do not violate stationary property, i.e. rotating around itself, dynamically changing multipath.

  Pros:

  - Can be used to differentiate different stationary cases. E.g. stationary or stationary with rotating around itself.

  Cons:

  - Covers specific use case where device is rotating around itself.

- **Enhancement 6:** UE determines its confined mobility property based on subscription information (e.g. USIM). This kind of device is expected to be moving (slowly in many cases) or stationary, but different from Enhancement 5, these UEs are not expected to move out of a localized area in its lifetime.

  Pros:

  - It is simpler and faster than evaluating the quality of serving cell.

  - If network can obtain the confined mobility status, network can also use this information for other purpose in addition to RRM relaxation (e.g. paging resource optimization).

  Cons:

  - Only applicable to limited scenarios, e.g. devices with confined mobility.

  - Channel or link (RSRP/RSRQ) may change for confined mobility devices, RRM relaxation may impact the performance if the UE is located at cell edge.

For neighbour cell RRM relaxation methods for RedCap UEs in RRC_IDLE and RRC_INACTIVE, based on Rel-16 NR RRM relaxation methods, the following relaxation methods enhancements can be considered (other solutions are not precluded):

- **Enhancement 1:** UE can stop measurements on neighbour cells for T (T>>1) hours.

  Pros:

  - It is useful to further reduce power consumption for truly stationary UEs.

  Cons:

  - Based on evaluation in Clause E.2.1, the gain compared to 1-hour measurement interval is not significant.

- **Enhancement 2**: Enabling further relaxation by reducing the number of the monitored reference signals (RS). UE only needs to measure specific beams; thus, the power consumption can be reduced, and the time period of measurement can be reduced.

- **Enhancement 3**: UE only perform measurements on a number of dedicated intra-frequency, inter-frequency cells.

  Pros:

  - For stationary UEs, can avoid UE to measure all frequencies/cells broadcast.

  Cons:

  - May require additional effort for network planning and may require network to indicate deployment related information to UE (e.g. neighbour cells adjacent to each serving beam).

  - If the UE actually does moves or radio conditions change enough, there may be a negative impact on cell-reselection.

- **Enhancement 4:** Minimize the number of measured frequencies.

  Pros:

  - For stationary and confined mobility UEs, can avoid UE to measure all frequencies/cells broadcast.

  Cons:

  - If the UE actually does moves or radio conditions change enough, there may be impact on cell-reselection.
  - May require additional signalling from the network to provide the UE with potential frequencies to be used in IDLE/INACTIVE. And additional signalling to allow/prohibit the UE from re-selecting to other frequencies than provided by the network.

- **Enhancement 5**: Expand the Rel-16 scenario of performing "stop measurements for 1 hour" for stationary UEs. This would help to further reduce power consumption for a truly stationary UE.
- **Enhancement 6:** Upon UE fulfils the criterion (i.e. RSRP threshold evaluation), UE can trigger measurement relaxation on part of configured frequencies even if the criterion has not been fulfilled for a period of $T_{SearchDeltaP}$.

  Pros:

  - UE can maximize its power saving on the measurements because measurement relaxation can be started earlier.

  Cons:

  - Without evaluating the duration of criterion has been fulfilled, it may cause misjudgement due to weak robustness.

8.4.3 RRM relaxation in RRC_CONNECTED

For neighbour cell RRM relaxation in RRC_CONNECTED, due to the concern on potential mobility performance impact, it is RAN2 recommendation that "fixed or immobile UEs" are considered with higher priority than "slightly moving UEs".

For assisting triggering neighbour cell RRM relaxation for RedCap UEs in RRC_CONNECTED, following solutions can be considered (other solutions are not precluded):

- **Solution 1:** UE reports "stationary" status to network in Msg5. How the mobility status is determined, e.g. left up to UE implementation or based on measurements or location information, should be studied further in normative phase, if it is to be considered.

  Pros:

  - Allows UE to report to network if it is temporarily stationary, so network can change its RRM configuration timely.

  Cons:

  - Channel or link (RSRP/RSRQ) may change even if UE is stationary, so it may impact handover performance if UE cannot cancel RRM relaxing timely.

- **Solution 2:** Network provides (e.g. low mobility, not-at-cell-edge) evaluation parameters to UE via dedicated signalling.

  Pros:

  - Reusing Rel-16 mechanism in Connected UEs, maximize the commonality with idle/inactive UEs.
  - Network can set evaluation parameters to UE, so it is more reliable and impacts on performance can be reduced.

  Cons:

  - Network needs to configure UE with additional parameters for RRC_CONNECTED.

  - The mobility status is determined by UE based on evaluation of serving cell measurements. So, from network perspective, (compared to other solutions) network does not know whether the UE is relaxing RRM measurements or not.

- **Solution 3:** AMF sends "stationary" indication to gNB (based on UE subscription).

  Pros:

  - The information is derived from UE subscription information, such fixed-location UE will not move, so performance impact can be minimized.
  - It is useful in potentially reducing the amount of measurements and can enable network to configure more power-efficient RRM in RRC_CONNECTED.

  Cons:

  - Only applicable to limited scenarios, e.g. fixed-location devices.
  - Channel or link (RSRP/RSRQ) may change even if UE is stationary, so it may impact handover performance if UE cannot cancel RRM relaxing timely.

- **Solution 4**: UE reports "stationary" in UE Assistance Information to network. How the mobility status is determined, e.g. left up to UE implementation or based on measurements or location information, should be studied further in normative phase.

  Pros:

  - Allows UE to report to network if it is temporarily stationary, so network can change its RRM configuration timely.

  Cons:

  - Channel or link (RSRP/RSRQ) may change even if UE is purely stationary, so it may impact handover performance if UE is located at cell edge and cannot cancel RRM relaxing timely.

- **Solution 5:** Network enables measurement relaxation based on UE's measurement report.

  Pros:

  - It keeps the control fully on network side.
  - UE measurement report can be based on existing UE measurement report mechanism.

  Cons:

  - It relies on UE measurement reporting.

For neighbour cell RRM relaxation methods for RedCap UEs in RRC_CONNECTED, the exact mechanism, if any, will be decided by RAN4. The following solutions have been discussed in RAN2:

- **Solution 1**: Network does not configure measurements for mobility purposes.
- **Solution 2**: UE only performs measurement on single RS type.

From RAN2's perspective, other solutions are not precluded.

8.4.4 Analysis of UE power saving

Annex E.2 lists power saving results and analysis.

In summary, one source [9] presents plotted results for cases where the DRX cycle is 1.28 seconds, the number of intra- and inter-frequency cells is 8 with an SSB periodicity of 20 ms. The results are presented with the average power consumption plotted against how often the UE measures. The results show that power consumption does not change significantly for measurement relaxation beyond one hour (one-hour relaxation is the maximum possible in Rel-16).

One source [10] shows the power saving gain for serving cell RRM relaxation in idle and connected mode. The simulation results show that 3 .6%~13.4% power saving gain is observed when 4 times RRM relaxation for serving cell is adopted by high SINR for idle/inactive UE. Meanwhile, the results from [6] show that by increasing measurement period 4 times for RRC_CONNECTED UEs, 11.1% - 26.6% power saving gains are observed, at the cost of an increase of handover failure rate from 0% to 0.26% for stationary or low mobility (e.g., 3 km/h) case.

In addition, one source [11] shows the average power consumption and power saving gain when further expand the measurement interval from using three times scaling factor to stopping measurement for 1 hour. The result shows that for DRX cycle =1280 ms, stopping measurement for 1 hour can achieve power saving gain of 25.17% compared to 3-times relaxation. In addition, [11] shows the time reduction and power saving gain when the time duration for detecting/measuring SSBs can be reduced by reducing the number of measured SSBs. The power saving gain is 13.54% and 16.25% respectively if the time for SSBs detection/measurement is reduced by 62.5% and 75%.

9 Coverage recovery

9.0 Introduction to coverage recovery

Coverage recovery to compensate for potential coverage reduction due to the device complexity reduction was studied. The evaluation methodology is described in clause 6.3, evaluation results for different scenarios are described in clause 9.1 with a summary of observations from the evaluations in clause 9.1.5, and potential coverage recovery techniques for different physical channels are described in clauses 9.2 through 9.4.

9.1 Coverage recovery evaluation

9.1.1 Urban scenario at 2.6 GHz

For Urban scenario at 2.6 GHz, the bottleneck channel for the reference NR UE and the corresponding maximum isotropic loss (MIL) value by the sourcing companies [3] are shown in Table 9.1.1-1. More details are provided in Annex C.1. The estimated coverage loss for the RedCap UE relative to the bottleneck channel of the reference NR UE is summarized in Table 9.1.1-2 and Table 9.1.1-3. For every sourcing-company result, the amount of compensation for each channel that has MIL below the target value are highlighted. It is noted that the 3dB antenna efficiency loss is assumed in both DL and UL for the RedCap UE.

Table 9.1.1-1: Bottleneck channel and MIL value for Reference NR UE in Urban 2.6 GHz

	Bottleneck Channel	MIL (dB)
Samsung	PUSCH	139.4
ZTE	PUSCH	142.0
OPPO	PUSCH	145.1
CATT	PUSCH	145.9
vivo	PUSCH	137.8
Xiaomi	PUSCH	146.7
Futurewei	PUSCH	151.6
Nokia	PUSCH	138.6
DCM	PUSCH	145.7
CMCC	PUSCH	139.8
Huawei	PUSCH	139.0
Spreadtrum	PUSCH	145.7
Apple	PUSCH	140.0
Ericsson	PUSCH	143.9
InterDigital	PUSCH	143.2

Qualcomm	PUSCH	139.4
Intel	PUSCH	143.9

The representative values in the last row of Table 9.1.1-2 and Table 9.1.1-3 are derived by taking the mean value (in dB domain) from all the companies results and excluding the highest and the lowest values when the number of samples is more than 3. A negative value of the representative value for a channel of the RedCap UE indicates the coverage of the channel is worse than that of the bottleneck channel of the reference NR UE.

As can be seen in the last row for the representative value, all the channels except for PUSCH have better coverage than that of the bottleneck channel thus requiring no compensation. On average, a coverage degradation of approximately 3dB is observed for PUSCH.

It should be noted that the 3dB loss is resulted from the UE antenna efficiency loss assumed for the wearable use cases. Furthermore, the same target data rate of 1Mbps for PUSCH is assumed for both RedCap UE and the reference UE (see evaluation methodology described in clause 6.3). A smaller or no coverage loss for PUSCH is expected if the target data rate for RedCap UE is reduced.

Table 9.1.1-2: Coverage loss (dB) for 2Rx RedCap UE in Urban scenario at 2.6 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	20.6	24.6	17.2	16.3	17.2		15.8	12.2	8.9	-3.0	7.6	
ZTE							17.7	15.9	13.4	-3.0	11.5	
OPPO	16.0	20.0	19.5	10.1	13.8		6.8	6.8	6.7	-3.2	6.6	
CATT	13.2	17.2	15.7	7.8	11.4		11.4	10.0	7.9	-3.0	4.6	
vivo	14.2	22.2	17.2	11.8	13.7	17.6	15.4	12.9	10.3	-2.8	11.6	8.9
Xiaomi	14.0	14.0	14.1	8.6	11.6		11.9	9.2	7.5	-3.0	4.9	
Futurewei	7.3	9.3	7.6	5.6	6.4					-3.0	-1.1	
Nokia	23.9	23.9	21.7	22.9	21.7		10.1		8.6	-3.0	6.2	8.7
DCM	14.1	18.1	14.1	7.2	10.3		12.4	16.2		-3.0	5.9	
CMCC	17.4	23.0	21.3	14.8	17.6	19.0	13.5	11.7	9.6	-3.0	10.1	15.9
Huawei	19.0	23.0	17.9	15.7	15.6		18.6		16.3	-3.0	7.7	
Spreadtrum	13.2	17.2	15.1	12.0	12.0	14.5	9.7	7.9	7.5	-3.0	1.8	7.0
Apple	14.4	22.4	17.4	7.3	10.4				7.8	-3.0	1.8	
Ericsson	11.8	11.8	12.5	6.2	8.9	13.8	8.0	8.6	6.7	-3.0	4.3	8.1
InterDigital	15.5	19.6	17.1	10.6	13.6		13.9		9.6	-3.0	6.6	
Qualcomm	16.5		18.4	12.6	14.9				4.2	-3.0	5.9	
Intel	15.8	17.1	13.7	16.7	14.0	18.8	15.1	13.8	11.2	-3.0	7.6	9.8
Representative value (dB)	**15.4**	**19.2**	**16.5**	**11.3**	**13.2**	**17.0**	**12.9**	**11.3**	**8.9**	**-3.0**	**6.2**	**8.9**

Note: All sources except for Intel assume no TBS scaling for Msg2 evaluation.

Table 9.1.1-3: Coverage loss (dB) for 1Rx RedCap UE in Urban scenario at 2.6 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	17.1	21.1	12.4	11.1	13.7		15.8	12.2	8.9	-3.0	7.6	
ZTE	5.9	16.3	18.8	9.0	9.4		17.7	15.9	13.4	-3.0	11.5	
OPPO	12.1	16.1	16.9	4.1	9.9		6.8	6.8	6.7	-3.2	6.6	
CATT	9.5	13.5	11.9	1.6	8.0		11.4	10.0	7.9	-3.0	4.6	
vivo	10.9	19.0	12.8	6.9	9.0	14.5	15.4	12.9	10.3	-2.8	11.6	8.9
Xiaomi	10.9	10.9	10.5	3.4	7.6		11.9	9.2	7.5	-3.0	4.9	
Futurewei	4.7	6.7	5.6	2.6	3.2					-3.0	-1.1	

Nokia	19.9	19.9	18.2	19.2	17.9		10.1		8.6	-3.0	6.2	8.7
DCM	10.7	14.7	10.0	1.5	6.1		12.4	16.2		-3.0	5.9	
CMCC							13.5	11.7	9.6	-3.0	10.1	15.9
Huawei	15.9	19.9	14.1	11.4	11.7		18.6		16.3	-3.0	7.7	
Spreadtrum	10.2	14.2	12.1	9.0	9.0	11.5	9.7	7.9	7.5	-3.0	1.8	7.0
Apple	11.0	19.0	12.8	1.8	6.1				7.8	-3.0	1.8	
Ericsson	8.8	8.8	9.3	1.3	4.9	9.9	8.0	8.6	6.7	-3.0	4.3	8.1
InterDigital	12.3	16.3	14.0	6.0	10.5		13.9		9.6	-3.0	6.6	
Qualcomm	13.2		15.3	8.7	11.6				4.2	-3.0	5.9	
Intel							15.1	13.8	11.2	-3.0	7.6	9.8
Representative value (dB)	**11.4**	**15.7**	**13.1**	**5.9**	**9.1**	**12.0**	**12.9**	**11.3**	**8.9**	**-3.0**	**6.2**	**8.9**

Note: All sources except for Intel assume no TBS scaling for Msg2 evaluation.

9.1.2 Rural scenario at 0.7 GHz

For Rural scenario at 0.7 GHz, the bottleneck channel for the reference NR UE and the corresponding maximum isotropic loss (MIL) value by the sourcing companies [3] are shown in Table 9.1.2-1. More details are provided in Annex C.2. The estimated coverage loss for the RedCap UE in rural scenario at 0.7 GHz, relative to the bottleneck channel of the reference NR UE is summarized in Table 9.1.2-2 and Table 9.1.2-3. For every sourcing-company result, the amount of compensation for each channel that has MIL below the target value are highlighted. It is noted that the 3dB antenna efficiency loss is assumed in both DL and UL for the RedCap UE.

Table 9.1.2-1: Bottleneck channel and MIL value for Reference NR UE in rural 0.7 GHz

	Bottleneck Channel	MIL (dB)
Samsung	PUSCH	146.6
ZTE	Msg3	143.2
OPPO	PUCCH PF3 22 bits	148.9
CATT	PUSCH	147.9
vivo	PUSCH	144.0
Xiaomi	PUSCH	149.7
Futurewei	PUSCH	150.8
Nokia	Msg3	138.5
DCM	PUSCH	146.7
Panasonic	PUSCH	141.8
Huawei	PUSCH	141.8
Spreadtrum	PUSCH	151.5
Apple	PUSCH	143.7
Ericsson	PUSCH	142.9
InterDigital	Msg3	144.4
Qualcomm	PUSCH	141.3
Intel	PUSCH	146.7

The representative values in the last row of Table 9.1.2-2 and Table 9.1.2-3 are derived by taking the mean value (in dB domain) from all the companies results and excluding the highest and the lowest values when the number of samples is more than 3. A negative value of the representative value for a channel of the RedCap UE indicates the coverage of the channel is worse than that of the bottleneck channel of the reference NR UE.

As can be seen in the last row for the representative value, all the channels except for PUSCH and Msg3 have better coverage than that of the bottleneck channel thus requiring no compensation. On average, a coverage degradation of approximately 2.8 dB and 1 dB, respectively is observed for PUSCH and Msg3.

It should be noted that the 3 dB loss is resulted from the UE antenna efficiency loss assumed for the wearable use cases. Furthermore, the same target data rate of 100 kbps for PUSCH is assumed for both RedCap UE and the reference NR UE (see evaluation methodology described in clause 6.3). A smaller or no coverage loss for PUSCH is expected if the target data rate for RedCap UE is reduced.

Table 9.1.2-2: Coverage loss (dB) for 2Rx RedCap UE in rural scenario at 0.7 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH Format 0
Samsung	12.9	12.9	8.4	8.4	9.4		8.7	4.9	1.9	-3.0	-0.1	
ZTE							6.4	4.4	1.7	-2.6	-3.0	
OPPO	11.2	11.2	10.0	5.0	9.1		-2.9	-2.8	-3.0	-1.9	-2.5	
CATT	7.5	7.5	4.9	2.6	5.9		5.6	4.5	2.4	-3.1	-0.3	
vivo	8.0	8.1	5.0	2.8	5.8	12.2	3.3	0.5	-1.9	-3.0	-0.7	-1.3
Xiaomi	7.3	7.3	4.9	2.2	5.4		5.3	2.7	0.2	-3.0	-1.8	
Futurewei	7.4	7.4	4.4	4.2	5.4					-3.0	-0.8	
Nokia	16.5	16.5	18.0	15.1	17.9		3.4		2.2	2.6	-3.0	6.4
DCM							6.2	11.6		-3.0	-0.2	
Panasonic		17.0	7.0				7.8	5.4	1.4	-3.0	-0.2	
Huawei	12.5	12.5	8.1	8.1	8.8		8.0		5.8	-3.0	0.5	
Spreadtrum	6.6	6.6	4.6	5.6	5.6	8.6	6.0	3.0	2.8	-3.0	0.0	2.4
Apple	11.0	11.0	9.2	4.8	9.0					-3.0		
Ericsson	11.5	10.8	6.2	7.4	10.1	11.5	3.5	12.0	1.5	-3.0	-0.9	2.1
InterDigital	13.8	13.8	11.1	4.9	7.7		8.4		3.4	-0.7	-3.0	
Qualcomm	14.1		10.2	8.6	10.6				-0.5	-3.0	-0.5	
Intel							4.7	5.0	2.3	-3.0	-0.2	2.6
Representative value (dB)	**10.6**	**10.8**	**7.5**	**5.7**	**7.9**	**11.5**	**5.7**	**4.7**	**1.4**	**-2.8**	**-1.0**	**2.3**

Note: All sources except for Intel assume no TBS scaling for Msg2 evaluation.

Table 9.1.2-3: Coverage loss (dB) for 1Rx RedCap UE in rural scenario at 0.7 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH Format 0
Samsung	9.2	9.2	4.1	2.5	5.7		8.7	4.9	1.9	-3.0	-0.1	
ZTE	5.1	8.8	6.5	3.3	3.5		6.4	4.4	1.7	-2.6	-3.0	
OPPO	6.6	6.6	6.5	-0.4	4.8		-2.9	-2.8	-3.0	-1.9	-2.5	
CATT	4.0	4.0	1.7	-3.9	1.5		5.6	4.5	2.4	-3.1	-0.3	
vivo	5.3	5.3	1.5	-2.5	1.8	8.4	3.3	0.5	-1.9	-3.0	-0.7	-1.3
Xiaomi	3.9	3.9	0.8	-3.5	0.9		5.3	2.7	0.2	-3.0	-1.8	
Futurewei	3.5	3.5	0.1	-1.7	2.4					-3.0	-0.8	
Nokia	12.2	12.2	15.4	11.5	14.9		3.4		2.2	2.6	-3.0	6.4
DCM	9.5	9.5	4.2	-0.9	4.1		6.2	11.6		-3.0	-0.2	
Panasonic		14.1	3.3				7.8	5.4	1.4	-3.0	-0.2	
Huawei	9.1	9.1	4.4	3.8	4.8		8.0		5.8	-3.0	0.5	
Spreadtrum	3.6	3.6	1.6	2.6	1.6	5.6	6.0	3.0	2.8	-3.0	0.0	2.4
Apple	8.0	8.0	5.1	0.3	4.3					-3.0		
Ericsson	7.1	7.3	6.2	3.3	6.4	7.1	3.5	12.0	1.5	-3.0	-0.9	2.1
InterDigital	10.0	10.0	7.4	-0.7	4.1		8.4		3.4	-0.7	-3.0	
Qualcomm	10.3		6.8	4.1	7.2				-0.5	-3.0	-0.5	

Intel	7.9	7.9	5.2	9.7	6.9	10.7	4.7	5.0	2.3	-3.0	-0.2	2.6
Representative value (dB)	**7.1**	**7.5**	**4.4**	**1.4**	**4.2**	**7.8**	**5.7**	**4.7**	**1.4**	**-2.8**	**-1.0**	**2.3**

Note: All sources except for Intel assume no TBS scaling for Msg2 evaluation.

9.1.3 Urban scenario at 4 GHz

For Urban scenario at 4 GHz, the bottleneck channel for the reference NR UE and the corresponding maximum isotropic loss (MIL) value by the sourcing companies [3] are shown in Table 9.1.3-1. More details are provided in Annex C.3.

For RedCap UE with 1 Rx and 2 Rx, the MIL loss relative to the bottleneck channel of the reference NR UE is studied under different downlink power spectrum density assumptions. For DL PSD 33 dBm/MHz, the estimated coverage loss for 1 Rx and 2 Rx is summarized in Table 9.1.3-2 and Table 9.1.3-3, respectively. For DL PSD 24 dBm/MHz, the estimated coverage loss for 1 Rx and 2 Rx is summarized in Table 9.1.3-4 and Table 9.1.3-5, respectively. For every sourcing-company result, the amount of compensation for each channel that has MIL below the target value are highlighted. It is noted that the 3dB antenna efficiency loss is assumed in both DL and UL for the RedCap UE.

Table 9.1.3-1: Bottleneck channel and MIL values for Reference NR UE in Urban 4 GHz

	Bottleneck Channel	MIL (dB)
Samsung	PUSCH	142.0
ZTE	PUSCH	143.0
OPPO	PUSCH	147.0
vivo	PUSCH	139.3
Futurewei	PUSCH	152.6
Nokia	PUSCH	140.8
DCM	PUSCH	146.8
Huawei	PUSCH	140.0
Spreadtrum	PUSCH	145.4
Ericsson	Msg2	143.6
InterDigital	PUSCH	144.9
Qualcomm	PUSCH	140.7
Intel	PUSCH	140.0
Lenovo	PUSCH	148.3

The representative values in the last row of Table 9.1.3-2 to Table 9.1.3-5 are derived by taking the mean value (in dB domain) from all the companies results and excluding the highest and the lowest values when the number of samples is more than 3. A negative value of the representative value for a channel of the RedCap UE indicates the coverage of the channel is worse than that of the bottleneck channel of the reference NR UE.

As can be seen in the last row for the representative value, all uplink channels except for PUSCH have better coverage than that of the bottleneck channel thus requiring no compensation. On average, a coverage degradation of approximately 3dB is observed for PUSCH.

It should be noted that the 3dB loss is resulted from the UE antenna efficiency loss assumed for the wearable use cases. Furthermore, the same target data rate of 1 Mbps for PUSCH is assumed for both RedCap UE and the reference NR UE (see evaluation methodology described in clause 6.3). A smaller or no coverage loss for PUSCH is expected if the target data rate for RedCap UE is reduced.

As seen from Table 9.1.3-2 and Table 9.1.3-3, for DL PSD 33 dBm/MHz, all the downlink channels are not coverage limited for both 1 Rx and 2 Rx RedCap UEs. For DL PSD 24 dBm/MHz and 2 Rx RedCap UE, a coverage degradation of approximately 1.1 dB is observed for Msg2 as seen from Table 9.1.3-4. For DL PSD 24 dBm/MHz and 1 Rx RedCap UE, a coverage degradation of approximately 6.2 dB, 2.5 dB and 0.8 dB, respectively is observed for Msg2, Msg4 and PDCCH CSS as seen from Table 9.1.3-5. It should be noted that for DL PSD 24 dBm/MHz case, Msg2 results are based on no TBS scaling.

Table 9.1.3-2: Coverage loss (dB) for 2Rx RedCap UE in Urban 4 GHz with 33 dBm/MHz PSD (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	18.0	22.0	14.8	13.7	14.7		13.3	9.5	6.5	-3.0	5.0	
Vivo	12.7	20.7	16.0	10.3	12.3	16.0	14.0	11.5	8.8	-2.8	10.3	7.3
Nokia	21.7	21.7	17.8	22.6	19.2		7.9		6.4	-3.0	3.5	11.3
Huawei	18.0	22.0	16.9	14.6	14.6		17.5		15.7	-3.0	6.6	
Representative value (dB)	**18.0**	**21.9**	**16.4**	**14.2**	**14.7**	**16.0**	**13.6**	**10.5**	**7.6**	**-3.0**	**5.8**	**9.3**

Note: All sources assume no TBS scaling for Msg2 evaluation.

Table 9.1.3-3: Coverage loss (dB) for 1Rx RedCap UE in Urban 4 GHz with 33 dBm/MHz PSD (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	14.5	18.5	10.1	8.5	11.1		13.3	9.5	6.5	-3.0	5.0	
Vivo	9.6	17.6	11.4	5.6	7.5	13.4	14.0	11.5	8.8	-2.8	10.3	7.3
Nokia	17.7	17.7	14.0	18.8	15.7		7.9		6.4	-3.0	3.5	11.3
Huawei	14.5	18.5	13.0	10.3	10.7		17.5		15.7	-3.0	6.6	
Representative value (dB)	**14.5**	**18.1**	**12.2**	**9.4**	**10.9**	**13.4**	**13.6**	**10.5**	**7.6**	**-3.0**	**5.8**	**9.3**

Note: All sources assume no TBS scaling for Msg2 evaluation.

Table 9.1.3-4: Coverage loss (dB) for 2Rx RedCap UE in Urban 4 GHz with 24 dBm/MHz PSD (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
OPPO	5.1	9.1	7.5	-0.7	3.0		4.9	5.0	4.9	-3.0	4.7	
Futurewei	-2.4	-0.4	-2.6	-6.4	-3.6					-3.0	-2.1	
DCM	4.1	8.1	4.0	-2.8	0.2		11.5	15.1		-3.0	4.9	
Spreadtrum	4.3	8.5	6.3	3.3	3.3	6.3	9.8	7.8	9.6	-3.0	5.1	7.1
Ericsson	-0.8	3.2	-0.1	-6.4	-3.7	1.4	7.0	9.0	7.1	-2.5	4.7	8.3
InterDigital	4.9	8.9	6.4	0.0	2.9		12.2		7.9	-3.0	5.0	
Qualcomm	6.1		4.9	0.1	2.4				2.8	-3.7	3.3	
Intel	10.4	11.5	6.5	11.4	8.6	13.3	18.5	17.3	14.7	-2.3	11.2	13.3
Representative value (dB)	**4.0**	**7.6**	**4.7**	**-1.1**	**1.4**	**6.3**	**10.1**	**10.6**	**7.4**	**-2.9**	**4.6**	**8.3**

Note: All sources except for Intel assume no TBS scaling for Msg2 evaluation.

Table 9.1.3-5: Coverage loss (dB) for 1Rx RedCap UE in Urban 4 GHz with 24 dBm/MHz PSD (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
ZTE	-4.5	6.0	8.6	-1.3	-1.1		16.6	14.9	12.3	-3.0	10.3	
OPPO	1.2	5.2	4.9	-6.2	-0.8		4.9	5.0	4.9	-3.0	4.7	
Futurewei	-6.0	-4.0	-7.4	-13.4	-9.7					-3.0	-2.1	
DCM	0.8	4.8	0.0	-8.5	-3.9		11.5	15.1		-3.0	4.9	
Spreadtrum	1.3	5.5	3.3	0.3	0.3	3.3	9.8	7.8	9.6	-3.0	5.1	7.1
Ericsson	-3.9	0.2	-3.8	-11.2	-7.6	-2.2	7.0	9.0	7.1	-2.5	4.7	8.3
InterDigital	1.7	5.7	3.3	-4.6	-0.2		12.2		7.9	-3.0	5.0	

Qualcomm	2.8		1.7	-3.8	-0.9				2.8	-3.7	3.3	
Lenovo	-2.0		-2.6	-8.1	-2.9		11.7	6.9	5.7	-3.0	2.9	
Representative value (dB)	**-0.8**	**4.3**	**1.0**	**-6.2**	**-2.5**	**0.6**	**10.4**	**9.6**	**7.0**	**-3.0**	**4.4**	**7.7**

Note: All sources assume no TBS scaling for Msg2 evaluation.

9.1.4 Indoor scenario at 28 GHz

For indoor scenario at 28 GHz, the bottleneck channel for the reference NR UE and the corresponding maximum isotropic loss (MIL) value by the sourcing companies [3] are shown in Table 9.1.4-1. More details are provided in Annex C.4. It is noted that max TRP 12 dBm is assumed for both the reference NR UE and RedCap UE. For results presented by companies assuming max TRP 23 dBm, the corresponding MIL values have been reduced by 11dB.

For RedCap UE with 1 Rx and 2 Rx, the MIL loss relative to the bottleneck channel of the reference NR UE is studied under different maximum UE bandwidth assumptions. The estimated coverage loss for maximum 100 MHz BW and 1 Rx RedCap UE is summarized in Table 9.1.4-2. The estimated coverage loss for maximum 50 MHz BW and 1 Rx and 2 Rx is summarized in Table 9.1.4-3 and Table 9.1.4-4, respectively. For every sourcing-company result, the amount of compensation for each channel that has MIL below the target value are highlighted.

Table 9.1.4-1: Bottleneck channel and MIL values for Reference NR UE in indoor 28 GHz

	Bottleneck channel	**MIL**
Samsung	PUSCH	133.3
ZTE	PUSCH	123.3
OPPO	PUSCH	130.9
vivo	PUSCH	131.4
Nokia	PUSCH	133.9
DCM	PUSCH	136.3
Ericsson	PUSCH	127.7
InterDigital	PUSCH	132.4
Qualcomm	PUSCH	127.8
Intel	PUSCH	126.4

The representative values in the last row of Table 9.1.4-2 to Table 9.1.4-4 are derived by taking the mean value (in dB domain) from all the companies results and excluding the highest and the lowest values when the number of samples is more than 3. A negative value of the representative value for a channel of the RedCap UE indicates the coverage of the channel is worse than that of the bottleneck channel of the reference NR UE.

As can be seen in the last row for the representative value, all uplink channels are not coverage limited for the RedCap UE with either better or similar coverage as the bottleneck channel of the reference NR UE. This is because at FR2 there is no assumption of reduced antenna efficiency for the RedCap UE and UL coverage is expected to be same as the reference NR UE.

For RedCap UE with maximum 100MHz BW and 1Rx, although there is performance loss from reducing the number of Rx branches to 1, the representative values of all the downlink channels are larger than zero indicating a better performance than the bottleneck channel of the reference NR UE.

For RedCap UE with maximum 50MHz BW and 2Rx, the similar observation can be drawn. The MIL(s) of all the downlink channels are better than that of the bottleneck channel for the reference NR UE.

For RedCap UE with maximum 50MHz BW and 1Rx, an averaged coverage degradation of approximately 2.2 dB is observed for PDSCH. This is because a same target data rate (i.e. 25 Mbps) is assumed even maximum UE bandwidth is reduced by half. A smaller or no coverage loss for PDSCH is expected if the target data rate for RedCap UE with maximum 50MHz BW is reduced.

Table 9.1.4-2: Coverage loss (dB) for RedCap UE (1Rx, 100MHz BW) in indoor scenario at 28 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	9.0	9.1	3.1	6.2	3.9		24.2	20.6	17.1	0.0	16.1	
ZTE	13.1	13.8	5.8	10.8	11.3		23.1	18.8	18.0	0.0	18.0	
OPPO	10.1	10.1	7.9	9.3	8.5		18.2	17.8	18.1	0.0	18.4	
vivo	0.4	5.4	-0.6	-4.0	-0.8		22.6	20.9	17.6	0.0	11.4	11.2
Nokia	5.6	5.4	2.1	8.6	7.6		15.6		14.0	0.0	8.2	12.6
DCM	8.5	8.5	2.1	0.8	0.6		11.3	16.7		0.0	12.9	
Ericsson	0.5	1.5	-3.3	-2.9	-4.2	2.9	11.8	11.8	9.4	0.0	7.6	10.4
InterDigital	11.1	11.1	6.2	5.6	5.5		22.9		17.3	0.0	16.0	
Qualcomm	12.3	18.3	9.8	10.6	16.0	21.8	32.0	25.8	23.3	0.0	8.6	24.6
Intel	8.7	9.5	1.6	10.7	7.6	11.4	19.6	19.9	16.8	0.0	13.5	13.5
Representative value (dB)	**8.2**	**9.1**	**3.5**	**6.1**	**5.5**	**11.4**	**19.7**	**19.1**	**17.0**	**0.0**	**13.1**	**12.4**

Note 1: All sources except for Intel assume no TBS scaling for Msg2 evaluation

Note 2: Most of the Msg4 results are based on MCS0. However, a few results are based on a higher MCS

Table 9.1.4-3: Coverage loss (dB) for RedCap UE (2Rx, 50MHz BW) in indoor scenario at 28 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	12.7	12.6	3.7	11.8	9.2		24.2	20.6	17.1	0.0	16.1	
OPPO	14.9	14.9	6.4	13.8	13.3		18.2	17.8	18.1	3.0	18.4	
DCM	8.5	8.5	1.1	7.0	5.6		11.3	16.7		-1.4	12.9	
Ericsson	2.5	3.5	-2.9	1.5	0.3	6.6	11.8	11.8	9.4	4.9	7.6	10.4
Qualcomm			10.6	16.1	16.4	25.1	32.0	25.8	23.3	0.1	8.6	24.6
Representative value (dB)	**10.6**	**10.5**	**3.7**	**10.8**	**9.4**	**15.8**	**18.1**	**18.4**	**17.6**	**1.0**	**12.5**	**17.5**

Note 1: All sources assume no TBS scaling for Msg2 evaluation

Note 2: Most of the Msg4 results are based on MCS0. However, a few results are based on a higher MCS

Table 9.1.4-4: Coverage loss (dB) for RedCap UE (1Rx, 50MHz BW) in indoor scenario at 28 GHz (Option 3)

	PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22 bits	PUSCH	Msg3	PRACH B4
Samsung	8.3	8.3	-2.4	6.2	3.9		24.2	20.6	17.1	0.0	16.1	
OPPO	10.0	10.0	0.9	9.3	8.5		18.2	17.8	18.1	3.0	18.4	
DCM	3.9	3.9	-5.0	0.8	0.6		11.3	16.7		-1.4	12.9	
Ericsson	-1.6	-0.6	-7.6	-2.9	-4.2	2.9	11.8	11.8	9.4	4.9	7.6	10.4
Qualcomm			5.6	10.6	12.4	22.1	32.0	25.8	23.3	0.1	8.6	24.6
Representative value (dB)	**6.1**	**6.1**	**-2.2**	**5.4**	**4.3**	**12.5**	**18.1**	**18.4**	**17.6**	**1.0**	**12.5**	**17.5**

Note 1: All sources assume no TBS scaling for Msg2 evaluation

Note 2: Most of the Msg4 results are based on MCS0. However, a few results are based on a higher MCS

9.1.5 Summary of coverage recovery evaluation

In summary, based on the evaluation results, the following observations can be made.

For FR1:

- For FR1, under the consideration of potential reduced antenna efficiency due to device size limitations, the MIL(s) of PUSCH and/or Msg3 are worse than that of the bottleneck channel for the reference NR UE and coverage recovery is needed. The amount of coverage recovery is up to 3 dB. For other UL channels, coverage recovery may be not needed.

- For RedCap UE with 2 Rx and reduced antenna efficiency, dependent on frequency bands and the assumption of DL PSD, the need for coverage recovery can be different.

  - For carrier frequency of 4 GHz with DL PSD 24 dBm/MHz, coverage recovery may be needed for the downlink channels of Msg2. A small or moderate compensation can be considered, where the square brackets indicate that the exact amount will depend on the techniques, scenarios, etc.:

    - [1 dB] for Msg2 without TBS scaling. It is noted that coverage loss for Msg2 can be compensated by using the existing TBS scaling technique.

  - For other carrier frequencies or DL PSD of 33 dBm/MHz, coverage recovery is not needed for the downlink channels if the target for coverage recovery is based on the MIL of the bottleneck channel for the reference NR UE.

- For RedCap UE with 1 Rx and reduced antenna efficiency, dependent on frequency bands and the assumption of DL PSD, the need for coverage recovery can be different.

  - For carrier frequency of 4 GHz with DL PSD 24 dBm/MHz, coverage recovery may be needed for the downlink channels of Msg2, Msg4 and PDCCH CSS. A small or moderate compensation can be considered, where the square brackets indicate that the exact amount will depend on the techniques, scenarios, etc.:

    - [1 dB] for PDCCH CSS

    - [2-3 dB] for Msg4

    - [6 dB] for Msg2 without TBS scaling. It is noted that coverage loss for Msg2 can be compensated by using the existing TBS scaling technique.

  - For other carrier frequencies or DL PSD of 33 dBm/MHz, coverage recovery is not needed for the downlink channels if the target for coverage recovery is based on the MIL of the bottleneck channel for the reference NR UE.

- It is noted that in the methodology for RedCap UE coverage recovery target determination, absolute ISD/MPL targets are not considered.

- The determination of which channels require coverage recovery and the amount of coverage recovery depend on the choice of the target for coverage recovery.

For FR2:

- For FR2, there is no assumption of reduced antenna efficiency for RedCap UE and the MIL of the UL channels is the same as the reference NR UE and coverage recovery for UL channels is not needed.

- For RedCap UE with 100 MHz BW and 1Rx in FR2 indoor scenario, although there is performance loss from reducing the number of Rx branches to 1, the MIL(s) of all the DL channels is better that that of the bottleneck channel for the reference NR UE, for which max TRP 12dBm is assumed, and coverage recovery for DL channels is thus not needed.

- For RedCap UE with 50MHz BW and 1Rx, coverage recovery may be needed for PDSCH when the same target data rate as the reference NR UE is assumed, and the amount of coverage recovery to be considered is approximately [2-3 dB] , where the square brackets indicate that the exact amount will depend on the techniques, scenarios, etc.

  - The trade-off between data rate and coverage can be considered and the amount of coverage recovery may depend on this choice.

- The determination of which channels require coverage recovery and the amount of coverage recovery depend on the choice of the target for coverage recovery and/or max TRP for the reference NR UE.

  - E.g. coverage recovery may not be needed for FR2 indoor scenario when the target is based on an MPL value from a target ISD of 20m.

  - E.g. coverage recovery for some DL channels may be needed for RedCap UE with 100 MHz BW (e.g. Msg2/4, PDSCH) or 50 MHz BW (e.g. Msg2/4, PDSCH, PDCCH) and 1Rx when max TRP 23 dBm is assumed for the reference NR UE.

9.2 Coverage recovery for PUSCH

9.2.1 Description of coverage recovery features

Coverage recovery for PUSCH has been studied, including both PUSCH for data and Msg3.

Coverage recovery for PUSCH data was studied from several aspects, including cross-slot or cross-repetition channel estimation, lower DM-RS density in time domain, enhancements on PUSCH repetition Type A and/or Type B, frequency hopping or BWP switching across a larger system bandwidth.

Some techniques, such as cross-slot or cross-repetition channel estimation, lower DM-RS density in time domain, enhancements on PUSCH repetition Type A and/or Type B have been studied also in the Rel-17 Coverage Enhancement SI [5].

Coverage recovery for Msg3 was studied including repetition for Msg3 PUSCH initial and/or retransmission.

It is noted that enhancements on Msg3 PUSCH repetition have been studied also in the Rel-17 Coverage Enhancement SI [5].

9.2.2 Analysis of coexistence with legacy UEs

Potential coexistence impacts introduced by potential coverage recovery solutions described in clause 9.2.1 have not been analysed.

9.2.3 Analysis of specification impacts

Potential specification impacts of frequency hopping or BWP switching across a larger system bandwidth include:

- Frequency domain hopping offsets/positions
- Faster switching/RF retuning time.
  - Note this aspect requires RAN4 involvement, where the corresponding study in RAN4 is not performed yet.
- Transmission/reception interruption during RF retuning time

9.3 Coverage recovery for PDSCH

9.3.1 Description of coverage recovery features

Coverage recovery for PDSCH has been studied, including both PDSCH for data, Msg2 and Msg4.

Coverage recovery for PDSCH was studied from several aspects, including the use of the lower-MCS table, larger aggregation factor for PDSCH reception, cross-slot or cross-repetition channel estimation, increasing the granularity of PRB bundling, frequency hopping or BWP switching across a larger system bandwidth.

Some techniques, such as the lower-MCS table and larger aggregation factor for PDSCH reception are existing techniques with optional UE capability signalling.

Coverage recovery for Msg2 PDSCH was studied from several aspects, including TBS scaling and Msg2 PDSCH repetition.

It is noted that TBS scaling is an existing technique mandatory for Rel-15 UE.

Coverage recovery for Msg4 PDSCH was studied from several aspects, including scaling factor for TBS determination, PDSCH repetition and the use of the lower-MCS table. Some techniques, such as scaling factor for TBS determination and PDSCH repetition have been studied also in the Rel-17 Coverage Enhancement SI [5].

9.3.2 Analysis of coexistence with legacy UEs

Potential coexistence impacts introduced by potential coverage recovery solutions described in clause 9.2.1 have not been analysed.

9.3.3 Analysis of specification impacts

If cross-slot or cross-repetition channel estimation for PDSCH is supported, potential specification impacts include:

- Time-domain precoder cycling and DM-RS configuration

If hopping or BWP switching across a larger system bandwidth is supported, potential specification impacts include:

- PDSCH hopping configuration
- Faster switching/RF retuning time
    - Note this aspect requires RAN4 involvement, where the corresponding study in RAN4 is not performed yet.
- Transmission/reception interruption during RF retuning time

Potential specification impacts of increasing the granularity of PRB bundling include:

- Related signaling design

Potential specification impacts of Msg2 PDSCH repetition (if supported) include:

- Msg2 PDSCH repetition configuration
- Mechanism to differentiate enhanced UE and legacy UE, e.g., separate PRACH configurations (e.g., separate PRACH occasions or preambles)

Potential specification impacts of using the lower-MCS table for Msg4 PDSCH include:

- Related signaling design

9.4 Coverage recovery for PDCCH

9.4.1 Description of coverage recovery features

Coverage recovery for broadcast PDCCH (PDCCH monitored in a Type0/0A/1/2/3-PDCCH CSS) was studied from several aspects, including PDCCH repetition, compact DCI, new AL of 12, 24 or 32, PDCCH transmission via CORESET or search space bundling, PDCCH-less mechanism for SIB1 and/or SI message.

9.4.2 Analysis of coexistence with legacy UEs

It is noted that some of the techniques may have compatibility issue if RedCap and normal UEs share the same initial DL BWP.

9.4.3 Analysis of specification impacts

If PDCCH repetition is supported, the potential specification impacts include:

- Repetition configuration (e.g. intra-slot or inter-slot)
- DMRS design among PDCCH repetitions
- Search space design for PDCCH repetition

If compact DCI is supported, the potential specification impacts include:

- DCI format with a small payload size
- Reuse existing format by fixing some DCI bits

If new AL is supported, the potential specification impacts include:

- Mechanism for codeword generation and mapping to CCEs
- CORESET duration extension
- Related signaling design

If PDCCH transmission via CORESET bundling is supported, the potential specification impacts include:

- CORESET bundling configuration
- DMRS design among CORESET bundling

If PDCCH-less is supported, the potential specification impacts include:

- Mechanism or resource allocation for indicating scheduling information for SIB1 and/or SI message in L1 signals(s)/channels(s) other than PDCCH

10 Definition and constraining of reduced capabilities

10.1 Definition of reduced capabilities

At least for RedCap UE identification, explicit definition of RedCap UE type(s) is needed. Pending conclusions on the reduced complexity features (as described in clauses 7 and 12) and RedCap UE identification (as described in clause 11), the definition of the RedCap UE types can be based on one of:

- Option 1: All the reduced capabilities recommended at the end of the RedCap study
- Option 2: Only include the reduced capabilities that the network needs to know during initial access, if any.
- Option 3: All the recommended reduced capabilities as well as recommended power saving features
- Option 4: The corresponding minimum set of the reduced capabilities that one RedCap UE type shall mandatorily support

If early identification during initial access is supported, at least maximum supported UE bandwidth during initial access (20 MHz for FR1 and 100 MHz for FR2) is included in the set of L1 capabilities of the device type for RedCap early identification. Note that this does not preclude the case where the early indication only indicates whether it is a RedCap UE or which type of the RedCap UEs if multiple UE types are defined.

As a baseline, the existing UE capabilities framework is used to indicate the capabilities of RedCap UEs. As currently specified in Rel-16, the UE reports its radio access capabilities at least when the network requests the UE to do so.

The network should be able to control whether RedCap UEs can access the cell and differentiate them from other, non-RedCap UEs. The number of different UE types should be minimised to reduce market fragmentation, and UE types should be introduced only where essential to control UE accesses and differentiate them from other non-RedCap UEs.

The UE capabilities can be categorized as:

- Minimum mandatory capabilities that all RedCap UEs support, if identified.
- Optional capabilities, to be signalled explicitly.

For capability signalling of RedCap UEs, the following scenarios are possible, however feasibility, applicability of the cases and the final division to categories depend on the exact RedCap capabilities (to be defined):

- For the features that are mandatory for non-Redcap UEs:
  - The Redcap UE mandatorily supports the feature with the same value.
  - The Redcap UE mandatorily supports the feature, but with different value (e.g. bandwidth value).
  - The Redcap UE optionally supports the feature.
  - The Redcap UE does not support the feature at all.
- For the features that are optional for non-Redcap UEs:
  - The Redcap UE does not support the feature at all.
  - The Redcap UE supports the feature with a different value.
  - The Redcap UE supports the feature with the same value.
  - The Redcap UE mandatorily supports the feature.

Based on the above categorization and possible scenarios, the following capability design principle alternatives can be considered:

Alternative 1:

- The UE capability requirements for a RedCap device type, that are different from those for non-RedCap UEs, are listed in the specifications. That is:
  - Mandatory features for non-RedCap UEs that are not applicable for RedCap UEs.
  - Mandatory features for non-RedCap UEs that are optional for RedCap UEs.
  - Mandatory features for non-RedCap UEs that are supported for RedCap UEs but with different value.
  - Optional features for non-RedCap UE that are not applicable for RedCap UE.
  - Optional features for non-RedCap UE that are mandatorily supported for RedCap UE.

  For a RedCap device type, define new signalling fields in UE capability signalling for the features that are mandatory without capability signalling for non-RedCap UEs but are optional for Redcap UEs, or mandatory with capability signalling for non-RedCap UEs but with different value for RedCap UEs. Such new signalling is only applicable for RedCap UEs.

Alternative 2:

- Directly define the UE capabilities required for RedCap devices, including:
  - Mandatory features for RedCap UEs (defined in specification).
  - Optional features for Redcap UEs (introduce signalling fields in an independent container defined specifically for Redcap UE).

The network should know whether the UE is a RedCap UE or not in order to handle UE capabilities properly (see also Clause 11.1 on UE identification). The following options, which do not need to be mutually exclusive, can be considered for further analysis and down-selection:

- Option 1: RedCap device type is indicated as part of the capability signalling.

- Option 2: Define a new IE specifically for RedCap UEs containing RedCap-specific capabilities. The IE is included in the signalling only by Redcap UEs.

- Option 3: The network identifies RedCap UEs based on identification solution (see Clause 11.1), e.g. during Msg1, Msg3, MsgA, etc, (pending RAN1 conclusion). The identification is forwarded it to target gNB during handover.

- Option 4: The network identifies RedCap UE based on the reported capabilities, assuming the identification can be done through RedCap-specific capabilities not used by non-RedCap UEs.

From RAN2 perspective, the pros and cons to define only one device type or multiple device types are:

Only one RedCap UE type:

Pros:

- No market fragmentation of "types".

- Simpler specification, e.g. on early identification, access control, etc.

- Avoid non-technical discussion outside 3GPP's scope, e.g. product management, similar to the discussions on LTE categories.

Cons:

- Cannot provide independent access control for different UE types, if this was deemed necessary.

Multiple RedCap UE types:

Pros:

- Flexible access control is possible if necessary, e.g. independent access control for different UE types.

Cons:

- Potential market fragmentation of 'types' leading to loss of economies of scale and increased device costs.

- More specification complexity/effort, e.g. on early identification, access control, etc.

- May lead to non-technical discussion outside 3GPP's scope, e.g. product management, similar to the discussions on LTE categories.

The need on independent access control for different RedCap UE types is not discussed in the SI phase.

10.2 Constraining of reduced capabilities

10.2.1 Description of feature

The study also includes an objective on how to ensure RedCap UEs are only used for intended use cases, that is, UE identifying as RedCap UE can only use services and resources intended for RedCap UE type. The following potential solutions can be considered (the solutions do not need to be mutually exclusive):

- **Option 1**: RRC Reject based approach

  When the network knows the UE is a RedCap UE and the type of the service requested, RAN can reject an RRC connection establishment attempt if the service the UE requests is not allowed for RedCap UEs. The service type can be known, e.g., based on the establishment cause provided in Msg3, through higher layer mechanisms or other ways.

- **Option 2**: Subscription validation (Note: SA2, CT1 confirmation is needed)

  During the RRC connection setup, the UE indicates that it is a RedCap UE to the core network, e.g.

  - UE includes this indication in NAS signalling message to core network; or

  - UE informs this indication during its RRC connection establishment procedure to RAN; RAN then informs core network of the UE's RedCap type in the Initial UE Context message to core network.

    The network validates UE's indication against its subscription plan, which includes information such as the set of services allowed for the UE. Network then decides whether to accept or reject UE's registration request. For example, network may reject UE if UE indicates RedCap, but its subscription does not include any RedCap-specific services.

- **Option 3**: Verification of RedCap UE

  Network performs capability match between UE's reported radio capabilities and the set of capability criteria associated with UE's RedCap type.

- **Option 4**: Left up to network implementation to ensure RedCap UE uses intended services and/or resources.

The decision on which option or options to choose will be made during a possible normative phase, and if needed, based on consultation with other working groups (e.g. SA2, CT1).

11 UE identification and access restrictions

11.1 UE identification

11.1.1 Description of feature

RedCap UEs need to be identified in order to ensure the network can provide services properly in the cell, e.g., to schedule messages and to possibly restrict the UE's access to the network.

The necessity on when RedCap UE needs to be identified depends on when the network needs to have information of the UE type in order to properly schedule the UE e.g. during the initial access.

Feasibility, necessity, pros and cons for the following schemes for identification of RedCap UEs have been studied:

- Option 1: During Msg1 transmission
  - E.g., via separate initial UL BWP, separate PRACH resource, or PRACH preamble partitioning
- Option 2: During Msg3 transmission
- Option 3: Post Msg4 acknowledgment.
  - E.g., during Msg5 transmission or part of UE capability reporting
- Option 4: During MsgA transmission
  - E.g., via separate initial UL BWP, or in MsgA preamble part via separate PRACH resource or PRACH preamble partitioning, or in MsgA PUSCH part

The following observations have been made regarding Option 1, Option 2, Option 3 and Option 4.

Option 1: During Msg1 transmission:

Feasibility: Identification of RedCap UE type(s) during transmission of Msg1 could be feasible from the perspective of RAN1, at least for the following solutions:

- Separation of PRACH resources (e.g., occasions and/or formats) or PRACH preambles between RedCap and non-RedCap UEs
- Separation of initial UL BWP for RedCap and non-RedCap UEs

The appropriateness of each solution, considering the number of UE type(s) to be indicated, etc., would need further considerations.

Necessity: Early identification of RedCap UE type(s) during transmission of Msg1 may be necessary for:

- Coverage recovery (including link adaptation) for one or more of: Msg2 PDCCH/PDSCH, Msg3 PUSCH and PDCCH scheduling Msg3 retransmission, Msg4 PDCCH/PDSCH or PUCCH in response to Msg4, Msg5 PUSCH and associated PDCCH, if it is determined that coverage recovery for RedCap UEs is necessary for one of more of these channels

- Identifying UE minimum processing times capabilities for PDSCH processing and PUSCH preparation, if relaxations to UE min processing times are defined for N_1 and N_2

- Identifying UE capability for UL modulation order for Msg3 and Msg5 scheduling, if relaxations to max UL modulation order (i.e., UL modulation order restricted to lower than 64QAM) are introduced

- Identifying UE max bandwidth capability for Msg3 and Msg5 scheduling and PUCCH in response to Msg4

Exact necessity depends on outcome of studies on UE cost/complexity reduction and coverage recovery, and the SI on Coverage Enhancements [5].

Pros and cons: The pros and cons listed in Table 11.1.1-1 are identified for identification of RedCap UE type(s) during transmission of Msg1.

Table 11.1.1-1: Pros and cons for identification of RedCap UE type(s) during transmission of Msg1

Pros	Cons
Enables efficient handling of different UE minimum processing times between RedCap and non-RedCap UEs for: minimum timing between PDSCH carrying RAR and start of Msg3 PUSCH; minimum timing between PDSCH carrying Msg4 and the corresponding HARQ-ACK feedback; minimum timing between PDCCH with the retransmission grant and the corresponding Msg3 PUSCH retransmission, if relaxed UE min processing times are introduced for RedCap UEs.	Potential reduction in PRACH user capacity (for the options based on separation of PRACH preambles), impacting both RedCap and non-RedCap UEs respectively, e.g., if the total PRACH resources in the cell is not increased. The exact impact depends on numbers of device type(s)/sub-types/capabilities to be identified and exact details of PRACH preamble partitioning schemes.
Enables coverage recovery, including link adaptation, for any one or more of: broadcast PDCCH, PDSCH associated with Msg2, PDSCH associated with Msg4, and PUSCH associated with Msg3, if coverage recovery is needed for these channels.	Potential increase in UL OH from PRACH (for the options based on separation of PRACH resources), impacting both RedCap and non-RedCap UEs.
The option of configuring separate initial UL BWPs, in addition to the above pros, enables address congestion (if congestion may occur) in the initial UL BWP that may otherwise need to be restricted to the mandatory required BW for RedCap UEs in the band/FR.	Potential increase in UL OH and complexity in configuration and maintenance of multiple initial UL BWP for the gNB, for the option of configuring separate initial UL BWPs.
Enables RRC connection rejection of RedCap UE for access restriction (for UEs coming from RRC_IDLE and RRC_INACTIVE if the UE context is not found).	The indication mechanisms in this category may be limiting in terms of the number of further sub-types/capabilities within RedCap device type that may be distinguished, if such sub-types/capability indication are introduced.
Makes it possible to differentiate or enable prioritization of non-RedCap UEs vs. RedCap UEs during contention resolution if RedCap UE type is visible to MAC layer.	Higher impact to RAN1 and RAN2 specifications as well as increased SIB signalling OH compared to other options.
Enables the RedCap UE to operate in an initial BWP which is wider than the RedCap UE bandwidth, as the gNB can take into account UE RF-retuning time while transmitting RAR	
Enables handling of different processing delay requirements (if such are agreed and specified) for RRC procedures between RedCap and non-RedCap i.e. RRC Setup -> RRC Setup Complete and RRC Resume and RRC Resume Complete delays.	

Option 2: During Msg3 transmission:

Feasibility: Identification of RedCap UE type(s) during transmission of Msg3 may be feasible, at least for the following solutions:

- Using the spare bit in existing Msg3 definition
- Extending the Msg3 size to carry additional one or more bits, indicating RedCap UE type(s)
- Introduction of new larger RRC message (e.g. on CCCH1)
- New MAC control element or LCID

The option of carrying identification as part of UCI multiplexed in Msg3 PUSCH was not studied. The appropriateness and feasibility of each solution, considering the number of UE type(s) to be indicated, coverage performance for Msg3, etc., would need further considerations.

Necessity: If early identification of RedCap UE type(s) via Option 1 is not supported, identification of RedCap UE type(s) during transmission of Msg3 may be necessary for coverage recovery (including link adaptation) for one or more of: Msg4 PDCCH/PDSCH, Msg5 PUSCH and associated PDCCH. Exact necessity depends on outcome of studies on coverage recovery and the SI on Coverage Enhancements [5].

From higher layer perspective, whether it is needed for the network to identify a RedCap UE during reception of Msg3 depends on whether Msg4 and/or Msg5 need special handling and whether there is a need to provide opportunity for the network to reject connection establishment based on that the UE is a RedCap UE.

Pros and cons: The pros and cons listed in Table 11.1.1-2 are identified for identification of RedCap UE type(s) during transmission of Msg3.

Table 11.1.1-2: Pros and cons for identification of RedCap UE type(s) during transmission of Msg3

Pros	Cons
Enables coverage recovery (if needed) and/or appropriate link adaptation for PDSCH (and associated PDCCH and PUCCH) for Msg4, and scheduling of Msg5.	If only the spare bit in Msg3 is used, it would consume the single spare bit currently available in Msg3 payload, and this may not be desirable.
Limited impact to RAN1 specifications if only the spare bit in Msg3 payload is utilized.	If extended Msg3 size is introduced, mechanisms to enable detection between use of legacy Msg3 and extended Msg3 definitions necessary.
The option of extending Msg3 size may offer good scalability in the number of bits for such UE identification; e.g., if sub-types of RedCap device types (if defined) are to be indicated in Msg3.	The option of only using the spare bit in Msg3 scales poorly – limiting to a single-bit indication may not be sufficient if intending to distinguish between further sub-types/capabilities within RedCap device type, if RedCap UE sub-types/capabilities are defined in the context of RedCap UE identification.
Enables RRC connection rejection of RedCap UE for access restriction (for UEs coming from RRC_IDLE and RRC_INACTIVE if the UE context is not found).	Cannot facilitate additional coverage recovery (including separate link adaptation) for broadcast PDCCH and/or Msg2 PDSCH, and/or Msg3 PUSCH (and associated PDCCH) for RedCap UEs.
Makes it possible to differentiate or enable prioritization of non-RedCap UEs vs. RedCap UEs during contention resolution if RedCap UE type is visible to MAC layer.	If UE minimum processing times are relaxed, cannot facilitate scheduling with separate minimum timing relationships for RedCap UEs (compared to non-RedCap UEs) between PDSCH carrying RAR and start of Msg3 PUSCH; minimum timing between PDCCH with the retransmission grant and the corresponding Msg3 PUSCH retransmission. This could result in increased initial access latency for non-RedCap UEs.
Enables handling of different processing delay requirements (if such are agreed and specified) for RRC procedures between RedCap and non-RedCap i.e. RRC Setup -> RRC Setup Complete and RRC Resume and RRC Resume Complete delays.	May degrade reliability/coverage of Msg3 in case of increased Msg3 payload size.

	Cannot address the issue where Msg3 is scheduled with a bandwidth/hopping range larger than the maximum RedCap UE bandwidth in the UL initial BWP.

Option 3: Post Msg4 transmission:

Feasibility: Identification of RedCap UE type(s) during transmission of Msg5 or as part of UE capability reporting are feasible options from the perspective of RAN1. From RAN2 perspective this is already covered by existing signalling with limited specification impact.

Necessity: If early identification of RedCap UE type(s) via Options 1, 2, or 4 are not supported, then RedCap UE type(s) need to be identified either during transmission of Msg5 or as part of UE capability reporting.

Pros and cons: The pros and cons listed in Table 11.1.1-3 are identified for identification of RedCap UE type(s) during transmission of Msg5 or in UE capability report.

Table 11.1.1-3: Pros and cons for identification of RedCap UE type(s) during transmission of Msg5 or in UE capability report

Pros	Cons
This option of UE capability reporting offers a simple option for indication of RedCap UE type, including possibility of indicating further RedCap sub-types/capabilities if introduced.	Cannot facilitate additional coverage recovery (if needed) or separate link adaptation for broadcast PDCCH and/or Msg2 and/or Msg4 PDSCH, and/or Msg3 PUSCH for RedCap UEs. Too conservative scheduling and link adaptation for all UEs imply increased system OH for initial access in the initial DL and UL BWPs.
Limited or no impact to RAN1 and RAN2 specifications.	If UE minimum processing times are relaxed, cannot facilitate scheduling with separate minimum timing relationships for RedCap UEs between PDSCH carrying RAR and start of Msg3 PUSCH; minimum timing between PDSCH carrying Msg4 and the corresponding HARQ-ACK feedback; minimum timing between PDCCH with the retransmission grant and the corresponding Msg3 PUSCH retransmission. This could result in increased initial access latency for non-RedCap UEs.
	Cannot address the issue where Msg3 or PUCCH in response to Msg4 or Msg5 is scheduled with a bandwidth/hopping range larger than the maximum RedCap UE bandwidth in the UL initial BWP.
	Cannot enable RRC connection rejection of RedCap UE for RedCap-specific access restriction (for UEs coming from RRC_IDLE and RRC_INACTIVE if the UE context is not found)

Option 4: During MsgA transmission:

Feasibility: Identification of RedCap UE type(s) during transmission of MsgA could be feasible, at least for the following solutions:

- Separation of 2-step RACH resources (e.g., occasions and/or formats) or MsgA preambles between RedCap and non-RedCap UEs
- Separation of initial UL BWP for RedCap and non-RedCap UEs
- Using a new indication in MsgA PUSCH part

The appropriateness of each solution, considering the number of UE type(s) to be indicated, etc., would need further considerations.

Necessity: Early identification of RedCap UE type(s) during transmission of MsgA may be necessary for:

- Coverage recovery (including link adaptation) for MsgA transmission (UE selection of RedCap specific 2-step resources, i.e. MsgA indication in preamble part).
- Coverage recovery (including link adaptation) for MsgB and later messages, and associated PDCCH.

Pros and cons: Due to the differences the pros and cons for identification of RedCap UE type(s) during transmission of MsgA with indication in the MsgA preamble part are listed in Table 11.1.1-4, and the pros and cons for identification of RedCap UE type(s) during transmission of MsgA with indication in the MsgA PUSCH part are listed in Table 11.1.1-5.

Table 11.1.1-4: Pros and cons for identification of RedCap UE type(s) during transmission of MsgA in preamble part

Pros	Cons
Enables coverage recovery, including link adaptation, for any one or more of: MsgA, broadcast PDCCH, PDSCH associated with MsgB.	Potential reduction in 2-step RACH user capacity (for the option based on separation of PRACH preambles), impacting both RedCap and non-RedCap UEs respectively, e.g., if the total 2-step RACH resources in the cell is not increased. The exact impact depends on numbers of device type(s)/sub-types/capabilities to be identified and exact details of PRACH preamble partitioning schemes.
The option of configuring separate initial UL BWPs, in addition to the above pros, address congestion (if congestion may occur) in the initial UL BWP that may otherwise need to be restricted to the mandatory required BW for RedCap UEs in the band/FR.	Potential increase in UL OH from 2-step PRACH (for the options based on separation of PRACH resources), impacting both RedCap and non-RedCap UEs.
Enables RRC connection rejection of RedCap UE for access restriction (for UEs coming from RRC_IDLE and RRC_INACTIVE if the UE context is not found).	Potential increase in UL OH and complexity in configuration and maintenance of multiple initial UL BWP for the gNB, for the option of configuring separate initial UL BWPs.
Makes it possible to differentiate or enable prioritization of non-RedCap UEs vs. RedCap UEs during contention resolution if RedCap UE type is visible to MAC layer.	The indication mechanisms in this category may be limiting in terms of the number of further sub-types/capabilities within RedCap device type that may be distinguished, if such sub-types/capability indication are introduced.
In case of fallback from 2-step to 4-step RACH during MsgA PUSCH failure, possibility for coverage recovery.	Higher impact to RAN1 and RAN2 specifications as well as increased SIB signalling OH compared to other options.

Table 11.1.1-5: Pros and cons for identification of RedCap UE type(s) during transmission of MsgA in PUSCH part

Pros	Cons
Enables coverage recovery, including link adaptation, for MsgB and later messages.	Cannot provide coverage recovery for MsgA transmission.
Enables RRC connection rejection of RedCap UE for access restriction (for UEs coming from RRC_IDLE and RRC_INACTIVE if the UE context is not found).	Either MsgA PUSCH part need to be differentiated for RedCap UEs and non-RedCap UEs, or the will be impact on non-RedCap UEs from the increases MsgA PUSCH size.
More limited impact to specifications	May degrade reliability/coverage of MsgA PUSCH in case of increased MsgA PUSCH payload size.
The option of MsgA PUSCH indication may offer good scalability in the number of bits for such UE identification, e.g., if sub-types of RedCap device types (if defined) are to be indicated in MsgA.	Cannot provide coverage recovery in case of PUSCH failure and fallback to 4-step RACH.
Makes it possible to differentiate or enable prioritization of non-RedCap UEs vs. RedCap UEs during contention resolution if RedCap UE type is visible to MAC layer.	

11.2 Access restrictions

11.2.1 Description of feature

NG-RAN supports overload and access control functionality such as RACH back off, RRC Connection Reject, RRC Connection Release and UE based access barring mechanisms. The purpose of the feature is to not only provide the same functionality as for legacy UEs but to have RedCap specific access restrictions to be able to avoid or limit negative impact on legacy performance.

11.2.2 Cell barring

For RedCap UEs, an explicit or implicit indication in broadcast system information can be used to indicate whether a RedCap UE can camp on the cell or not. If a RedCap UE is not allowed to camp on a cell or the RedCap UE considers the cell as barred, it could be of interest to bar all cells on the frequency to ensure RedCap UEs only camp on the strongest cell. Legacy UEs have the same functionality and the IE intraFreqReselection configures in the UE should consider only the current cell as barred or all cells on the frequency. For RedCap it remains to be determined if the functionality should be controlled by the same intraFreqReselection IE or if a new separate parameter should be introduced.

11.2.3 Unified access control

The unified access control (UAC) framework is specified in TS 22.261 and it applies to all UEs in RRC_IDLE, RRC_CONNECTED and RRC_INACTIVE. This mechanism should also apply to RedCap UEs to control RedCap UEs accesses to the network. In UAC each access attempt is associated with an Access Category and one or more Access Identities (defined in TS 24.501). As baseline, the legacy principles apply to RedCap UEs and further details on using Access Identitiy(ies) and Access Categories are to be discussed during normative phase. One option, also to be discussed further in the normative phase, is that the network is able to differentiate between RedCap and non-RedCap UEs using UAC.

The possible solutions for RedCap UAC that have been considered in the study are the following (the options do not need to be mutually exclusive):

- Define one or more RedCap specific Access Identities. Access Identities are connected to the UE type and are (currently) used to lift the barring for certain identities, e.g. for special access classes or UEs configured for prioritized services.

- Define RedCap specific Access Categories. Access Categories are related to the type of access attempt and is set per access attempt type depending on what triggered the access (set by NAS if NAS triggered, or by RRC if AS triggered). There can only be one Access Category per access attempt. To be able to treat different RedCap access attempt types differently, e.g. apply different barring to different access types, multiple Access Categories for RedCap could be defined.

- Use some of the operator defined Access Categories for RedCap. The description of the previous solution applies also to this solution, the difference is that this solution has no specification impact but cannot be used for initial attach to the network since it depends to CN configuration of the UE.

- Broadcast a different set of UAC parameters for RedCap UEs. This makes it possible for NW to flexibly and separately provide UAC parameters for RedCap UEs while avoiding impact on UAC configuration of non-RedCap UEs.

- Use existing broadcasted UAC parameters for RedCap UEs with no changes, that is, the same UAC parameters apply for all UEs (non-RedCap UEs and RedCap UEs) and no new Access Categories and Access Identities are defined. This option requires no specification changes.

UAC is defined in TS 22.261 and TS 24.501, and feasibility of the options (e.g. defining new Access Identities or Access Categories) should be consulted with SA1/CT1.

11.2.4 RRC connection reject

To save radio resources and limit negative impact on legacy network performance it is beneficial to bar or reject UEs as early as possible, preferably without additional signalling. Therefore, cell barring and UAC is beneficial compared to RRC connection rejection. However, if the network is aware of the UEs type during initial access, it is possible for the network to reject RRC connection based on the UE type. There is no additional specification impact in case early indication is specified.

11.2.5 Analysis of coexistence with legacy UEs

The purpose of the RedCap access restrictions is to eliminate or limit the impact on legacy UEs. The impact for enabling any of above features is an increase is in OH due to added parameters in SI broadcast signalling.

One possibility is that separate RACH configuration is provided for RedCap UEs. In such case, it would be possible to configure different RACH parameters to RedCap and non-RedCap UEs, such as different maximum number for preamble transmission, different back-off timer after an attempt or a different power ramping step for RedCap UEs.

11.2.6 Analysis of specification impacts

Cell barring would have small impact on RAN2 specification if explicit indication is used, and if a separate *intraFreqReselection* parameter is introduced for RedCap. With an implicit indication e.g. implicit from the presence of RedCap configuration in SI, there would be no additional specification impact from cell barring.

For UAC, using operator defined Access Categories for RedCap would not have any specification impact. Introducing new Access Categories or Access Identity for RedCap would have SA1 and CT1 specification impact. Introducing a separate configuration for RedCap UE would increase the amount of broadcast system information.

Supporting RRC connection reject would have no specification impact.

12 Impact to network capacity and spectral efficiency

The system-level simulation (SLS) evaluations for the impacts of UE complexity reduction and antenna inefficiency to network capacity and spectrum efficiency [3] are summarized in Table D-1 to D-25 in Annex D. The methodology for the SLS evaluations is described in clause 6.4. Burst traffic model and optional full buffer traffic are considered.

The impact from potential coverage recovery techniques is reflected in some of the SLS results in the sense that we allow the PDSCH/PUSCH spectral efficiency to go lower due to, e.g. repetitions and/or HARQ transmissions (i.e. trading data rate for coverage).

For burst traffic evaluation, FTP model 3 is assumed for eMBB users. The assumption of traffic model for RedCap users varies across the sourcing companies. The instant message (IM) traffic model which in average generates an offered load of 400 kbps (0.1 MB payload every 2 s) is assumed for RedCap users by some sourcing companies. Compared to the assumed traffic model for the eMBB users which have an offered load of 20 Mbps (0.5 MB payload every 200 ms), the RedCap users will produce a very low data volume even with a 50-50 split of eMBB and RedCap users. The use of IM traffic for downlink capacity evaluation corresponds to video surveillance and industrial wireless sensor use cases for which traffic pattern is dominated by UL transmissions. In addition, the IM traffic may also be possible for some low data rate wearable use cases.

Some companies have considered to reuse the same FTP model 3 for RedCap users by assuming wearable use cases have DL heavy traffic and the traffic pattern is the same for RedCap users and eMBB users. It should be noted that among the companies assuming FTP3 traffic model for RedCap, there may be differences in the average traffic volume assumption. Such a difference may contribute to different conclusion.

For burst traffic evaluation with IM traffic model for RedCap users:

- 3 sources (Ericsson, Vivo, Qualcomm) observed that the RedCap users have minor or no impact on spectral efficiency and capacity, and little impact to the performance of co-existing eMBB users in the system

- It is further noted that the 1 Rx RedCap users do not make an appreciable change on the user throughput performance of the eMBB users compared to the 2 Rx RedCap users

For burst traffic evaluation with FTP model 3 for RedCap users:

- One source (Nokia) with the respective simulation assumptions including the schedulable bandwidth reported the user throughput performance of the eMBB users is not degraded with the presence of the RedCap users in the system.

- One source (Huawei/HiSilicon) with the respective simulation assumptions including the schedulable bandwidth reported the impact on spectral efficiency will be substantial. It is further observed substantial cell spectral efficiency loss about 30% due to UE Rx antenna reduced from four to two and DL modulation order restriction from 256QAM to 64QAM in FR1 and about 50% spectral efficiency reduction due to UE Rx antenna reduced from four to one and DL modulation order restriction from 256QAM to 64QAM in FR1.

For optional full buffer traffic evaluation:

- One source (Nokia) with the respective simulation assumptions including the schedulable bandwidth reported a minor degradation of the spectral efficiency for the eMBB users and the degree of spectral efficiency loss is irrespective of the number of Rx antennas for RedCap users.

- One source (Huawei/HiSilicon) with the respective simulation assumptions including the schedulable bandwidth reported the impact on spectral efficiency will be substantial. It is further observed substantial cell spectral efficiency loss about 54% due to UE Rx antenna reduced from four to two and DL modulation order restriction from 256QAM to 64QAM in FR1 and about 70% spectral efficiency reduction due to UE Rx antenna reduced from four to one and DL modulation order restriction from 256QAM to 64QAM in FR1.

13 Conclusions and recommendations

UE complexity reduction techniques have been analysed individually in clauses 7.2 through 7.7 as well as in different combinations in clause 7.8 (cost/complexity), clause 9 (coverage recovery), and clause 12 (impact on network capacity and spectral efficiency). The main observations from the coverage recovery evaluations are summarized in clause 9.1.5.

Based on the analysis of the UE complexity reduction techniques, the following is recommended for a RedCap UE.

- Maximum UE bandwidth:
  - Maximum bandwidth of an FR1 RedCap UE during and after initial access is 20 MHz
    - Whether an FR1 RedCap UE can optionally support a maximum bandwidth larger than 20 MHz after initial access can be discussed during the WI phase or at RAN plenary.
  - Maximum bandwidth of an FR2 RedCap UE during and after initial access is 100 MHz
- Number of Rx branches:
  - For FR1 FDD or FR2 bands where a non-RedCap UE is required to be equipped with a minimum of 2 Rx branches, the minimum number of Rx branches supported by specification for a RedCap UE is 1. The specification also supports of 2 Rx branches for a RedCap UE.
  - For FR1 TDD bands where a non-RedCap UE is required to be equipped with a minimum of 4 Rx branches, the minimum number of Rx branches supported by specification for a RedCap UE is N, where N is to be down-selected during the WI phase or at RAN plenary between the following alternatives:
    - Alt 1: N=2
    - Alt 2: N=1, where N=2 is also supported
- Number of DL MIMO layers:
  - For a RedCap UE with 1 Rx branch, the maximum number of DL MIMO layers is 1.
  - For a RedCap UE with 2 Rx branches, the maximum number of DL MIMO layers is M, where M is to be down-selected during the WI phase or at RAN plenary between the following options (where different options may be selected for FR1 FDD, FR1 TDD, and FR2, respectively):
    - Option 1: M=1, where M=2 is also supported

    - Option 2: M=2
- Half-duplex FDD operation:
    - HD-FDD operation type B is not supported for RedCap FR1 FDD UEs in Rel-17.
    - Decide at RAN plenary whether to have support FD-FDD or HD-FDD operation type A or both by specification for an FR1 FDD RedCap UE.
- Relaxed UE processing time:
    - Decide at RAN plenary whether to support relaxed UE processing time in terms of N_1 and N_2 by specification for a RedCap UE.
- Relaxed maximum modulation order:
    - Support of 256QAM in DL is optional (instead of mandatory) for an FR1 RedCap UE.
    - No other relaxations of maximum modulation order are supported by specification for a RedCap UE.

The study of UE power saving through reduced PDCCH monitoring can be summarized as follows:

- The PDCCH monitoring reduction for RedCap UEs has been studied. The study includes the evaluation of power saving benefit, system performance impacts, coexistence impacts, potential schemes, and the corresponding specification impacts.
- The power saving benefit by PDCCH monitoring reduction for RedCap UEs has been evaluated based on the agreed power model and traffic model, with the results and observations captured in clause 8.2.2.
- The system performance impact has been evaluated using PDCCH blocking rate as the metric, with the results and observations captured in clause 8.2.3. In addition, scheduling flexibility and latency impacts have also been studied in clause 8.2.3.
- Three candidate schemes for PDCCH monitoring reduction have been identified and studied with the corresponding coexistence and specification impacts captured in clause 8.2.4 and clause 8.2.5, respectively.

The study of UE power saving on extended DRX in RRC_INACTIVE and/or RRC_IDLE can be summarized as follows:

- Extended DRX for RedCap UEs for RRC_IDLE and RRC_INACTIVE have been studied. The study includes analysis of UE power saving, possible upper and lower bounds for eDRX cycles and study of possible mechanisms for eDRX for RedCap UEs in clauses 8.3.1-8.3.4.
    - The upper bound for DRX cycles and shorter eDRX values than 5.12 seconds, i.e. 2.56 seconds have been studied and options are discussed in clause 8.3.3.
    - Solutions for PTW and eDRX cycle configuration and which node should configure the eDRX cycle for RRC_INACTIVE have been studied and solutions are captured in clause 8.3.4.

Based on the study of UE power saving on extended DRX, the following are recommended from RAN2 perspective, where feasibility is to be confirmed with SA2 and/or CT1:

- The applicable parts of eDRX mechanisms for LTE, including use of H-SFN, PH and PTW are expected to be re-used for RedCap UEs.
- It is recommended that for eDRX cycles below and equal to 10.24 seconds PTW and PH is not used and that common design for handling eDRX cycle equal to 10.24 seconds in RRC_IDLE and RRC_INACTIVE is specified.
- It is recommended eDRX cycles in RRC_IDLE are extended up to 10485.76 seconds, unless RAN4 indicates such eDRX value requires UE to perform RRM on serving cell outside PTW.
- It is recommended eDRX cycles in RRC_INACTIVE are extended > 10.24 seconds.

The study of UE power saving on RRM relaxation for stationary UEs can be summarized as follows:

- RRM relaxation for RedCap UEs has been studied. The study includes the definition of the possible RRM relaxation triggers and the candidate RRM relaxation methods for stationary UEs in clauses 8.4.2 and 8.4.3.
  - It is recommended that enabling or disabling RRM relaxation should be under network's control.
  - RAN4 should be consulted on feasibility of any RRM relaxation methods which are to be defined.
- RRM relaxation has been studied for all the RRC states (RRC_IDLE, RRC_INACTIVE and RRC_CONNECTED) and both for neighbour cell and for serving cell measurements.
  - For RRC_CONNECTED, it is recommended that UEs which are fixed or immobile are considered with higher priority compared to UEs which are slightly moving.
- Irrespective of RRC state, serving cell RRM relaxation for RedCap UEs is not recommended to be specified.

The study of reduced capability signaling framework can be summarized as follows:

- The studied alternatives and options for RedCap UE type definition and categorization of RedCap capabilities are captured in clause 10.1. Down-selection can be discussed further during WI phase.
- At least for device type identification and possibly for constraining the use of reduced capabilities, the network needs to know whether the UE is RedCap UE or not.
- As a baseline, the existing UE capability framework is used to indicate the capabilities of RedCap UEs.
  - The capabilities for RedCap UEs can be categorized as mandatory capabilities, which all RedCap UEs support, and possible optional capabilities, signaled explicitly.
  - The final categorization of capabilities into the studied categories depends on the exact capabilities applicable to RedCap UEs, to be defined during the WI phase.
- The network should be able to control that the RedCap UEs are only used for the intended use cases, the studied solutions are listed in clause 10.2.

The study of identification and access restriction can be summarized as follows:

- RedCap early indication in Msg1, Msg3, MsgA, or in a later message have been studied and analysis is presented in clause 11.1.1. The necessity of early indication depends on the need for the network to know whether the UE accessing the system is a RedCap UE during the initial access, e.g. depending on the need of coverage recovery, different scheduling of RedCap UEs, or additional access restrictions.
- Different mechanisms for access control of RedCap UEs in RAN have been studied and analysis is presented in clause 11.2.
  - System information indication has been studied in clause 11.2.2. It is recommended to specify a system information indication to indicate whether a RedCap UE can camp on the cell or not.
  - Unified access control is studied in clause 11.2.3. UAC should apply to RedCap UEs and one option is that UAC can differentiate between RedCap and non-RedCap UEs. Different solutions for RedCap UAC have been studied and down-selection can be done in WI phase.
  - It is possible to use RRC connection reject (clause 11.2.4) if the network knows the UE is a RedCap UE, however, preferably access control should happen earlier.

Annex A: UE power saving results

In the following tables for UE power saving results, Case 1 and Case 2 represent the following:

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

A.1 UE power saving results for FR1

Table A.1-1: Power Saving gain, FR1, Same-Slot Scheduling, 1 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Schemes (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	vivo	3.54%	7.08%	2.29%	4.59%	2.13%	4.25%	2.85%	5.70%	S1	
		-	6.32%	-	4.07%	-	4.16%	-	-	S2	Note 2
		-	9.72%	-	4.44%	-	4.38%	-	-	S2	Note 2, 3
		-		-	-	-	-	3.80%	5.70%	S1	Note 4, 5
2	Ericsson	0.70%	1.30%	0.01%	0.02%	0.01%	0.02%	1.19%	2.22%	S1	Note 6
		2.42%	4.49%	0.01%	0.02%	0.01%	0.02%	2.64%	4.90%	S1	Note 4
		0.32%	0.59%	0.01%	0.02%	0.01%	0.02%			S1	Note 6B
3	Qualcomm	3.22%	6.44%	0.96%	1.92%	0.65%	1.30%	1.53%	3.06%	S1	Note 7
4	CATT	1.83%	3.67%	1.10%	2.20%	1.04%	2.08%	0.90%	1.82%	S1	
5	Spreadtrum	5.70%	11.40%	3.40%	6.80%	3.20%	6.40%	3.10%	6.00%	S1	
6	OPPO	3.51%	7.02%	2.48%	4.96%	2.38%	4.76%	-	-	S1	Note 4
7	Huawei, HiSilicon	0.71%	1.41%	0.21%	0.41%	0.18%	0.36%	2.58%	5.16%	S1	Note 4, 8A,9A
		0.75%	1.53%	0.21%	0.41%	0.18%	0.36%	2.75%	5.24%	S1	Note 4, 8B, 9A
		2.57%	5.14%	2.11%	4.06%	1.96%	3.91%	3.71%	6.23%	S1	Note 4, 8A, 9B
		2.88%	5.65%	2.15%	4.29%	1.98%	3.93%	3.88%	6.48%	S1	Note 4, 8B, 9B
8	Apple	4.46%	8.92%	2.66%	5.33%	-	-	-	-	S1	Note 4
		3.38%	6.77%	0.65%	1.32%	-	-	-	-	S1	Note 4, 10
9	Futurewei	2.70%	5.40%	0.50%	1.10%	0.30%	0.60%	2.20%	4.40%	S1	
10	Intel	3.31%	6.4%	2.24%	4.75%	2.03%	4.36%	-	-	S1	Note 11, 12
		3.2%	6.2%	2.1%	4.16%	1.76%	3.81%	-	-	S1	Note 13, 12
11	ZTE	4.15%	8.29%	2.60%	5.21%	2.29%	4.57%	-	-	S1	Note 4
12	InterDigital	4.40%	8.80%	1.16%	2.04%	0.45%	0.92%			S1	Note 4

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: $X = 2$
Note 3: Multi-slot scheduling
Note 4: DL-only
Note 5: Size budget reduction by decoupling the configuration of DCI format 0_1 and 1_1, VOIP like DL only traffic
Note 6: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 6B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 7: slots "DDDU"
Note 8A: BD reduction with the same DCI size budget.
Note 8B: BD reduction by reducing DCI size budget.
Note 9A: UE can only transit to micro sleep in connected mode.
Note 9B: UE can transit to micro sleep, light sleep and deep sleep in connected mode according to the sleep duration.
Note 10: Wake-Up Signal (WUS)
Note 11: TDD: DDDDDDDSUU
Note 12: TDD: DDDSUDDSUU

Note 13: 1 packet requires 1 PDSCH for Heartbeat traffic model; 1 packet requires 24 PDSCHs for IM model, assuming cell centre UE.

Table A.1-2: Power Saving gain, FR1, Cross-Slot Scheduling, 1 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Schemes (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	vivo	3.13%	4.77%	1.95%	2.98%	1.80%	2.75%	2.47%	3.76%	S1	
2	Ericsson	0.66%	0.81%	0.01%	0.01%	0.01%	0.01%	1.14%	1.39%	S1	Note 2
		2.39%	2.91%	0.01%	0.02%	0.01%	0.02%	2.62%	3.19%	S1	Note 3
		0.30%	0.36%	0.01%	0.01%	0.01%	0.01%			S1	Note 2B
3	Samsung	4.50%	9%	2.70%	5.50%	2.60%	5.10%	3.50%	7%	S1, S2	Note 3
		4.50%	9%	2.70%	5.50%	2.60%	5.10%	4.50%	3.5%	S3	
4	Qualcomm	2.82%	4.30%	0.79%	1.20%	0.52%	0.80%	1.28%	1.94%	S1	Note 4
5	OPPO	2.77%	5.54%	2.13%	4.25%	2.04%	4.07%	-	-	S1	Note 3
6	Apple	4.05%	6.17%	2.29%	3.50%	-	-	-	-	S1	Note 3
		2.98%	4.53%	0.54%	0.82%	-	-	-	-	S1	Note 3, 5
7	ZTE	3.7%	7.4%	2.28%	4.57%	2.03%	4.05%	-	-	S1	Note 3
8	MediaTek	2.43%	4.45%					2.72%	5.41%	S1	Note 6
		0.84%	1.68%					0.87%	1.74%	S1	Note 7

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 2B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 3: DL-only
Note 4: slots "DDDU"
Note 5: Wake-Up Signal (WUS)
Note 6: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot
Note 7: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots

Table A.1-3: Power Saving gain, FR1, Same-Slot Scheduling, 2 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Schemes (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	vivo	4.22%	8.44%	2.88%	5.76%	2.71%	5.43%	3.45%	6.89%	S1	
		-	8.99%	-	7.02%	-	6.87%	-	-	S2	Note 2
		-	9.58%	-	7.56%	-	6.89%	-	-	S2	Note 2, Note 3
		-	-	-	-	-	-	4.60%	6.89%		Note 4, Note 5
2	Ericsson	0.95%	1.76%	0.01%	0.02%	0.01%	0.02%	1.56%	2.89%	S1	Note 6
		3.05%	5.66%	0.22%	0.42%	0.20%	0.38%	3.33%	6.17%	S1	Note 4
		0.44%	0.82%	0.01%	0.03%	0.01%	0.02%			S1	Note 6B
3	Qualcomm	3.72%	7.44%	1.25%	2.50%	0.86%	1.71%	1.98%	3.96%		Note 7
4	Nokia	-	9.2%	-	6.8%	-	6.1%	-	-	S1	Note 4
5	CATT	2.16%	4.12%	1.30%	2.61%	1.23%	2.46%	1.16%	2.32%	S1	
6	Spreadtrum	6.20%	12.3%	4.10%	8.20%	3.90%	7.80%	3.70%	7.20%	S1	
7	OPPO	3.94%	7.88%	2.81%	5.61%	2.70%	5.40%	-	-	S1	Note 4
8	Huawei, HiSilicon	0.64%	1.55%	0.24%	0.47%	0.21%	0.41%	2.79%	5.69%	S1	Note 4, 8A, 9A
		0.82%	1.63%	0.24%	0.47%	0.21%	0.41%	2.85%	5.70%	S1	Note 4, 8B, 9A
		1.47%	4.92%	2.19%	4.39%	2.00%	3.99%	2.96%	6.31%	S1	Note 4, 8A, 9B

		2.83%	5.65%	2.19%	4.47%	2.00%	4.02%	3.17%	6.33%	S1	Note 4, 8B, 9B
9	Apple	5.10%	10.1%	3.30%	6.60%	-	-	-	-	S1	Note 4
		4.00%	8.06%	0.90%	1.80%	-	-	-	-	S1	Note 4, 10
10	Futurewei	3.20%	6.30%	0.70%	1.30%	0.40%	0.80%	2.70%	5.50%	S1	
11	Intel	3.46%	6%	2%	4.13%	2.4%	5.12%	-	-	S1	Note 11,13
		2.51%	4.9%	1.9%	4.04%	2.3%	4.43%	-	-	S1	Note 12,13
12	ZTE	4.77%	9.54%	3.03%	6.06%	2.94%	5.87%	-	-	S1	Note 4
13	InterDigital	5%	10%	1.20%	2.40%	0.64%	1.28%	-	-	S1	Note 4

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: $X = 2$
Note 3: Multi-slot scheduling
Note 4: DL-only
Note 5: Size budget reduction by decoupling the configuration of DCI format 0_1 and 1_1, VOIP like DL only traffic
Note 6: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 6B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 7: Slots "DDDU",
Note 8A: BD reduction with the same DCI size budget.
Note 8B: BD reduction by reducing DCI size budget.
Note 9A: UE can only transit to micro sleep in connected mode.
Note 9B: UE can transit to micro sleep, light sleep and deep sleep in connected mode according to the sleep duration.
Note 10: Wake-Up Signal (WUS)
Note 11: TDD: DDDDDDDSUU
Note 12: TDD: DDDSUDDSUU
Note 13: 1 packet requires 1 PDSCH for Heartbeat traffic model; 1 packet requires 24 PDSCHs for IM model, assuming cell centre UE.

Table A.1-4: Power Saving gain, FR1, Cross-Slot Scheduling, 2 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Schemes (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	vivo	3.80%	7.61%	2.50%	4.99%	2.34%	4.68%	3.04%	6.07%	S1	
2	Ericsson	0.77%	1.44%	0.01%	0.02%	0.01%	0.02%	1.30%	2.41%	S1	Note 2
		2.46%	4.57%	0.64%	0.78%	0.58%	0.71%	2.71%	5.02%	S1	Note3
		0.36%	0.67%	0.01%	0.02%	0.01%	0.02%			S1	Note 2B
3	Samsung	4.50%	6.90%	2.80%	4.20%	2.50%	3.90%	3.50%	5.30%	S1, S2	Note 3
		4.50%	6.90%	2.70%	4.20%	2.50%	3.90%	3.50%	5.30%	S3	
4	Qualcomm	3.31%	6.61%	1.03%	2.07%	0.71%	1.40%	1.67%	3.34%	S1	Note 4
5	OPPO	3.10%	6.21%	2.43%	4.85%	2.33%	4.66%	-	-	S1	Note 3
6	Apple	4.69%	9.38%	2.90%	5.70%	-	-	-	-	S1	Note 3
		3.60%	7.22%	0.75%	1.49%	-	-	-	-	S1	Note 3, 5
7	ZTE	4.35%	8.7%	2.76%	5.52%	2.47%	4.94%	-	-	S1	Note 3
8	MediaTek	2.64%	4.83%					2.67%	5.30%		Note 6
		0.88%	1.76%					0.83%	1.65%		Note 7

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 2B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 3: DL-only
Note 4: slots "DDDU",
Note 5: Wake-Up Signal (WUS)
Note 6: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot
Note 7: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots

A.2 UE power saving results for FR2

Table A.2-1: Power Saving gain, FR2, Same-Slot Scheduling, 1 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Scheme (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	Ericsson	1.94%	3.59%	0.03%	0.07%	0.03%	0.06%	2.52%	4.66%	S1	Note2
		4.37%	8.10%	0.04%	0.08%	0.04%	0.07%	4.66%	8.64%	S1	Note 3
		0.77%	1.43%	0.03%	0.06%	0.03%	0.05%			S1	Note 2B
2	CATT	4.53%	9.07%	2.97%	5.93%	2.75%	5.50%	2.88%	5.76%	S1	
3	Spreadtrum	6.60%	13.10%	4.30%	8.60%	4.00%	7.90%	5.00%	9.40%	S1	
4	Futurewei	4.40%	8.70%	2.00%	1.00%	0.50%	1.10%	3.90%	7.90%	S1	
5	Intel	5.48%	10.62%	4.78%	7.94%	3.36%	6.6%			S1	Note 4,5
6	ZTE	5.76%	11.52%	3.55%	7.11%	3.09%	6.18%	-	-	S1	Note 3

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 2B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 3: DL-only
Note 4: TDD: DDDSUDDDSU
Note 5: 1 packet requires 1 PDSCH for Heartbeat traffic model; 1 packet requires 16 PDSCHs for IM model, assuming cell centre UE.

Table A.2-2: Power Saving gain, FR2, Cross-Slot Scheduling, 1 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Scheme (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	Ericsson	1.40%	2.70%	0.02%	0.04%	0.02%	0.04%	1.94%	3.60%	S1	Note 2
		3.65%	6.76%	0.03%	0.06%	0.03%	0.05%	3.94%	7.31%	S1	Note 3
		0.55%	1.03%	0.02%	0.04%	0.02%	0.04%			S1	Note 2B
2	Samsung	6.30%	12.70%	4.20%	8.30%	3.90%	7.60%	6.50%	13.10%	S1, S2	Note 3
		6.30%	12.70%	4.20%	8.30%	3.90%	7.60%	6.50%	13.10%	S3	Note 3
3	ZTE	5.33%	10.67%	2.56%	5.13%	2.45%	4.9%	-	-	S1	Note 3
4	MediaTek	3.61%	6.81%					3.80%	7.55%	S1	Note 4
		1.96%	3.92%					2.06%	4.12%	S1	Note 5

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 2B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 3: DL-only
Note 4: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot
Note 5: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots

Table A.2-3: Power Saving gain, FR2, Same-Slot Scheduling, 2 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Scheme (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	Ericsson	2.45%	4.54%	0.04%	0.10%	0.04%	0.09%	3.10%	5.74%	S1	Note 2
		4.84%	8.96%	0.06%	0.11%	0.05%	0.10%	5.13%	9.51%	S1	Note 3
		1.04%	1.92%	0.04%	0.08%	0.04%	0.07%			S1	Note 2B
2	CATT	4.81%	9.61%	3.34%	6.68%	3.12%	6.06%	3.19%	6.39%	S1	
3	Spreadtrum	6.80%	13.6%	4.90%	11.9%	4.6%	9.2%	5.5%	10.5%	S1	
4	Futurewei	4.60%	9%	1.10%	2.10%	0.50%	1.00%	4.50%	8.90%	S1	
5	Intel	4.43%	9.73%	4.2%	7.80%	4.57%	8.74%	-	-	S1	Note 4,5
6	ZTE	6.01%	12.03%	4.03%	8.07%	3.64%	7.29%	-	-	S1	Note 3

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 2B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 3: DL-only
Note 4: TDD: DDDSUDDDSU
Note 5: 1 packet requires 1 PDSCH for Heartbeat traffic model; 1 packet requires 16 PDSCHs for IM model, assuming cell centre UE.

Table A.2-4: Power Saving gain, FR2, Cross-Slot Scheduling, 2 Rx antenna

#	Company	IM traffic model		Heartbeat traffic model				VoIP traffic model		Scheme (Note 1)	Notes
				IAT = 200ms		IAT = 80ms					
		Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2		
1	Ericsson	1.89%	3.50%	0.03%	0.07%	0.03%	0.06%	2.45%	4.54%	S1	Note 2
		4.12%	7.64%	0.04%	0.08%	0.04%	0.07%	4.44%	8.22%	S1	Note 3
		0.75%	1.40%	0.03%	0.06%	0.03%	0.05%			S1	Note 2B
2	Samsung	6.60%	13.20%	4.90%	9.60%	4.60%	8.90%	6.80%	13.7%	S1, S2	Note 3
		6.60%	13.20%	4.90%	9.60%	4.60%	8.90%	6.80%	13.7%	S3	Note 3
3	ZTE	5.53%	11.05%	3.08%	6.17%	2.7%	5.4%	-	-	S1	Note 3
4	MediaTek	3.63%	6.86%					3.72%	7.39%	S1	Note 4
		1.96%	3.91%					1.97%	3.95%	S1	Note 5

Note 1: 'S1' represents Scheme#1, 'S2' represents Scheme#2, 'S3' represents Scheme#3
Note 2: DL and UL (for VoIP, traffic is 50% in DL and 50% in UL)
Note 2B: DL and UL (For IM traffic and Heartbeat, traffic is 50% in DL and 50% in UL)
Note 3: DL-only
Note 4: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 1 slot
Note 5: Baseline: static cross-slot scheduling (FR1: k0=2) + PDCCH monitoring periodicity of 4 slots

Annex B: PDCCH blocking rate results

In the following tables for PDCCH blocking rate results, Case 1, Case 2 and Case 3 represent the following:

- 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

B.1 PDCCH blocking rate results for FR1

Table B.1-1: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: A1

#	Company	# users	# DCI sizes	Case 1		Case 2			Case 3			Notes
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
1	Vivo	2	2	C1	2.02%	C1	3.52%	1.5%	C1	3.59%	1.6%	
		3	2	C1	3.56%	C1	5.03%	1.5%	C1	5.08%	1.5%	
		4	2	C1	4.82%	C1	6.39%	1.6%	C1	7.01%	2.2%	
		5	2	C1	5.94%	C1	7.64%	1.7%	C1	9.42%	3.5%	
		1~5	2	C1	0.25%	C1	0.41%	0.2%	C1	0.41%	0.2%	Note 1
2	Ericsson	3	<=2	C2	3.00%	C2	3.00%	0.0%	C2	3.50%	0.5%	Note 8
		6	<=2	C2	6.00%	C2	7.00%	1.0%	C2	9.00%	3.0%	Note 8
3	Qualcomm	1	2	C1	0.00%	C6	0.00%	0.0%	C1	0.00%	0.0%	Note 2
		2	2	C1	0.42%	C6	0.65%	0.2%	C1	0.81%	0.4%	Note 2
		3	2	C1	1.00%	C6	1.30%	0.3%	C1	1.68%	0.7%	Note 2
		4	2	C1	1.62%	C6	2.09%	0.5%	C1	2.87%	1.3%	Note 2
		5	2	C1	2.67%	C6	3.27%	0.6%	C1	4.65%	2.0%	Note 2
		6	2	C1	3.55%	C6	4.33%	0.8%	C1	6.50%	3.0%	Note 2
		7	2	C1	4.69%	C6	5.89%	1.2%	C1	8.72%	4.0%	Note 2
		8	2	C1	6.40%	C6	8.07%	1.7%	C1	11.5%	5.1%	Note 2
		9	2	C1	8.25%	C6	10.4%	2.2%	C1	14.3%	6.1%	Note 2
		10	2	C1	10.6%	C6	13.1%	2.5%	C1	17.4%	6.8%	Note 2
		1	2	C4	0.00%	C7	0.00%	0.0%	C6	0.00%	0.0%	Note 3
		2	2	C4	0.08%	C7	0.08%	0.0%	C6	0.08%	0.0%	Note 3
		3	2	C4	0.48%	C7	0.53%	0.1%	C6	0.55%	0.1%	Note 3
		4	2	C4	1.12%	C7	1.17%	0.1%	C6	1.23%	0.1%	Note 3
		5	2	C4	2.10%	C7	2.16%	0.1%	C6	2.22%	0.1%	Note 3
		6	2	C4	3.00%	C7	3.04%	0.0%	C6	3.07%	0.1%	Note 3
		7	2	C4	4.03%	C7	4.06%	0.0%	C6	4.11%	0.1%	Note 3
		8	2	C4	5.43%	C7	5.49%	0.1%	C6	5.57%	0.1%	Note 3
		9	2	C4	7.00%	C7	7.04%	0.0%	C6	7.16%	0.2%	Note 3
		10	2	C4	8.95%	C7	9.00%	0.1%	C6	9.15%	0.2%	Note 3
4	Nokia	2	2	C2	4.00%	C8	4.00%	0.0%	C2	4.00%	0.0%	Note 8
		3	2	C2	6.00%	C8	6.00%	0.0%	C2	6.00%	0.0%	Note 8
		4	2	C2	9.00%	C8	10.0%	1.0%	C2	12.0%	3.0%	Note 8
		5	2	C2	12.0%	C8	15.0%	3.0%	C2	20.0%	8.0%	Note 8
		6	2	C2	18.0%	C8	21.0%	3.0%	C2	31.0%	13.0%	Note 8
		7	2	C2	28.0%	C8	31.0%	3.0%	C2	44.0%	16.0%	Note 8
		8	2	C2	38.0%	C8	41.0%	3.0%	C2	58.0%	20.0%	Note 8

5	Huawei, HiSilicon	5	Note 4	C5	6.07%	-		-	C7	6.07%	0.0%	Note 5
		5	2	C5	6.07%	C6	6.90%	0.8%	C1	9.30%	3.2%	
		10	Note 4	C5	17.3%	-		-	C7	17.3%	0.0%	Note 5
		10	2	C5	17.3%	C6	23.3%	6.0%	C1	24.1%	6.8%	
6	InterDigital	2		C1	1.96%	C1	3.31%	1.4%	C1	3.43%	1.5%	
		3		C1	3.50%	C1	5.08%	1.6%	C1	5.30%	1.8%	
		4		C1	4.67%	C1	6.31%	1.6%	C1	7.04%	2.4%	
		5		C1	5.83%	C1	7.32%	1.5%	C1	9.22%	3.4%	
		6		C1	7.19%	C1	8.55%	1.4%	C1	11.8%	4.6%	
		7		C1	8.65%	C1	10.1%	1.5%	C1	14.4%	5.8%	
		8		C1	10.82%	C1	12.2%	1.4%	C1	17.6%	6.8%	
		9		C1	13.71%	C1	15.1%	1.4%	C1	20.8%	7.1%	
		10		C1	17.26%	C1	18.4%	1.1%	C1	24.2%	6.9%	
7	Intel	2	1	C6	1.9%	C9	1.9%	0.0%	C8	1.9%	0.0%	
		4	1	C6	6%	C9	6%	0.0%	C8	6%	0.0%	
		8	1	C6	20%	C9	20%	0.0%	C8	20%	0.0%	
8	ZTE	2	2	C7	2.01%	C10	2.01%	0.0%	C9	4.21%	2.2%	
		4	2	C7	3.04%	C10	3.10%	0.1%	C9	10.8%	7.8%	
		6	2	C7	4.72%	C10	4.87%	0.2%	C9	16.9%	12.2%	
		8	2	C7	7.31%	C10	7.53%	0.2%	C9	35.5%	28.2%	
9	Samsung	1	2	C3	0.00%	C2	0.00%	0.0%	C2	0.00%	0.0%	Note 8
		2	2	C3	0.00%	C2	0.00%	0.0%	C2	0.00%	0.0%	Note 8
		3	2	C3	0.00%	C2	0.00%	0.0%	C2	2.00%	2.0%	Note 8
		4	2	C3	0.00%	C2	1.00%	1.0%	C2	7.00%	7.0%	Note 8
		5	2	C3	0.00%	C2	3.00%	3.0%	C2	13.0%	13.0%	Note 8
		6	2	C3	1.00%	C2	6.00%	5.0%	C2	20.0%	19.0%	Note 8
		7	2	C3	2.00%	C2	10.0%	8.0%	C2	26.0%	24.0%	Note 8
		8	2	C3	4.00%	C2	15.0%	11.0%	C2	32.0%	28.0%	Note 8
		9	2	C3	6.00%	C2	20.0%	14.0%	C2	37.0%	31.0%	Note 8
		10	2	C3	8.00%	C2	25.0%	17.0%	C2	42.0%	34.0%	Note 8
		1	2	C3	0.00%	C2	0.00%	0.0%	C2	0.00%	0.0%	Note 6, 8
		2	2	C3	0.00%	C2	0.00%	0.0%	C2	0.00%	0.0%	Note 6, 8
		3	2	C3	0.00%	C2	0.00%	0.0%	C2	0.00%	0.0%	Note 6, 8
		4	2	C3	0.00%	C2	0.00%	0.0%	C2	0.00%	0.0%	Note 6, 8
		5	2	C3	0.00%	C2	0.00%	0.0%	C2	2.00%	2.0%	Note 6, 8
		6	2	C3	0.00%	C2	0.00%	0.0%	C2	2.00%	2.0%	Note 6, 8
		7	2	C3	0.00%	C2	1.00%	1.0%	C2	7.00%	7.0%	Note 6, 8
		8	2	C3	0.00%	C2	1.00%	1.0%	C2	7.00%	7.0%	Note 6, 8
		9	2	C3	0.00%	C2	3.00%	3.0%	C2	13.0%	13.0%	Note 6, 8
		10	2	C3	0.00%	C2	3.00%	3.0%	C2	13.0%	13.0%	Note 6, 8
		1	2	C3	0.00%	C3	0.00%	0.0%	C3	0.00%	0.0%	Note 7, 8
		2	2	C3	0.00%	C3	0.00%	0.0%	C3	8.00%	8.0%	Note 7, 8
		3	2	C3	0.00%	C3	0.00%	0.0%	C3	14.0%	14.0%	Note 7, 8
		4	2	C3	0.00%	C3	1.00%	1.0%	C3	19.0%	19.0%	Note 7, 8
		5	2	C3	0.00%	C3	1.00%	1.0%	C3	22.0%	22.0%	Note 7, 8
		6	2	C3	1.00%	C3	2.00%	1.0%	C3	25.0%	24.0%	Note 7, 8
		7	2	C3	2.00%	C3	3.00%	1.0%	C3	28.0%	26.0%	Note 7, 8
		8	2	C3	3.00%	C3	5.00%	2.0%	C3	31.0%	28.0%	Note 7, 8
		9	2	C3	6.00%	C3	7.00%	1.0%	C3	34.0%	28.0%	Note 7, 8
		10	2	C3	8.00%	C3	10.0%	2.0%	C3	38.0%	30.0%	Note 7, 8
10	Futurewei	1	<= 2	C1	0.00%	C6	0.00%	0.0%	C1	0.00%	0.0%	
		2	<= 2	C1	0.00%	C6	1.00%	1.0%	C1	1.00%	1.0%	
		3	<= 2	C1	0.00%	C6	3.00%	3.0%	C1	4.00%	4.0%	
		4	<= 2	C1	1.00%	C6	4.00%	3.0%	C1	7.00%	6.0%	
		5	<= 2	C1	2.00%	C6	7.00%	5.0%	C1	12.0%	10.0%	
		6	<= 2	C1	3.00%	C6	9.00%	6.0%	C1	15.0%	12.0%	
		7	<= 2	C1	3.00%	C6	15.0%	12.0%	C1	23.0%	20.0%	
		8	<= 2	C1	5.00%	C6	17.0%	12.0%	C1	25.0%	20.0%	
		9	<= 2	C1	7.00%	C6	20.0%	13.0%	C1	33.0%	26.0%	
		10	<= 2	C1	11.0%	C6	26.0%	15.0%	C1	36.0%	25.0%	

Note 1: Metric: the whole system blocking rate. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking rate.
Note 2: Each UE is configured with all the ALs
Note 3: Each UE is configured with a single AL
Note 4: Reference case：2；50% BD reduction case:1
Note 5: For RedCap UEs using 2RX; BD reduction by reducing DCI size budget is evaluated (i.e. 'the number of DCI sizes to monitor per PDCCH candidate' is set to 2 for the reference case and 1 for approximately 50% reduction in BD limits).
Note 6: With enhancement of UE group scheduling with 2 UEs per DCI.
Note 7: With enhancement of PDCCH dropping based on predetermined CCE AL priority order = [1 2 4 8 16]
Note 8: Good coverage

Table B.1-2: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: A2

#	Company	# users	# DCI sizes	Case 1		Case 2			Case 3			Notes
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
1	Ericsson	3	<=2	C2	17.0%	C2	17.0%	0.0%	C2	21.0%	4.0%	Note 8
		6	<=2	C2	40.0%	C2	42.0%	2.0%	C2	46.0%	6.0%	Note 8
2	Qualcomm	1	2	C1	0.0%	C6	0.0%	0.0%	C1	0.0%	0.0%	Note 2
		2	2	C1	3.9%	C6	4.3%	0.4%	C1	9.4%	5.5%	Note 2
		3	2	C1	10.5%	C6	11.2%	0.7%	C1	18.3%	7.8%	Note 2
		4	2	C1	17.4%	C6	18.4%	1.0%	C1	25.7%	8.3%	Note 2
		5	2	C1	24.8%	C6	26.3%	1.5%	C1	32.4%	7.6%	Note 2
		6	2	C1	32.1%	C6	33.8%	1.7%	C1	38.9%	6.8%	Note 2
		7	2	C1	38.5%	C6	40.4%	1.9%	C1	44.3%	5.8%	Note 2
		8	2	C1	44.4%	C6	46.2%	1.8%	C1	49.2%	4.8%	Note 2
		9	2	C1	48.9%	C6	50.7%	1.8%	C1	53.1%	4.2%	Note 2
		10	2	C1	53.2%	C6	55.0%	1.8%	C1	56.7%	3.5%	Note 2
		1	2	C4	0.0%	C7	0.0%	0.0%	C6	0.0%	0.0%	Note 3
		2	2	C4	3.5%	C7	3.5%	0.0%	C6	3.5%	0.0%	Note 3
		3	2	C4	8.1%	C7	8.1%	0.0%	C6	8.1%	0.0%	Note 3
		4	2	C4	13.9%	C7	13.9%	0.0%	C6	13.9%	0.0%	Note 3
		5	2	C4	21.1%	C7	21.1%	0.0%	C6	21.2%	0.1%	Note 3
		6	2	C4	28.7%	C7	28.8%	0.1%	C6	28.9%	0.2%	Note 3
		7	2	C4	35.8%	C7	35.9%	0.1%	C6	36.0%	0.2%	Note 3
		8	2	C4	42.1%	C7	42.2%	0.1%	C6	42.3%	0.2%	Note 3
		9	2	C4	47.3%	C7	47.3%	0.0%	C6	47.4%	0.1%	Note 3
		10	2	C4	51.8%	C7	51.9%	0.1%	C6	52.0%	0.2%	Note 3
3	Nokia	2	2	C2	19.0%	C8	21.0%	2.0%	C2	21.0%	2.0%	Note 8
		3	2	C2	36.0%	C8	38.0%	2.0%	C2	47.0%	11.0%	Note 8
		4	2	C2	64.0%	C8	68.0%	4.0%	C2	78.0%	14.0%	Note 8
		5	2	C2	87.0%	C8	88.0%	1.0%	C2	94.0%	7.0%	Note 8
		6	2	C2	97.0%	C8	98.0%	1.0%	C2	99.0%	2.0%	Note 8
		7	2	C2	100%	C8	100%	0.0%	C2	100%	0.0%	Note 8
4	ZTE	2	2	C8	9.5%	C11	9.5%	0.0%	C10	10.0%	0.5%	
		4	2	C8	24.7%	C11	24.8%	0.1%	C10	27.2%	2.5%	
		6	2	C8	39.2%	C11	39.4%	0.2%	C10	42.8%	3.6%	
		8	2	C8	49.5%	C11	49.6%	0.1%	C10	53.9%	4.4%	
5	Samsung	1	2	C3	0.0%	C2	0.0%	0.0%	C2	0.00	0.0%	Note 8
		2	2	C3	0.0%	C2	1.0%	1.0%	C2	3.0%	3.0%	Note 8
		3	2	C3	0.0%	C2	1.0%	1.0%	C2	7.0%	7.0%	Note 8
		4	2	C3	1.0%	C2	3.0%	2.0%	C2	12.0%	11.0%	Note 8
		5	2	C3	2.0%	C2	5.0%	3.0%	C2	18.0%	16.0%	Note 8
		6	2	C3	3.0%	C2	8.0%	5.0%	C2	23.0%	20.0%	Note 8

		7	2	C3	5.0%	C2	11.0%	6.0%	C2	28.0%	23.0%	Note 8
		8	2	C3	8.0%	C2	15.0%	7.0%	C2	32.0%	24.0%	Note 8
		9	2	C3	11.0%	C2	18.0%	7.0%	C2	36.0%	25.0%	Note 8
		10	2	C3	15.0%	C2	22.0%	7.0%	C2	40.0%	25.0%	Note 8
		1	2	C3	0.0%	C2	0.0%	0.0%	C2	0.0%	0.0%	Note 6, 8
		2	2	C3	0.0%	C2	0.0%	0.0%	C2	0.00,	0.0%	Note 6, 8
		3	2	C3	0.0%	C2	2.6%	2.6%	C2	3.0%	3.0%	Note 6, 8
		4	2	C3	0.0%	C2	2.6%	2.6%	C2	3.0%	3.0%	Note 6, 8
		5	2	C3	0.0%	C2	4.6%	4.6%	C2	7.0%	7.0%	Note 6, 8
		6	2	C3	0.0%	C2	4.6%	4.6%	C2	7.0%	7.0%	Note 6, 8
		7	2	C3	1.0%	C2	7.3%	6.3%	C2	12.0%	11.0%	Note 6, 8
		8	2	C3	1.0%	C2	7.3%	6.3%	C2	12.0%	11.0%	Note 6, 8
		9	2	C3	2.0%	C2	12.4%	10.4%	C2	18.0%	16.0%	Note 6, 8
		10	2	C3	2.0%	C2	12.4%	10.4%	C2	18.0%	16.0%	Note 6, 8
		1	2	C3	0.0%	C4	0.0%	0.0%	C4	0.0%	0.0%	Note 7, 8
		2	2	C3	0.0%	C4	1.0%	1.0%	C4	3.0%	3.0%	Note 7, 8
		3	2	C3	0.0%	C4	1.0%	1.0%	C4	6.0%	6.0%	Note 7, 8
		4	2	C3	1.0%	C4	2.0%	1.0%	C4	9.0%	8.0%	Note 7, 8
		5	2	C3	2.0%	C4	3.0%	1.0%	C4	11.0%	9.0%	Note 7, 8
		6	2	C3	3.0%	C4	5.0%	2.0%	C4	15.0%	12.0%	Note 7, 8
		7	2	C3	5.0%	C4	7.0%	2.0%	C4	18.0%	13.0%	Note 7, 8
		8	2	C3	8.0%	C4	10.0%	2.0%	C4	22.0%	14.0%	Note 7, 8
		9	2	C3	11.0%	C4	13.0%	2.0%	C4	25.0%	14.0%	Note 7, 8
		10	2	C3	15.0%	C4	16.0%	1.0%	C4	29.0%	14.0%	Note 7, 8

Note 1: Metric: the whole system blocking rate. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking rate.
Note 2: Each UE is configured with all the ALs
Note 3: Each UE is configured with a single AL
Note 4: Reference case：2；50% BD reduction case:1
Note 5: For RedCap UEs using 2RX; BD reduction by reducing DCI size budget is evaluated (i.e. 'the number of DCI sizes to monitor per PDCCH candidate' is set to 2 for the reference case and 1 for approximately 50% reduction in BD limits).
Note 6: With enhancement of UE group scheduling with 2 UEs per DCI.
Note 7: With enhancement of PDCCH dropping based on predetermined CCE AL priority order = [1 2 4 8 16]
Note 8: Medium coverage

Table B.1-3: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: A3

#	Company	# users	# DCI sizes	Case 1		Case 2			Case 3			Notes
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
1	Ericsson	3	<= 2	C2	46.0%	C2	47.0%	1.0%	C2	49.0%	3.0%	Note 8
		6	<= 2	C2	66.0%	C2	67.0%	1.0%	C2	69.0%	3.0%	Note 8
2	Qualcomm	1	2	C1	0.0%	C6	0.0%	0.0%	C1	0.0%	0.0%	Note 2
		2	2	C1	18.5%	C6	19.0%	0.4%	C1	23.4%	4.9%	Note 2
		3	2	C1	35.5%	C6	36.3%	0.8%	C1	40.0%	4.5%	Note 2
		4	2	C1	48.0%	C6	49.1%	1.1%	C1	51.5%	3.5%	Note 2
		5	2	C1	56.8%	C6	58.0%	1.2%	C1	59.7%	2.9%	Note 2
		6	2	C1	62.7%	C6	64.0%	1.3%	C1	65.4%	2.7%	Note 2
		7	2	C1	67.4%	C6	68.8%	1.4%	C1	70.0%	2.6%	Note 2
		8	2	C1	70.9%	C6	72.3%	1.4%	C1	73.4%	2.5%	Note 2
		9	2	C1	73.5%	C6	74.8%	1.3%	C1	75.9%	2.4%	Note 2
		10	2	C1	75.7%	C6	77.0%	1.3%	C1	78.0%	2.3%	Note 2
		1	2	C4	0.0%	C7	0.0%	0.0%	C6	0.0%	0.0%	Note 3
		2	2	C4	17.9%	C7	17.9%	0.0%	C6	17.9%	0.0%	Note 3

		3	2	C4	33.9%	C7	33.9%	0.0%	C6	33.9%	0.0%	Note 3
		4	2	C4	46.2%	C7	46.3%	0.0%	C6	46.3%	0.1%	Note 3
		5	2	C4	54.8%	C7	54.9%	0.1%	C6	54.9%	0.1%	Note 3
		6	2	C4	60.8%	C7	60.8%	0.1%	C6	60.9%	0.1%	Note 3
		7	2	C4	65.4%	C7	65.5%	0.1%	C6	65.6%	0.2%	Note 3
		8	2	C4	69.0%	C7	69.1%	0.1%	C6	69.1%	0.2%	Note 3
		9	2	C4	71.5%	C7	71.6%	0.1%	C6	71.7%	0.2%	Note 3
		10	2	C4	73.7%	C7	73.8%	0.1%	C6	73.9%	0.2%	Note 3
3	ZTE	2	2	C9	32.0%	C12	32.1%	0.1%	C11	32.2%	0.2%	
		4	2	C9	55.3%	C12	55.5%	0.1%	C10	57.7%	2.3%	
		6	2	C9	66.4%	C12	66.6%	0.2%	C10	69.0%	2.6%	
		8	2	C9	72.0%	C12	72.5%	0.5%	C10	75.0%	3.0%	
4	Samsung	1	2	C3	0.0%	C2	0.0%	0.0%	C2	0.00	0.0%	Note 8
		2	2	C3	0.0%	C2	8.0%	8.0%	C2	12.0%	12.0%	Note 8
		3	2	C3	3.0%	C2	15.0%	12%	C2	22.0%	19.0%	Note 8
		4	2	C3	7.0%	C2	20.0%	13%	C2	30.0%	23.0%	Note 8
		5	2	C3	12.0%	C2	26.0%	14%	C2	36.0%	24.0%	Note 8
		6	2	C3	17.0%	C2	30.0%	13%	C2	41.0%	24.0%	Note 8
		7	2	C3	22.0%	C2	34.0%	12%	C2	46.0%	24.0%	Note 8
		8	2	C3	28.0%	C2	37.0%	9.0%	C2	49.0%	21.0%	Note 8
		9	2	C3	33.0%	C2	41.0%	8.0%	C2	52.0%	19.0%	Note 8
		10	2	C3	38.0%	C2	43.0%	5.0%	C2	55.0%	17.0%	Note 8
		1	2	C3	0.0%	C2	0.0%	0.0%	C2	0.0%	0.0%	Note 6, 8
		2	2	C3	0.0%	C2	0.0%	0.0%	C2	0.0%	0.0%	Note 6, 8
		3	2	C3	0.0%	C2	1.0%	1.0%	C2	12.0%	12.0%	Note 6, 8
		4	2	C3	0.0%	C2	1.0%	1.0%	C2	12.0%	12.0%	Note 6, 8
		5	2	C3	3.0%	C2	1.0%	-2.0%	C2	22.0%	19.0%	Note 6, 8
		6	2	C3	3.0%	C2	1.0%	-2.0%	C2	22.0%	19.0%	Note 6, 8
		7	2	C3	7.0%	C2	3.0%	-4.0%	C2	30.0%	23.0%	Note 6, 8
		8	2	C3	7.0%	C2	3.0%	-4.0%	C2	30.0%	23.0%	Note 6, 8
		9	2	C3	12.0%	C2	5.0%	-7.0%	C2	36.0%	24.0%	Note 6, 8
		10	2	C3	12.0%	C2	5.0%	-7.0%	C2	36.0%	24.0%	Note 6, 8
		1	2	C3	0.0%	C5	0.0%	0.0%	C5	0.0%	0.0%	Note 7, 8
		2	2	C3	0.0%	C5	0.0%	0.0%	C5	0.0%	0.0%	Note 7, 8
		3	2	C3	3.0%	C5	3.0%	0.0%	C5	4.0%	1.0%	Note 7, 8
		4	2	C3	7.0%	C5	8.0%	1.0%	C5	8.0%	1.0%	Note 7, 8
		5	2	C3	12.0%	C5	13.0%	1.0%	C5	13.0%	1.0%	Note 7, 8
		6	2	C3	17.0%	C5	18.0%	1.0%	C5	18.0%	1.0%	Note 7, 8
		7	2	C3	22.0%	C5	23.0%	1.0%	C5	24.0%	2.0%	Note 7, 8
		8	2	C3	28.0%	C5	28.0%	0.0%	C5	30.0%	2.0%	Note 7, 8
		9	2	C3	33.0%	C5	34.0%	1.0%	C5	35.0%	2.0%	Note 7, 8
		10	2	C3	38.0%	C5	38.0%	0.0%	C5	40.0%	2.0%	Note 7, 8

Note 1: Metric: the whole system blocking rate. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking rate.
Note 2: Each UE is configured with all the ALs
Note 3: Each UE is configured with a single AL
Note 4: Reference case：2；50% BD reduction case:1
Note 5: For RedCap UEs using 2RX; BD reduction by reducing DCI size budget is evaluated (i.e. 'the number of DCI sizes to monitor per PDCCH candidate' is set to 2 for the reference case and 1 for approximately 50% reduction in BD limits).
Note 6: With enhancement of UE group scheduling with 2 UEs per DCI.
Note 7: With enhancement of PDCCH dropping based on predetermined CCE AL priority order = [1 2 4 8 16]
Note 8: Poor coverage

Table B.1-4: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: Others except A1/A2/A3

Company	AL distribution in Table	# users	# DCI sizes	Case 1		Case 2			Case 3			Comments
				# PDCCH candidates for AL [1,2,4,8	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,	PDCCH blocking rate	Blocking rate increase relative to Case 1	

	6.2-5			,16] in Table 6.2-6		,16] in Table 6.2-6			8,16] in Table 6.2-6			
Huawei, HiSilicon	A4	5	Note 4	C5	12.3%	-		-	C7	12.30%	0.0%	Note 1, 2
	A4	5	2	C5	12.3%	C6	13.8%	1.5%	C1	16.30%	4.0%	Note1
	A4	10	Note 4	C5	29.4%	-		-	C7	29.40%	0.0%	Note1, 2
	A4	10	2	C5	29.4%	C6	33.9%	4.5%	C1	34.30%	4.9%	Note1
Panasonic [5]	A7	4		C1	5.93%	C14	7.07%	1.1%	C13	13.9%	8.0%	
	A7	6		C1	10.1%	C14	13.7%	3.6%	C13	23.2%	13.1%	

Note 1: For RedCap UEs using 1RX;
Note 2: 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).

Table B.1-5: PDCCH blocking rate for FR1, with 15kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1

Company	AL distribution in Table 6.2-5	# users	# DCI sizes	Case 1		Case 2			Case 3			Comments
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
vivo	A1	2	2	C1	0.00%	C1	1.36%	1.36%	C1	1.17%	1.17%	
	A1	3	2	C1	0.56%	C1	2.14%	1.58%	C1	2.32%	1.76%	
	A1	4	2	C1	1.31%	C1	2.94%	1.63%	C1	3.35%	2.04%	
	A1	5	2	C1	1.90%	C1	3.73%	1.83%	C1	4.14%	2.24%	
	A1	1~5	2	C1	0.02%	C1	0.17%	0.15%	C1	0.05%	0.03%	Note 1

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

Table B.1-6: PDCCH blocking rate for FR1, with 15kHz/20MHz, CORESET duration: 3 symbols, Delay toleration: 1

Company	AL distribution in Table1 6.2-5	# users	# DCI sizes	Case 1		Case 2			Case 3			Note
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
vivo	A1	2	2	C1	0.00%	C1	0.89%	0.89%	C1	0.90%	0.90%	
	A1	3	2	C1	0.34%	C1	1.54%	1.20%	C1	1.59%	1.25%	
	A1	4	2	C1	0.62%	C1	2.25%	1.63%	C1	2.16%	1.54%	
	A1	5	2	C1	1.08%	C1	2.76%	1.68%	C1	2.82%	1.74%	

	A1	1~5	2	C1	0.01%	C1	0.18%	0.17%	C1	0.25%	0.24%	Note 1
Nokia	A1	2	2	C2	0.00%	C8	0.00%	0.00%	C2	0.00%	0.00%	
	A1	3	2	C2	1.00%	C8	1.00%	0.00%	C2	2.00%	1.00%	
	A1	4	2	C2	2.00%	C8	3.00%	1.00%	C2	6.00%	4.00%	
	A1	5	2	C2	4.00%	C8	7.00%	3.00%	C2	11.0%	7.00%	
	A1	6	2	C2	10.0%	C8	12.0%	2.00%	C2	16.0%	6.00%	
	A1	7	2	C2	15.0%	C8	17.0%	2.00%	C2	23.0%	8.00%	
	A1	8	2	C2	18.0%	C8	22.0%	4.00%	C2	31.0%	13.0%	
Intel	A1	2	1	C10	0.01%	C13	0.01%	0.00%	C12	0.01%	0.00%	
	A1	4	1	C10	0.02%	C13	0.02%	0.00%	C12	0.12%	0.10%	
	A1	8	1	C10	0.07%	C13	0.07%	0.00%	C12	0.28%	0.21%	
	A1	10	1	C10	0.20%	C13	0.20%	0.00%	C12	0.6%	0.40%	
	A1	15	1	C10	1.80%	C13	1.80%	0.00%	C12	2.5%	0.70%	

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

Table B.1-7: PDCCH blocking rate for FR1, with 15kHz/20MHz, CORESET duration: 2 symbols, Delay toleration: 1, 2 or 3 slots

Company	AL distribution in Table 6.2-5	# users	# DCI sizes	Case 1		Case 2			Case 3			Comments
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
ZTE	A1	2	2	C7	0.00%	C10	0.00%	0.00%	C9	0.14%	0.14%	Note 1
	A1	4	2	C7	0.08%	C10	0.08%	0.00%	C9	0.62%	0.54%	Note 1
	A1	6	2	C7	0.30%	C10	0.49%	0.19%	C9	1.34%	1.04%	Note 1
	A1	8	2	C7	0.70%	C10	1.12%	0.42%	C9	2.26%	1.56%	Note 1
	A1	2	2	C7	0.00%	C10	0.00%	0.00%	C9	0.06%	0.06%	Note 2
	A1	4	2	C7	0.03%	C10	0.05%	0.02%	C9	0.29%	0.26%	Note 2
	A1	6	2	C7	0.15%	C10	0.25%	0.10%	C9	0.67%	0.52%	Note 2
	A1	8	2	C7	0.37%	C10	0.61%	0.24%	C9	1.18%	0.81%	Note 2
	A1	2	2	C7	0.00%	C10	0.00%	0.00%	C9	0.04%	0.04%	Note 3
	A1	4	2	C7	0.03%	C10	0.04%	0.01%	C9	0.22%	0.19%	Note 3
	A1	6	2	C7	0.08%	C10	0.16%	0.08%	C9	0.46%	0.38%	Note 3
	A1	8	2	C7	0.24%	C10	0.40%	0.16%	C9	0.84%	0.60%	Note 3
	A2	2	2	C8	0.00%	C10	0.76%	0.76%	C9	2.02%	2.02%	Note 1
	A2	4	2	C8	2.48%	C10	4.28%	1.80%	C9	9.01%	6.53%	Note 1
	A2	6	2	C8	10.23%	C10	11.14%	0.91%	C9	16.91%	6.68%	Note 1
	A2	8	2	C8	18.23%	C10	18.88%	0.65%	C9	24.53%	6.30%	Note 1
	A3	2	2	C9	0.00%	C10	0.03%	0.03%	C9	0.03%	0.03%	Note 1
	A3	4	2	C9	23.58%	C10	24.32%	0.74%	C9	26.61%	3.03%	Note 1
	A3	6	2	C9	39.39%	C10	39.50%	0.11%	C9	41.55%	2.16%	Note 1
	A3	8	2	C9	48.95%	C10	49.18%	0.23%	C9	51.50%	2.55%	Note 1

Note 1: Delay toleration is 1 slot
Note 2: Delay toleration is 2 slots
Note 3: Delay toleration is 3 slots

Table B.1-8: PDCCH blocking rate for FR1, with 30kHz/20MHz, CORESET duration: 3 symbols, Delay toleration: 1

				Case 1		Case 2			Case 3			Comments

Company	AL distribution in Table 6.2-5	# users	# DCI sizes	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
vivo	A1	2	2	C1	0.67%	C1	1.58%	0.91%	C1	1.48%	0.81%	
	A1	3	2	C1	1.62%	C1	2.95%	1.33%	C1	3.13%	1.51%	
	A1	4	2	C1	2.34%	C1	4.39%	2.05%	C1	4.80%	2.46%	
	A1	5	2	C1	3.35%	C1	5.74%	2.39%	C1	5.81%	2.46%	
	A1	1~5	2	C1	0.10%	C1	0.20%	0.10%	C1	0.20%	0.10%	Note 1
Note 1: Metric: the whole system blocking rate. It can be calculated by summing the product of the percentage of each number of UE simultaneously scheduled per slot and its corresponding blocking rate.												

Table B.1-9: 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 Table 6.2-5	# users	# DCI sizes	Case 1		Case 2		Case 3			Comments
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
Huawei, HiSilicon	A5	5	Note 1	C5	8.60%	-	-	C2	8.60%	0.0%	Note 2
	A5	10	Note 1	C5	23.20%	-	-	C2	23.20%	0.0%	Note 2
	A6	5	Note 1	C5	14.5%	-	-	C2	14.5%	0.0%	Note 2
	A6	10	Note 1	C5	33.70%	-	-	C2	33.70%	0.0%	Note 2
Note 1: Reference case：2；50% BD reduction case:1 Note 2: For RedCap UEs using 2RX; BD reduction by reducing DCI size budget is evaluated (i.e. 'the number of DCI sizes to monitor per PDCCH candidate' is set to 2 for the reference case and 1 for approximately 50% reduction in BD limits).											

B.2 PDCCH blocking rate results for FR2

Table B.2-1: PDCCH blocking rate due to reduced blind decoding for FR2, with 120kHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: A1

#	Company	# users	# DCI sizes	Case 1		Case 2			Case 3			Comments
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
1	Ericsson	3	<=2	C2	1.00%	C2	1.2%	0.20%	C2	4.4%	3.4%	Note 1,5
		6	<= 2	C2	3.90%	C2	6.8%	2.90%	C2	14.0%	10.1%	Note 1, 5
2	Qualcomm	2	2	C1	0.20%	C5	0.4%	0.20%	C1	4.0%	3.8%	
		4	2	C1	1.10%	C5	1.9%	0.80%	C1	11.4%	10.3%	
		6	2	C1	2.60%	C5	4.5%	1.90%	C1	17.7%	15.1%	

		8	2	C1	5.10%	C5	7.8%	2.70%	C1	23.5%	18.4%	
		10	2	C1	8.40%	C5	12.0%	3.60%	C1	28.9%	20.5%	
		12	2	C1	12.70%	C5	16.6%	3.90%	C1	33.5%	20.8%	
		14	2	C1	17.70%	C5	21.5%	3.80%	C1	38.0%	20.3%	
		16	2	C1	22.90%	C5	26.5%	3.60%	C1	41.7%	18.8%	
		18	2	C1	28.20%	C5	31.4%	3.20%	C1	45.4%	17.2%	
		20	2	C1	33.50%	C5	36.1%	2.60%	C1	48.7%	15.2%	
3	Nokia	2	2	C1	0.00%	C1	1.0%	1.00%	C1	3.0%	3.0%	
		3	2	C1	2.00%	C1	4.0%	2.00%	C1	7.0%	5.0%	
		4	2	C1	6.00%	C1	9.0%	3.00%	C1	15.0%	9.0%	
		5	2	C1	11.00%	C1	14.0%	3.00%	C1	26.0%	15.0%	
		6	2	C1	15.00%	C1	20.0%	5.00%	C1	40.0%	25.0%	
		7	2	C1	20.00%	C1	29.0%	9.00%	C1	59.0%	39.0%	
		8	2	C1	26.00%	C1	40.0%	14.00%	C1	77.0%	51.0%	
4	Samsung	1	2	C1	0.00%	C2	5.0%	5.00%	C2	8.0%	8.0%	Note 5
		2	2	C1	0.00%	C2	5.0%	5.00%	C2	8.0%	8.0%	Note 5
		3	2	C1	0.00%	C2	7.0%	7.00%	C2	14.0%	14.0%	Note 5
		4	2	C1	1.00%	C2	12.0%	11.00%	C2	22.0%	21.0%	Note 5
		5	2	C1	3.00%	C2	18.0%	15.00%	C2	31.0%	28.0%	Note 5
		6	2	C1	7.00%	C2	24.0%	17.00%	C2	38.0%	31.0%	Note 5
		7	2	C1	11.00%	C2	31.0%	20.00%	C2	45.0%	34.0%	Note 5
		8	2	C1	16.00%	C2	37.0%	21.00%	C2	50.0%	34.0%	Note 5
		9	2	C1	22.00%	C2	42.0%	20.00%	C2	55.0%	33.0%	Note 5
		10	2	C1	26.00%	C2	47.0%	21.00%	C2	59.0%	33.0%	Note 5
		1	2	C1	0.00%	C2	5.0%	5.00%	C2	8.0%	8.0%	Note 3, 5
		2	2	C1	0.00%	C2	5.0%	5.00%	C2	8.0%	8.0%	Note 3, 5
		3	2	C1	0.00%	C2	5.0%	5.00%	C2	8.0%	8.0%	Note 3, 5
		4	2	C1	0.00%	C2	5.0%	5.00%	C2	8.0%	8.0%	Note 3, 5
		5	2	C1	0.00%	C2	7.0%	7.00%	C2	14.0%	14.0%	Note 3, 5
		6	2	C1	0.00%	C2	7.0%	7.00%	C2	14.0%	14.0%	Note 3, 5
		7	2	C1	1.00%	C2	12.0%	11.00%	C2	22.0%	21.0%	Note 3, 5
		8	2	C1	1.00%	C2	12.0%	11.00%	C2	22.0%	21.0%	Note 3, 5
		9	2	C1	3.00%	C2	18.0%	15.00%	C2	31.0%	28.0%	Note 3, 5
		10	2	C1	3.00%	C2	18.0%	15.00%	C2	31.0%	28.0%	Note 3,5
		1	2	C1	0.00%	C3	10.0%	10.00%	C3	10.0%	10.0%	Note 4,5
		2	2	C1	0.00%	C3	10.0%	10.00%	C3	18.0%	18.0%	Note 4,5
		3	2	C1	0.00%	C3	10.0%	10.00%	C3	24.0%	24.0%	Note 4,5
		4	2	C1	1.00%	C3	11.0%	10.00%	C3	29.0%	28.0%	Note 4,5
		5	2	C1	3.00%	C3	13.0%	10.00%	C3	32.0%	29.0%	Note 4,5
		6	2	C1	7.00%	C3	16.0%	9.00%	C3	36.0%	29.0%	Note 4,5
		7	2	C1	11.00%	C3	20.0%	9.00%	C3	41.0%	30.0%	Note 4,5
		8	2	C1	16.00%	C3	25.0%	9.00%	C3	44.0%	28.0%	Note 4,5
		9	2	C1	22.00%	C3	30.0%	8.00%	C3	49.0%	27.0%	Note 4,5
		10	2	C1	26.00%	C3	35.0%	9.00%	C3	52.0%	26.0%	Note 4,5

Note 1: Digital Beamforming.
Note 3: With enhancement of UE group scheduling with 2 UEs per DCI.
Note 4: With enhancement of PDCCH dropping based on predetermined CCE AL priority order = [1 2 4 8 16]
Note 5: Good coverage

Table B.2-2: PDCCH blocking rate due to reduced blind decoding for FR2, with 120kHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: A2

#	Company	# users	# DCI sizes	Case 1		Case 2			Case 3			Notes
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
1		3	<= 2	C2	18.0%	C2	20.0%	2.0%	C2	24.00%	6.0%	Note 1,6

	Ericsson	6	<= 2	C2	36.0%	C2	40.0%	4.0%	C2	44.00%	8.0%	Note 1,6
2	Qualcomm	1	2	C1	0.0%	C5	0.0%	0.0%	C1	0.00%	0.0%	
		2	2	C1	7.4%	C5	7.8%	0.4%	C1	10.80%	3.4%	
		3	2	C1	14.2%	C5	15.3%	1.1%	C1	20.30%	6.1%	
		4	2	C1	20.4%	C5	22.0%	1.6%	C1	28.00%	7.6%	
		5	2	C1	25.9%	C5	27.9%	2.0%	C1	34.50%	8.6%	
		6	2	C1	31.2%	C5	33.6%	2.4%	C1	40.40%	9.2%	
		7	2	C1	35.8%	C5	38.4%	2.6%	C1	45.30%	9.5%	
		8	2	C1	40.3%	C5	43.0%	2.7%	C1	49.70%	9.4%	
		9	2	C1	44.0%	C5	46.7%	2.7%	C1	53.30%	9.3%	
		10	2	C1	47.5%	C5	50.1%	2.6%	C1	56.60%	9.1%	
3	ZTE	2	2	C2	9.2%	C6	10.0%	0.8%	C1	22.88%	13.7%	Note 5
		4	2	C2	26.1%	C6	28.9%	2.9%	C1	44.00%	18.0%	Note 5
		6	2	C2	40.9%	C6	43.3%	2.5%	C1	54.92%	14.1%	Note 5
		8	2	C2	51.9%	C6	54.3%	2.5%	C1	62.61%	10.7%	Note 5
4	Samsung	1	2	C1	0.0%	C2	40.0%	40.0%	C2	61.00%	61.0%	Note 5
		2	2	C1	11.0%	C2	42.0%	31.0%	C2	61.00%	50.0%	Note 5
		3	2	C1	19.0%	C2	45.0%	26.0%	C2	61.00%	42.0%	Note 5
		4	2	C1	25.0%	C2	47.0%	22.0%	C2	62.00%	37.0%	Note 5
		5	2	C1	30.0%	C2	50.0%	20.0%	C2	63.00%	33.0%	Note 5
		6	2	C1	35.0%	C2	52.0%	17.0%	C2	64.00%	29.0%	Note 5
		7	2	C1	39.0%	C2	54.0%	15.0%	C2	66.00%	27.0%	Note 5
		8	2	C1	43.0%	C2	56.0%	13.0%	C2	67.00%	24.0%	Note 5
		9	2	C1	46.0%	C2	58.0%	12.0%	C2	68.00%	22.0%	Note 5
		10	2	C1	49.0%	C2	60.0%	11.0%	C2	69.00%	20.0%	Note 5
		1	2	C1	0.0%	C2	40.0%	40.0%	C2	61.00%	61.0%	Note3, 5
		2	2	C1	0.0%	C2	40.0%	40.0%	C2	61.00%	61.0%	Note3, 5
		3	2	C1	11.0%	C2	42.0%	31.0%	C2	61.00%	50.0%	Note3, 5
		4	2	C1	11.0%	C2	42.0%	31.0%	C2	61.00%	50.0%	Note3, 5
		5	2	C1	19.0%	C2	45.0%	26.0%	C2	61.00%	42.0%	Note3, 5
		6	2	C1	19.0%	C2	45.0%	26.0%	C2	61.00%	42.0%	Note3, 5
		7	2	C1	25.0%	C2	47.0%	22.0%	C2	62.00%	37.0%	Note3, 5
		8	2	C1	25.0%	C2	47.0%	22.0%	C2	62.00%	37.0%	Note3, 5
		9	2	C1	30.0%	C2	50.0%	20.0%	C2	63.00%	33.0%	Note3, 5
		10	2	C1	30.0%	C2	50.0%	20.0%	C2	63.00%	33.0%	Note3, 5
		1	2	C1	0.0%	C4	0.0%	0.0%	C4	20.00%	20.0%	Note 4, 5
		2	2	C1	11.0%	C4	11.0%	0.0%	C4	30.00%	19.0%	Note 4, 5
		3	2	C1	19.0%	C4	19.0%	0.0%	C4	38.00%	19.0%	Note 4, 5
		4	2	C1	25.0%	C4	27.0%	2.0%	C4	43.00%	18.0%	Note 4, 5
		5	2	C1	30.0%	C4	32.0%	2.0%	C4	48.00%	18.0%	Note 4, 5
		6	2	C1	35.0%	C4	37.0%	2.0%	C4	52.00%	17.0%	Note 4, 5
		7	2	C1	39.0%	C4	41.0%	2.0%	C4	55.00%	16.0%	Note 4, 5
		8	2	C1	43.0%	C4	45.0%	2.0%	C4	58.00%	15.0%	Note 4, 5
		9	2	C1	46.0%	C4	49.0%	3.0%	C4	61.00%	15.0%	Note 4, 5
		10	2	C1	49.0%	C4	53.0%	4.0%	C4	63.00%	14.0%	Note 4, 5

Note 1: Digital Beamforming.
Note 3: With enhancement of UE group scheduling with 2 UEs per DCI.
Note 4: With enhancement of PDCCH dropping based on predetermined CCE AL priority order = [1 2 4 8 16]
Note 5: Medium coverage

Table B.2-3: PDCCH blocking rate due to reduced blind decoding for FR2, with 120kHz, CORESET duration: 2 symbols, Delay toleration: 1, AL distribution: A3

e	Company	# users	# DCI sizes	Case 1		Case 2			Case 3			Notes
				# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	# PDCCH candidates for AL [1,2,4,8,16] in Table 6.2-6	PDCCH blocking rate	Blocking rate increase relative to Case 1	
1	Ericsson	3	<= 2	C2	45.0%	C2	47.0%	2.0%	C2	49.0%	4.0%	Note 1, 5
		6	<= 2	C2	63.0%	C2	65.0%	2.0%	C2	67.0%	4.0%	Note 1, 5
2	Qualcomm	1	2	C1	0.0%	C5	0.0%	0.0%	C1	0.0%	0.0%	
		2	2	C1	21.2%	C5	21.7%	0.5%	C1	23.1%	1.9%	
		3	2	C1	36.2%	C5	37.0%	0.8%	C1	39.4%	3.2%	
		4	2	C1	46.8%	C5	47.9%	1.1%	C1	50.5%	3.7%	
		5	2	C1	54.1%	C5	55.4%	1.3%	C1	58.3%	4.2%	
		6	2	C1	59.5%	C5	60.9%	1.4%	C1	63.8%	4.3%	
		7	2	C1	63.9%	C5	65.4%	1.5%	C1	68.3%	4.4%	
		8	2	C1	67.2%	C5	68.7%	1.5%	C1	71.5%	4.3%	
		9	2	C1	69.7%	C5	71.2%	1.5%	C1	74.1%	4.4%	
		10	2	C1	71.7%	C5	73.1%	1.4%	C1	76.1%	4.4%	
3	Samsung	1	2	C1	0.0%	C2	20.0%	20.0%	C2	49.0%	49.0%	Note 5
		2	2	C1	15.0%	C2	32.0%	17.0%	C2	58.0%	43.0%	Note 5
		3	2	C1	25.0%	C2	42.0%	17.0%	C2	64.0%	39.0%	Note 5
		4	2	C1	34.0%	C2	49.0%	15.0%	C2	68.0%	34.0%	Note 5
		5	2	C1	41.0%	C2	55.0%	14.0%	C2	72.0%	31.0%	Note 5
		6	2	C1	47.0%	C2	59.0%	12.0%	C2	74.0%	27.0%	Note 5
		7	2	C1	52.0%	C2	63.0%	11.0%	C2	76.0%	24.0%	Note 5
		8	2	C1	56.0%	C2	66.0%	10.0%	C2	78.0%	22.0%	Note 5
		9	2	C1	59.0%	C2	68.0%	9.0%	C2	79.0%	20.0%	Note 5
		10	2	C1	62.0%	C2	71.0%	9.0%	C2	80.0%	18.0%	Note 5
		1	2	C1	0.0%	C2	20.0%	20.0%	C2	49.0%	49.0%	Note 3, 5
		2	2	C1	0.0%	C2	20.0%	20.0%	C2	49.0%	49.0%	Note 3, 5
		3	2	C1	15.0%	C2	32.0%	17.0%	C2	58.0%	43.0%	Note 3, 5
		4	2	C1	15.0%	C2	32.0%	17.0%	C2	58.0%	43.0%	Note 3, 5
		5	2	C1	25.0%	C2	42.0%	17.0%	C2	64.0%	39.0%	Note 3, 5
		6	2	C1	25.0%	C2	42.0%	17.0%	C2	64.0%	39.0%	Note 3, 5
		7	2	C1	34.0%	C2	49.0%	15.0%	C2	68.0%	34.0%	Note 3, 5
		8	2	C1	34.0%	C2	49.0%	15.0%	C2	68.0%	34.0%	Note 3, 5
		9	2	C1	41.0%	C2	55.0%	14.0%	C2	72.0%	31.0%	Note 3, 5
		10	2	C1	41.0%	C2	55.0%	14.0%	C2	72.0%	31.0%	Note 3, 5
		1	2	C1	0.0%	C4	0.0%	0.0%	C5	5.0%	5.0%	Note 4,5
		2	2	C1	14.0%	C4	15.0%	1.0%	C5	19.0%	5.0%	Note 4,5
		3	2	C1	26.0%	C4	26.0%	0.0%	C5	31.0%	5.0%	Note 4,5
		4	2	C1	34.0%	C4	35.0%	1.0%	C5	40.0%	6.0%	Note 4,5
		5	2	C1	41.0%	C4	42.0%	1.0%	C5	47.0%	6.0%	Note 4,5
		6	2	C1	47.0%	C4	48.0%	1.0%	C5	52.0%	5.0%	Note 4,5
		7	2	C1	52.0%	C4	52.0%	0.0%	C5	57.0%	5.0%	Note 4,5
		8	2	C1	56.0%	C4	56.0%	0.0%	C5	61.0%	5.0%	Note 4,5
		9	2	C1	59.0%	C4	60.0%	1.0%	C5	64.0%	5.0%	Note 4,5
		10	2	C1	62.0%	C4	63.0%	1.0%	C5	67.0%	5.0%	Note 4,5

Note 1: Digital Beamforming.
Note 3: With enhancement of UE group scheduling with 2 UEs per DCI.
Note 4: With enhancement of PDCCH dropping based on predetermined CCE AL priority order = [1 2 4 8 16]
Note 5: Poor coverage

Annex C: Link budget evaluation results

C.1 Urban scenario at 2.6 GHz

Link budget evaluation results for the Urban scenario at 2.6 GHz from all the sourcing companies are captured in Tables C.1-1, C.1-2, C.1-3, and C.1-4. Tables C.1-1, C.1-2, and C.1-3 show the MIL results for reference NR UEs with 4 Rx branches (100MHz bandwidth), RedCap UEs with 2 Rx branches (20MHz bandwidth), and RedCap UEs with 1 Rx branch (20MHz bandwidth), respectively. For every sourcing-company result, the values of the target MIL and the amount of compensation for each channel that has MIL below the target value are highlighted.

Additionally, the MPL results are provided Table C.1-4. The detailed link budget calculations from the sourcing companies can be found in [3].

Table C.1-1: Link budget performance (MIL) for the reference NR UE (100MHz BW, 4Rx)

Urban 2.6GHz, 4Rx Reference UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	165.9	170.1	163.6	162.3	162.4		158.6	154.8	151.8	139.4	150.0		139.4
	Margin (dB)	26.4	30.6	24.1	22.8	22.9		19.2	15.4	12.4	0.0	10.6		
ZTE	MIL (dB)	157.0	167.4	167.6	157.7	158.0		162.6	160.9	158.4	142.0	156.5		142.0
	Margin (dB)	15.0	25.4	25.7	15.7	16.0		20.7	18.9	16.4	0.0	14.5		
OPPO	MIL (dB)	167.5	171.5	169.9	162.2	165.2		155.0	155.1	155.2	145.1	154.7		145.1
	Margin (dB)	22.3	26.3	24.8	17.1	20.1		9.9	9.9	10.1	0.0	9.6		
CATT	MIL (dB)	164.7	168.7	167.6	161.5	163.8		160.3	158.9	156.9	145.9	153.5		145.9
	Margin (dB)	18.7	22.7	21.6	15.5	17.8		14.4	12.9	10.9	0.0	7.6		
vivo	MIL (dB)	157.6	165.6	162.0	157.1	158.6	160.8	156.2	153.6	151.1	137.8	152.5	149.7	137.8
	Margin (dB)	19.8	27.8	24.2	19.4	20.9	23.0	18.4	15.9	13.3	0.0	14.7	11.9	
Xiaomi	MIL (dB)	166.3	166.3	168.4	162.9	165.3		161.6	158.9	157.2	146.7	154.6		146.7
	Margin (dB)	19.5	19.5	21.6	16.1	18.5		14.9	12.2	10.5	0.0	7.9		
Futurewei	MIL (dB)	164.8	166.8	164.3	162.8	163.2					151.6	153.5		151.6
	Margin (dB)	13.1	15.1	12.6	11.1	11.5					0.0	1.9		
Nokia	MIL (dB)	168.3	168.3	166.8	167.3	165.8		151.7		150.2	138.6	147.8	150.3	138.6
	Margin (dB)	29.7	29.7	28.2	28.7	27.2		13.1		11.6	0.0	9.2	11.7	
DOCOMO	MIL (dB)	165.6	169.6	166.2	160.5	162.6		161.1	164.9		145.7	154.6		145.7
	Margin (dB)	19.9	23.9	20.4	14.7	16.9		15.4	19.2		0.0	8.9		
CMCC	MIL (dB)	162.8	168.4	166.7	160.8	163.4	163.8	156.3	154.5	152.3	139.8	152.8	158.6	139.8
	Margin (dB)	23.0	28.6	26.9	21.0	23.6	24.1	16.5	14.7	12.6	0.0	13.1	18.9	
Panasonic	MIL (dB)		169.0	161.0										
	Margin (dB)													
Huawei	MIL (dB)	164.0	168.0	164.2	161.1	160.9		160.6		158.3	139.0	149.6		139.0

	Margin (dB)	25.0	29.0	25.3	22.1	21.9		21.6		19.3	0.0	10.7		
Spreadtrum	MIL (dB)	165.0	169.0	166.9	163.8	163.8	166.3	158.4	156.6	156.2	145.7	153.5	155.8	145.7
	Margin (dB)	19.3	23.3	21.2	18.1	18.1	20.6	12.7	10.9	10.5	0.0	7.8	10.1	
Apple	MIL (dB)	160.5	168.5	163.9	153.8	157.0				150.8	140.0	144.7		140.0
	Margin (dB)	20.5	28.5	23.9	13.8	17.0				10.8	0.0	4.8		
Ericsson	MIL (dB)	162.0	162.0	162.5	156.9	159.4	163.8	154.8	155.5	153.6	143.9	151.2	155.1	143.9
	Margin (dB)	18.0	18.0	18.5	12.9	15.4	19.8	10.9	11.6	9.6	0.0	7.3	11.1	
InterDigital	MIL (dB)	164.47	168.47	166.15	160.47	162.55		160.6		156.4	143.24	152.84		143.24
	Margin (dB)	21.23	25.23	22.91	17.23	19.31		17.36		13.16	0.0	9.6		
Qualcomm	MIL (dB)	161.3		163.4	158.3	159.8				146.5	139.4	148.2		139.4
	Margin (dB)	22.0		24.0	18.9	20.4				7.2	0.0	8.9		
Intel	MIL (dB)	165.7	166.9	163.5	166.4	164.1	165.7	162.0	160.8	158.2	143.9	154.6	156.8	143.9
	Margin (dB)	21.7	23.0	19.6	22.4	20.1	21.8	18.1	16.8	14.2	0.0	10.6	12.8	

Table C.1-2: Link budget performance (MIL) for the RedCap UE (20MHz BW, 2Rx)

Urban 2.6GHz, 2Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	160.1	164.1	156.7	155.8	156.7		155.2	151.6	148.3	136.4	147.0		139.4
	Margin (dB)	20.6	24.6	17.2	16.3	17.2		15.8	12.2	8.9	-3.0	7.6		
ZTE	MIL (dB)							159.6	157.9	155.4	139.0	153.5		142.0
	Margin (dB)							17.7	15.9	13.4	-3.0	11.5		
OPPO	MIL (dB)	161.2	165.2	164.6	155.2	159.0		151.9	152.0	151.9	141.9	151.7		145.1
	Margin (dB)	16.0	20.0	19.5	10.1	13.8		6.8	6.8	6.7	-3.2	6.6		
CATT	MIL (dB)	159.2	163.2	161.7	153.7	157.4		157.3	155.9	153.9	142.9	150.5		145.9
	Margin (dB)	13.2	17.2	15.7	7.8	11.4		11.4	10.0	7.9	-3.0	4.6		
vivo	MIL (dB)	151.9	160.0	154.9	149.6	151.4	155.4	153.2	150.6	148.1	135.0	149.4	146.7	137.8
	Margin (dB)	14.2	22.2	17.2	11.8	13.7	17.6	15.4	12.9	10.3	-2.8	11.6	8.9	
Xiaomi	MIL (dB)	160.8	160.8	160.9	155.4	158.4		158.6	155.9	154.2	143.7	151.6		146.7
	Margin (dB)	14.0	14.0	14.1	8.6	11.6		11.9	9.2	7.5	-3.0	4.9		
Futurewei	MIL (dB)	159.0	161.0	159.3	157.3	158.1					148.6	150.5		151.6
	Margin (dB)	7.3	9.3	7.6	5.6	6.4					-3.0	-1.1		
Nokia	MIL (dB)	162.5	162.5	160.3	161.5	160.3		148.7		147.2	135.6	144.8	147.3	138.6
	Margin (dB)	23.9	23.9	21.7	22.9	21.7		10.1		8.6	-3.0	6.2	8.7	
DOCOMO	MIL (dB)	159.8	163.8	159.9	152.9	156.0		158.1	161.9		142.7	151.6		145.7
	Margin (dB)	14.1	18.1	14.1	7.2	10.3		12.4	16.2		-3.0	5.9		
CMCC	MIL (dB)	157.2	162.8	161.1	154.6	157.4	158.8	153.3	151.5	149.3	136.8	149.8	155.6	139.8

	Margin (dB)	17.4	23.0	21.3	14.8	17.6	19.0	13.5	11.7	9.6	-3.0	10.1	15.9	
Panasonic	MIL (dB)		163.5	154.7										
	Margin (dB)													
Huawei	MIL (dB)	158.0	162.0	156.9	154.6	154.6		157.6		155.3	136.0	146.6		139.0
	Margin (dB)	19.0	23.0	17.9	15.7	15.6		18.6		16.3	-3.0	7.7		
Spreadtrum	MIL (dB)	159.0	163.0	160.9	157.8	157.8	160.3	155.4	153.6	153.2	142.7	147.5	152.8	145.7
	Margin (dB)	13.2	17.2	15.1	12.0	12.0	14.5	9.7	7.9	7.5	-3.0	1.8	7.0	
Apple	MIL (dB)	154.4	162.4	157.4	147.3	150.4				147.8	137.0	141.7		140.0
	Margin (dB)	14.4	22.4	17.4	7.3	10.4				7.8	-3.0	1.8		
Ericsson	MIL (dB)	155.8	155.8	156.5	150.2	152.9	157.8	151.9	152.5	150.6	140.9	148.2	152.1	143.9
	Margin (dB)	11.8	11.8	12.5	6.2	8.9	13.8	8.0	8.6	6.7	-3.0	4.3	8.1	
InterDigital	MIL (dB)	158.77	162.8	160.29	153.87	156.80		157.1		152.8	140.24	149.84		143.24
	Margin (dB)	15.53	19.56	17.05	10.63	13.56		13.86		9.56	-3.0	6.6		
Qualcomm	MIL (dB)	155.8		157.8	152.0	154.3				143.5	136.4	145.2		139.4
	Margin (dB)	16.5		18.4	12.6	14.9				4.2	-3.0	5.9		
Intel	MIL (dB)	159.8	161.0	157.6	160.7	158.0	162.7	159.0	157.8	155.2	140.9	151.6	153.8	143.9
	Margin (dB)	15.8	17.1	13.7	16.7	14.0	18.8	15.1	13.8	11.2	-3.0	7.6	9.8	

Table C.1-3: Link budget performance (MIL) for the RedCap UE (20MHz BW, 1Rx)

Urban 2.6GHz, 1Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	156.6	160.6	151.9	150.6	153.2		155.2	151.6	148.3	136.4	147.0		139.4
	Margin (dB)	17.1	21.1	12.4	11.1	13.7		15.8	12.2	8.9	-3.0	7.6		
ZTE	MIL (dB)	147.8	158.3	160.8	151.0	151.4		159.6	157.9	155.4	139.0	153.5		142.0
	Margin (dB)	5.9	16.3	18.8	9.0	9.4		17.7	15.9	13.4	-3.0	11.5		
OPPO	MIL (dB)	157.2	161.2	162.0	149.2	155.1		151.9	152.0	151.9	141.9	151.7		145.1
	Margin (dB)	12.1	16.1	16.9	4.1	9.9		6.8	6.8	6.7	-3.2	6.6		
CATT	MIL (dB)	155.5	159.5	157.8	147.6	154.0		157.3	155.9	153.9	142.9	150.5		145.9
	Margin (dB)	9.5	13.5	11.9	1.6	8.0		11.4	10.0	7.9	-3.0	4.6		
vivo	MIL (dB)	148.7	156.8	150.6	144.7	146.8	152.3	153.2	150.6	148.1	135.0	149.4	146.7	137.8
	Margin (dB)	10.9	19.0	12.8	6.9	9.0	14.5	15.4	12.9	10.3	-2.8	11.6	8.9	
Xiaomi	MIL (dB)	157.6	157.6	157.3	150.2	154.4		158.6	155.9	154.2	143.7	151.6		146.7
	Margin (dB)	10.9	10.9	10.5	3.4	7.6		11.9	9.2	7.5	-3.0	4.9		
Futurewei	MIL (dB)	156.4	158.4	157.3	154.3	154.9					148.6	150.5		151.6
	Margin (dB)	4.7	6.7	5.6	2.6	3.2					-3.0	-1.1		
Nokia	MIL (dB)	158.5	158.5	156.8	157.8	156.5		148.7		147.2	135.6	144.8	147.3	138.6

	Margin (dB)	19.9	19.9	18.2	19.2	17.9		10.1		8.6	-3.0	6.2	8.7	
DOCOMO	MIL (dB)	156.4	160.4	155.7	147.3	151.9		158.1	161.9		142.7	151.6		145.7
	Margin (dB)	10.7	14.7	10.0	1.5	6.1		12.4	16.2		-3.0	5.9		
CMCC	MIL (dB)							153.3	151.5	149.3	136.8	149.8	155.6	139.8
	Margin (dB)							13.5	11.7	9.6	-3.0	10.1	15.9	
Panasonic	MIL (dB)		160.6	150.9										
	Margin (dB)													
Huawei	MIL (dB)	154.9	158.9	153.1	150.3	150.7		157.6		155.3	136.0	146.6		139.0
	Margin (dB)	15.9	19.9	14.1	11.4	11.7		18.6		16.3	-3.0	7.7		
Spreadtrum	MIL (dB)	156.0	160.0	157.9	154.8	154.8	157.3	155.4	153.6	153.2	142.7	147.5	152.8	145.7
	Margin (dB)	10.2	14.2	12.1	9.0	9.0	11.5	9.7	7.9	7.5	-3.0	1.8	7.0	
Apple	MIL (dB)	151.0	159.0	152.8	141.8	146.1				147.8	137.0	141.7		140.0
	Margin (dB)	11.0	19.0	12.8	1.8	6.1				7.8	-3.0	1.8		
Ericsson	MIL (dB)	152.8	152.8	153.3	145.3	148.9	153.9	151.9	152.5	150.6	140.9	148.2	152.1	143.9
	Margin (dB)	8.8	8.8	9.3	1.3	4.9	9.9	8.0	8.6	6.7	-3.0	4.3	8.1	
InterDigital	MIL (dB)	155.57	159.57	157.22	149.27	153.69		157.1		152.8	140.24	149.84		143.24
	Margin (dB)	12.33	16.33	13.98	6.03	10.45		13.86		9.56	-3.0	6.6		
Qualcomm	MIL (dB)	152.5		154.7	148.1	151.0				143.5	136.4	145.2		139.4
	Margin (dB)	13.2		15.3	8.7	11.6				4.2	-3.0	5.9		
Intel	MIL (dB)							159.0	157.8	155.2	140.9	151.6	153.8	143.9
	Margin (dB)							15.1	13.8	11.2	-3.0	7.6	9.8	

Table C.1-4: MPL (dB) results for Urban 2.6 GHz

Urban 2.6GHz													
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4
Samsung	Reference NR UE	132.1	136.3	132.8	131.5	131.6		124.8	121.0	118.0	108.7	119.3	
	2Rx RedCap	126.3	130.3	125.9	125.0	125.9		121.4	117.8	114.5	105.7	116.3	
	1Rx RedCap	122.8	126.8	121.1	119.8	122.4		121.4	117.8	114.5	105.7	116.3	
ZTE	Reference NR UE	123.2	133.6	136.9	126.9	127.2		128.8	127.1	124.6	111.2	125.8	
	2Rx RedCap							125.8	124.1	121.6	108.2	122.8	
	1Rx RedCap	114.0	124.4	130.0	120.2	120.7		125.8	124.1	121.6	108.2	122.8	
OPPO	Reference NR UE	133.7	137.7	139.2	131.5	134.5		121.2	121.3	121.4	114.4	124.0	
	2Rx RedCap	127.3	131.3	133.9	124.5	128.2		118.1	118.2	118.1	111.2	121.0	
	1Rx RedCap	123.4	127.4	131.3	118.5	124.3		118.1	118.2	118.1	111.2	121.0	
CATT	Reference NR UE	130.9	134.9	136.8	130.7	133.0		126.5	125.1	123.1	115.2	122.8	
	2Rx RedCap	125.4	129.4	130.9	123.0	126.6		123.5	122.1	120.1	112.2	119.8	

	1Rx RedCap	121.7	125.7	127.1	116.8	123.2		123.5	122.1	120.1	112.2	119.8	
vivo	Reference NR UE	123.8	131.8	131.2	126.4	127.9	127.0	122.4	119.8	117.3	107.0	121.8	115.9
	2Rx RedCap	118.1	126.2	124.2	118.9	120.7	121.6	119.4	116.8	114.3	104.2	118.6	112.9
	1Rx RedCap	114.9	123.0	119.9	113.9	116.0	118.5	119.4	116.8	114.3	104.2	118.6	112.9
Xiaomi	Reference NR UE	132.5	132.5	137.6	132.1	134.5		127.8	125.1	123.4	116.0	123.9	
	2Rx RedCap	127.0	127.0	130.1	124.6	127.6		124.8	122.1	120.4	113.0	120.9	
	1Rx RedCap	123.8	123.8	126.5	119.4	123.6		124.8	122.1	120.4	113.0	120.9	
Futurewei	Reference NR UE	131.0	133.0	133.5	132.0	132.4					120.9	122.8	
	2Rx RedCap	125.2	127.2	128.5	126.5	127.3					117.9	119.8	
	1Rx RedCap	122.6	124.6	126.5	123.5	124.1					117.9	119.8	
Nokia	Reference NR UE	134.5	134.5	136.1	136.6	135.1		117.9		116.4	107.9	117.1	119.2
	2Rx RedCap	128.7	128.7	129.6	130.8	129.6		114.9		113.4	104.9	114.1	116.2
	1Rx RedCap	124.7	124.7	126.1	127.1	125.8		114.9		113.4	104.9	114.1	116.2
DOCOMO	Reference NR UE	131.8	135.8	135.4	129.8	131.9		127.3	131.1		115.0	123.9	
	2Rx RedCap	126.0	130.0	129.1	122.2	125.3		124.3	128.1		112.0	120.9	
	1Rx RedCap	122.6	126.6	125.0	116.5	121.2		124.3	128.1		112.0	120.9	
CMCC	Reference NR UE	129.0	134.6	135.9	130.0	132.6	130.0	122.5	120.7	118.5	109.0	122.1	124.8
	2Rx RedCap	123.4	129.0	130.3	123.8	126.6	125.0	119.5	117.7	115.5	106.0	119.1	121.8
	1Rx RedCap							119.5	117.7	115.5	106.0	119.1	121.8
Panasonic	Reference NR UE		135.2	130.2									
	2Rx RedCap		129.7	123.9									
	1Rx RedCap		126.8	120.1									
Huawei	Reference NR UE	133.2	137.2	136.5	133.4	133.2		129.8		127.5	111.2	121.9	
	2Rx RedCap	127.1	131.1	129.2	126.9	126.9		126.8		124.5	108.2	118.9	
	1Rx RedCap	124.1	128.1	125.3	122.6	123.0		126.8		124.5	108.2	118.9	
Spreadtrum	Reference NR UE	131.2	135.2	136.1	133.0	133.0	135.5	124.6	122.8	122.4	115.0	122.8	122.0
	2Rx RedCap	125.2	129.2	130.1	127.0	127.0	129.5	121.6	119.8	119.4	112.0	116.8	119.0
	1Rx RedCap	122.2	126.2	127.1	124.0	124.0	126.5	121.6	119.8	119.4	112.0	116.8	119.0
Apple	Reference NR UE	126.7	134.7	133.1	123.0	126.2				117.0	109.2	114.0	
	2Rx RedCap	120.6	128.6	126.6	116.5	119.6				114.0	106.2	111.0	
	1Rx RedCap	117.2	125.2	122.0	111.0	115.3				114.0	106.2	111.0	
Ericsson	Reference NR UE	128.2	128.2	131.7	126.1	128.6	133.0	121.0	121.7	119.7	113.2	120.5	121.3
	2Rx RedCap	122.0	122.0	125.7	119.4	122.1	127.0	118.1	118.7	116.8	110.2	117.5	118.3
	1Rx RedCap	119.0	119.0	122.5	114.5	118.1	123.1	118.1	118.7	116.8	110.2	117.5	118.3
InterDigital	Reference NR UE	130.7	134.7	135.4	129.7	131.8		126.8		122.6	112.5	122.1	
	2Rx RedCap	125.0	129.0	129.6	123.1	126.1		123.3		119.0	109.5	119.1	

	1Rx RedCap	121.8	125.8	126.5	118.5	123.0		123.3		119.0	109.5	119.1	
Qualcomm	Reference NR UE	127.5		132.6	127.5	129.0				112.7	108.6	117.5	
	2Rx RedCap	122.0		127.0	121.2	123.5				109.7	105.6	114.5	
	1Rx RedCap	118.7		123.9	117.3	120.2				109.7	105.6	114.5	
Intel	Reference NR UE	131.9	133.1	132.8	135.7	133.4	135.0	128.2	127.0	124.4	113.2	123.8	123.0
	2Rx RedCap	126.0	127.2	126.9	130.0	127.3	132.0	125.2	124.0	121.4	110.2	120.8	120.0
	1Rx RedCap							125.2	124.0	121.4	110.2	120.8	120.0

C.2 Rural scenario at 0.7 GHz

Link budget evaluation results for the Rural scenario at 0.7 GHz from all the sourcing companies are captured in Tables C.2-1, C.2-2, C.2-3, and C.2-4. Tables C.2-1, C.2-2, and C.2-3 show the MIL results for reference NR UEs with 2 Rx branches (100MHz bandwidth), RedCap UEs with 2 Rx branches (20MHz bandwidth), and RedCap UEs with 1 Rx branch (20MHz bandwidth), respectively. For every sourcing-company result, the values of the target MIL and the amount of compensation for each channel that has MIL below the target value are highlighted.

Additionally, the MPL results are provided Table C.2-4. The detailed link budget calculations from the sourcing companies can be found in [3].

Table C.2-1: Link budget performance (MIL) for the reference NR UE (20MHz BW, 2Rx)

Rural 700MHz, 2Rx Reference UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH format0	Target /Option3
Samsung	MIL (dB)	162.4	162.4	157.9	157.9	158.9		158.3	154.5	151.5	146.6	149.5		146.6
	Margin (dB)	15.9	15.9	11.4	11.4	12.4		11.7	7.9	4.9	0.0	2.9		
ZTE	MIL (dB)	154.8	158.5	157.4	154.4	154.7		152.6	150.6	147.9	143.6	143.2		143.2
	Margin (dB)	11.6	15.3	14.2	11.2	11.5		9.4	7.4	4.7	0.4	0.0		
OPPO	MIL (dB)	163.1	163.1	162.0	157.0	161.0		149.0	149.1	148.9	150.0	149.5		148.9
	Margin (dB)	14.2	14.2	13.0	8.0	12.1		0.1	0.2	0.0	1.1	0.5		
CATT	MIL (dB)	158.7	158.7	155.9	153.5	156.8		156.7	155.4	153.3	147.9	150.7		147.9
	Margin (dB)	10.7	10.7	8.0	5.6	8.9		8.7	7.5	5.4	0.0	2.7		
vivo	MIL (dB)	155.0	155.1	152.0	149.8	152.7	159.2	150.3	147.4	145.0	144.0	146.3	145.7	144.0
	Margin (dB)	11.0	11.1	8.0	5.8	8.8	15.2	6.3	3.5	1.1	0.0	2.3	1.7	
Xiaomi	MIL (dB)	160.0	160.0	157.6	154.9	158.1		158.0	155.4	152.9	149.7	150.9		149.7
	Margin (dB)	10.3	10.3	7.9	5.2	8.4		8.3	5.7	3.2	0.0	1.2		
Futurewei	MIL (dB)	161.1	161.1	158.1	157.9	159.1					150.8	153.0		150.8
	Margin (dB)	10.4	10.4	7.4	7.2	8.4					0.0	2.2		
Nokia	MIL (dB)	158.0	158.0	159.5	156.7	159.4		144.9		143.7	144.2	138.5	147.9	138.5
	Margin (dB)	19.5	19.5	21.0	18.1	20.9		6.4		5.2	5.6	0.0	9.4	
DOCOMO	MIL (dB)	162.5	162.5	158.1	155.1	158.1		155.9	161.2		146.7	149.5		146.7

	Margin (dB)	15.8	15.8	11.4	8.4	11.4		9.2	14.6		0.0	2.8		
Panasonic	MIL (dB)		161.8	151.8				152.6	150.2	146.2	141.8	144.6		141.8
	Margin (dB)		20.0	10.0				10.8	8.4	4.4	0.0	2.8		
Huawei	MIL (dB)	157.2	157.2	152.9	152.9	153.6		152.8		150.6	141.8	145.3		141.8
	Margin (dB)	15.5	15.5	11.1	11.1	11.8		11.0		8.8	0.0	3.5		
Spreadtrum	MIL (dB)	161.0	161.0	159.0	160.0	160.0	163.0	160.5	157.5	157.3	151.5	154.5	156.8	151.5
	Margin (dB)	9.6	9.6	7.6	8.6	8.6	11.6	9.0	6.0	5.8	0.0	3.0	5.4	
Apple	MIL (dB)	157.7	157.7	155.9	151.5	155.7					143.7			143.7
	Margin (dB)	14.0	14.0	12.2	7.8	12.0					0.0			
Ericsson	MIL (dB)	157.3	156.6	155.6	153.2	155.9	157.3	149.4	157.9	147.4	142.9	145.0	147.9	142.9
	Margin (dB)	14.5	13.8	12.8	10.4	13.1	14.5	6.5	15.0	4.5	0.0	2.1	5.1	
InterDigital	MIL (dB)	161.2	161.2	158.5	152.31	155.16		155.8		150.8	146.7	144.44		144.44
	Margin (dB)	16.76	16.76	14.06	7.87	10.72		11.36		6.36	2.26	0.0		
Qualcomm	MIL (dB)	158.4		154.5	152.9	154.9				143.8	141.3	143.8		141.3
	Margin (dB)	17.1		13.2	11.6	13.6				2.5	0.0	2.5		
Intel	MIL (dB)	161.6	161.6	158.3	162.7	160.1	160.4	154.4	154.7	152.0	146.7	149.6	152.3	146.7
	Margin (dB)	14.9	14.9	11.6	16.0	13.4	13.7	7.7	8.0	5.3	0.0	2.8	5.6	

Table C.2-2: Link budget performance (MIL) for the RedCap UE (20MHz BW, 2Rx)

Rural 700MHz, 2Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH format0	Target /Option3
Samsung	MIL (dB)	159.4	159.4	154.9	154.9	155.9		155.3	151.5	148.5	143.6	146.5		146.6
	Margin (dB)	12.9	12.9	8.4	8.4	9.4		8.7	4.9	1.9	-3.0	-0.1		
ZTE	MIL (dB)							149.6	147.6	144.9	140.6	140.2		143.2
	Margin (dB)							6.4	4.4	1.7	-2.6	-3.0		
OPPO	MIL (dB)	160.1	160.1	159.0	154.0	158.0		146.0	146.1	145.9	147.0	146.5		148.9
	Margin (dB)	11.2	11.2	10.0	5.0	9.1		-2.9	-2.8	-3.0	-1.9	-2.5		
CATT	MIL (dB)	155.4	155.4	152.8	150.5	153.8		153.6	152.4	150.3	144.9	147.7		147.9
	Margin (dB)	7.5	7.5	4.9	2.6	5.9		5.6	4.5	2.4	-3.1	-0.3		
vivo	MIL (dB)	152.0	152.1	149.0	146.8	149.7	156.2	147.3	144.4	142.0	141.0	143.3	142.7	144.0
	Margin (dB)	8.0	8.1	5.0	2.8	5.8	12.2	3.3	0.5	-1.9	-3.0	-0.7	-1.3	
Xiaomi	MIL (dB)	157.0	157.0	154.6	151.9	155.1		155.0	152.4	149.9	146.7	147.9		149.7
	Margin (dB)	7.3	7.3	4.9	2.2	5.4		5.3	2.7	0.2	-3.0	-1.8		
Futurewei	MIL (dB)	158.1	158.1	155.1	154.9	156.1					147.8	150.0		150.8
	Margin (dB)	7.4	7.4	4.4	4.2	5.4					-3.0	-0.8		
Nokia	MIL (dB)	155.0	155.0	156.5	153.7	156.4		141.9		140.7	141.2	135.5	144.9	138.5

	Margin (dB)	16.5	16.5	18.0	15.1	17.9		3.4		2.2	2.6	-3.0	6.4	
DOCOMO	MIL (dB)							152.9	158.2		143.7	146.5		146.7
	Margin (dB)							6.2	11.6		-3.0	-0.2		
Panasonic	MIL (dB)		158.8	148.8				149.6	147.2	143.2	138.8	141.6		141.8
	Margin (dB)		17.0	7.0				7.8	5.4	1.4	-3.0	-0.2		
Huawei	MIL (dB)	154.2	154.2	149.9	149.9	150.6		149.8		147.6	138.8	142.3		141.8
	Margin (dB)	12.5	12.5	8.1	8.1	8.8		8.0		5.8	-3.0	0.5		
Spreadtrum	MIL (dB)	158.0	158.0	156.0	157.0	157.0	160.0	157.5	154.5	154.3	148.5	151.5	153.8	151.5
	Margin (dB)	6.6	6.6	4.6	5.6	5.6	8.6	6.0	3.0	2.8	-3.0	0.0	2.4	
Apple	MIL (dB)	154.7	154.7	152.9	148.5	152.7					140.7			143.7
	Margin (dB)	11.0	11.0	9.2	4.8	9.0					-3.0			
Ericsson	MIL (dB)	154.3	153.6	149.0	150.2	152.9	154.3	146.4	154.9	144.4	139.9	142.0	144.9	142.9
	Margin (dB)	11.5	10.8	6.2	7.4	10.1	11.5	3.5	12.0	1.5	-3.0	-0.9	2.1	
InterDigital	MIL (dB)	158.2	158.2	155.52	149.31	152.16		152.8		147.8	143.7	141.44		144.44
	Margin (dB)	13.76	13.76	11.08	4.87	7.72		8.36		3.36	-0.74	-3.0		
Qualcomm	MIL (dB)	155.4		151.5	149.9	151.9				140.8	138.3	140.8		141.3
	Margin (dB)	14.1		10.2	8.6	10.6				-0.5	-3.0	-0.5		
Intel	MIL (dB)							151.4	151.7	149.0	143.7	146.6	149.3	146.7
	Margin (dB)							4.7	5.0	2.3	-3.0	-0.2	2.6	

Table C.2-3: Link budget performance (MIL) for the RedCap UE (20MHz BW, 1Rx)

Rural 700MHz, 1Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH format0	Target /Option3
Samsung	MIL (dB)	155.7	155.7	150.6	149.0	152.2		155.3	151.5	148.5	143.6	146.5		146.6
	Margin (dB)	9.2	9.2	4.1	2.5	5.7		8.7	4.9	1.9	-3.0	-0.1		
ZTE	MIL (dB)	148.3	152.0	149.7	146.5	146.7		149.6	147.6	144.9	140.6	140.2		143.2
	Margin (dB)	5.1	8.8	6.5	3.3	3.5		6.4	4.4	1.7	-2.6	-3.0		
OPPO	MIL (dB)	155.5	155.5	155.4	148.6	153.8		146.0	146.1	145.9	147.0	146.5		148.9
	Margin (dB)	6.6	6.6	6.5	-0.4	4.8		-2.9	-2.8	-3.0	-1.9	-2.5		
CATT	MIL (dB)	152.0	152.0	149.6	144.1	149.5		153.6	152.4	150.3	144.9	147.7		147.9
	Margin (dB)	4.0	4.0	1.7	-3.9	1.5		5.6	4.5	2.4	-3.1	-0.3		
vivo	MIL (dB)	149.3	149.3	145.5	141.5	145.7	152.4	147.3	144.4	142.0	141.0	143.3	142.7	144.0
	Margin (dB)	5.3	5.3	1.5	-2.5	1.8	8.4	3.3	0.5	-1.9	-3.0	-0.7	-1.3	
Xiaomi	MIL (dB)	153.6	153.6	150.5	146.2	150.6		155.0	152.4	149.9	146.7	147.9		149.7
	Margin (dB)	3.9	3.9	0.8	-3.5	0.9		5.3	2.7	0.2	-3.0	-1.8		
Futurewei	MIL (dB)	154.2	154.2	150.9	149.0	153.1					147.8	150.0		150.8

	Margin (dB)	3.5	3.5	0.1	-1.7	2.4					-3.0	-0.8		
Nokia	MIL (dB)	150.7	150.7	153.9	150.0	153.4		141.9		140.7	141.2	135.5	144.9	138.5
	Margin (dB)	12.2	12.2	15.4	11.5	14.9		3.4		2.2	2.6	-3.0	6.4	
DOCOMO	MIL (dB)	156.2	156.2	150.9	145.8	150.8		152.9	158.2		143.7	146.5		146.7
	Margin (dB)	9.5	9.5	4.2	-0.9	4.1		6.2	11.6		-3.0	-0.2		
Panasonic	MIL (dB)		155.9	145.1				149.6	147.2	143.2	138.8	141.6		141.8
	Margin (dB)		14.1	3.3				7.8	5.4	1.4	-3.0	-0.2		
Huawei	MIL (dB)	150.9	150.9	146.2	145.6	146.6		149.8		147.6	138.8	142.3		141.8
	Margin (dB)	9.1	9.1	4.4	3.8	4.8		8.0		5.8	-3.0	0.5		
Spreadtrum	MIL (dB)	155.0	155.0	153.0	154.0	153.0	157.0	157.5	154.5	154.3	148.5	151.5	153.8	151.5
	Margin (dB)	3.6	3.6	1.6	2.6	1.6	5.6	6.0	3.0	2.8	-3.0	0.0	2.4	
Apple	MIL (dB)	151.7	151.7	148.8	144.0	148.0					140.7			143.7
	Margin (dB)	8.0	8.0	5.1	0.3	4.3					-3.0			
Ericsson	MIL (dB)	149.9	150.1	149.0	146.1	149.2	149.9	146.4	154.9	144.4	139.9	142.0	144.9	142.9
	Margin (dB)	7.1	7.3	6.2	3.3	6.4	7.1	3.5	12.0	1.5	-3.0	-0.9	2.1	
InterDigital	MIL (dB)	154.4	154.4	151.87	143.79	148.53		152.8		147.8	143.7	141.44		144.44
	Margin (dB)	9.96	9.96	7.43	-0.65	4.09		8.36		3.36	-0.74	-3.0		
Qualcomm	MIL (dB)	151.6		148.1	145.4	148.5				140.8	138.3	140.8		141.3
	Margin (dB)	10.3		6.8	4.1	7.2				-0.5	-3.0	-0.5		
Intel	MIL (dB)	154.6	154.6	151.9	156.4	153.6	157.4	151.4	151.7	149.0	143.7	146.6	149.3	146.7
	Margin (dB)	7.9	7.9	5.2	9.7	6.9	10.7	4.7	5.0	2.3	-3.0	-0.2	2.6	

Table C.2-4: MPL (dB) results for Rural 700MHz

Rural 700MHz													
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH Format 0
Samsung	Reference NR UE	141.5	141.5	140.3	140.3	141.3		137.3	133.5	130.5	128.9	131.8	
	2Rx RedCap	138.5	138.5	137.3	137.3	138.3		134.3	130.5	127.5	125.9	128.8	
	1Rx RedCap	134.8	134.8	133.0	131.4	134.6		134.3	130.5	127.5	125.9	128.8	
ZTE	Reference NR UE	133.9	137.6	139.7	136.8	137.1		131.7	129.6	126.9	125.9	125.6	
	2Rx RedCap							128.7	126.6	123.9	122.9	122.6	
	1Rx RedCap	127.3	131.0	132.1	128.9	129.1		128.7	126.6	123.9	122.9	122.6	
OPPO	Reference NR UE	142.2	142.2	144.4	139.3	143.4		128.1	128.2	128.0	132.4	131.9	
	2Rx RedCap	139.2	139.2	141.4	136.3	140.4		125.1	125.2	125.0	129.4	128.9	
	1Rx RedCap	134.6	134.6	137.8	130.9	136.2		125.1	125.2	125.0	129.4	128.9	
CATT	Reference NR UE	137.7	137.7	138.3	135.9	139.2		135.7	134.4	132.3	130.3	133.0	
	2Rx RedCap	134.4	134.4	135.2	132.9	136.2		132.6	131.4	129.3	127.2	130.0	

	1Rx RedCap	131.0	131.0	132.0	126.4	131.9		132.6	131.4	129.3	127.2	130.0	
	Reference NR UE	134.0	134.2	134.4	132.2	135.1	138.2	129.3	126.5	124.1	126.3	128.7	124.7
vivo	2Rx RedCap	131.0	131.2	131.4	129.2	132.1	135.2	126.3	123.5	121.1	123.3	125.7	121.7
	1Rx RedCap	128.4	128.4	127.9	123.8	128.1	131.5	126.3	123.5	121.1	123.3	125.7	121.7
	Reference NR UE	139.1	139.1	140.0	137.3	140.5		137.0	134.4	132.0	132.1	133.3	
Xiaomi	2Rx RedCap	136.1	136.1	137.0	134.3	137.5		134.0	131.4	129.0	129.1	130.3	
	1Rx RedCap	132.7	132.7	132.9	128.6	133.0		134.0	131.4	129.0	129.1	130.3	
	Reference NR UE	140.2	140.2	140.5	140.3	141.5					133.1	135.3	
Futurewei	2Rx RedCap	137.2	137.2	137.5	137.3	138.5					130.1	132.3	
	1Rx RedCap	133.3	133.3	133.3	131.4	135.5					130.1	132.3	
	Reference NR UE	135.5	135.5	140.7	137.8	140.6		122.4		121.1	125.3	119.7	129.0
Nokia	2Rx RedCap	132.5	132.5	137.7	134.8	137.6		119.4		118.1	122.3	116.7	126.0
	1Rx RedCap	128.2	128.2	135.1	131.2	134.6		119.4		118.1	122.3	116.7	126.0
	Reference NR UE	141.5	141.5	140.5	137.4	140.5		135.0	140.3		129.1	131.9	
DOCOMO	2Rx RedCap							132.0	137.3		126.1	128.9	
	1Rx RedCap	135.2	135.2	133.3	128.2	133.2		132.0	137.3		126.1	128.9	
	Reference NR UE		140.9	134.2				131.7	129.3	125.3	124.2	127.0	
Panasonic	2Rx RedCap		137.9	131.2				128.7	126.3	122.3	121.2	124.0	
	1Rx RedCap		135.0	127.5				128.7	126.3	122.3	121.2	124.0	
	Reference NR UE	136.3	136.3	135.3	135.3	136.0		131.9		129.6	124.2	127.7	
Huawei	2Rx RedCap	133.3	133.3	132.3	132.3	133.0		128.9		126.6	121.2	124.7	
	1Rx RedCap	129.9	129.9	128.6	128.0	129.0		128.9		126.6	121.2	124.7	
	Reference NR UE	140.1	140.1	141.4	142.4	142.4	145.4	139.5	136.5	136.3	133.8	136.8	135.9
Spreadtrum	2Rx RedCap	137.1	137.1	138.4	139.4	139.4	142.4	136.5	133.5	133.3	130.8	133.8	132.9
	1Rx RedCap	134.1	134.1	135.4	136.4	135.4	139.4	136.5	133.5	133.3	130.8	133.8	132.9
	Reference NR UE	136.8	136.8	138.3	133.9	138.1					126.1		
Apple	2Rx RedCap	133.8	133.8	135.3	130.9	135.1					123.1		
	1Rx RedCap	130.8	130.8	131.2	126.4	130.4					123.1		
	Reference NR UE	136.4	135.7	138.0	135.6	138.3	139.7	128.4	136.9	126.4	125.2	127.3	127.0
Ericsson	2Rx RedCap	133.4	132.7	131.4	132.6	135.3	136.7	125.4	133.9	123.4	122.2	124.3	124.0
	1Rx RedCap	129.0	129.2	131.4	128.5	131.6	132.3	125.4	133.9	123.4	122.2	124.3	124.0
	Reference NR UE	140.3	140.3	140.9	134.7	137.5		134.8		129.8	129.1	126.8	
InterDigital	2Rx RedCap	137.3	137.3	137.9	131.7	134.5		131.8		126.8	126.1	123.8	
	1Rx RedCap	133.4	133.4	134.2	126.2	130.9		131.8		126.8	126.1	123.8	
Qualcomm	Reference NR UE	137.5		136.9	135.3	137.3				122.8	123.7	126.2	
	2Rx RedCap	134.5		133.9	132.3	134.3				119.8	120.7	123.2	

	1Rx RedCap	130.7		130.5	127.8	130.9				119.8	120.7	123.2	
Intel	Reference NR UE	140.7	140.7	140.7	145.1	142.5	142.8	133.4	133.7	131.0	129.1	131.9	131.4
	2Rx RedCap							130.4	130.7	128.0	126.1	128.9	128.4
	1Rx RedCap	133.7	133.7	134.3	138.8	136.0	139.8	130.4	130.7	128.0	126.1	128.9	128.4

C.3 Urban scenario at 4 GHz

Link budget evaluation results for the Urban scenario at 4 GHz from all the sourcing companies are captured in Tables C.3-1, C.3-2, C.3-3, and C.3-4. Tables C.3-1, C.3-2, and C.3-3 show the MIL results for reference NR UEs with 4 Rx branches (100MHz bandwidth), RedCap UEs with 2 Rx branches (20MHz bandwidth), and RedCap UEs with 1 Rx branch (20MHz bandwidth), respectively. For every sourcing-company result, the values of the target MIL and the amount of compensation for each channel that has MIL below the target value are highlighted.

Additionally, the MPL results are provided Table C.3-4. The detailed link budget calculations from the sourcing companies can be found in [3].

Table C.3-1: Link budget performance (MIL) for the reference NR UE (100MHz BW, 4Rx)

Urban, 4GHz, 4Rx Ref NR UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	165.9	170.1	162.6	162.3	162.4		158.6	154.8	151.9	142.0	150.0		142.0
	Margin (dB)	23.8	28.0	20.5	20.2	20.3		16.6	12.8	9.9	0.0	8.0		
ZTE	MIL (dB)	147.8	158.2	157.3	148.3	148.6		162.6	160.9	158.3	143.0	156.3		143.0
	Margin (dB)	4.8	15.2	14.3	5.3	5.5		19.6	17.9	15.3	0.0	13.3		
OPPO	MIL (dB)	158.5	162.5	158.9	153.4	156.2		155.0	155.0	155.2	147.0	154.7		147.0
	Margin (dB)	11.4	15.4	11.9	6.4	9.2		8.0	8.0	8.2	0.0	7.7		
vivo	MIL (dB)	157.7	165.7	161.9	157.1	158.6	160.8	156.3	153.8	151.0	139.3	152.3	149.6	139.3
	Margin (dB)	18.4	26.4	22.6	17.8	19.3		17.0	14.5	11.8	0.0	13.0	10.3	
Futurewei	MIL (dB)	155.9	157.9	156.0	153.0	155.1					152.6	153.5		152.6
	Margin (dB)	3.2	5.2	3.3	0.3	2.4		-152.6	-152.6	-152.6	0.0	0.9		
Nokia	MIL (dB)	168.4	168.4	165.3	168.8	165.9		151.7		150.2	140.8	147.3	155.1	140.8
	Margin (dB)	27.6	27.6	24.5	28.0	25.1		10.9	-140.8	9.4	0.0	6.5	14.3	
DOCOMO	MIL (dB)	156.8	160.8	157.5	151.5	153.6		161.2	164.8		146.8	154.6		146.8
	Margin (dB)	10.0	14.0	10.7	4.7	6.8		14.5	18.1	-146.8	0.0	7.9		
Huawei	MIL (dB)	164.0	168.0	164.2	161.1	160.9		160.5		158.8	140.0	149.7		140.0
	Margin (dB)	24.0	28.0	24.2	21.1	20.8		20.5	-140.0	18.7	0.0	9.6		
Spreadtrum	MIL (dB)	155.8	160.0	157.8	154.8	154.8	157.8	158.2	156.2	158.0	145.4	153.5	155.6	145.4
	Margin (dB)	10.3	14.5	12.3	9.3	9.3		12.8	10.8	12.6	0.0	8.1	10.1	
Ericsson	MIL (dB)	149.0	153.0	149.7	143.6	146.5	150.9	153.6	155.5	153.6	144.0	151.3	154.9	143.6
	Margin (dB)	5.4	9.4	6.1	0.0	2.9		10.0	12.0	10.1	0.5	7.7	11.3	

InterDigital	MIL (dB)	155.47	159.5	157.13	160.42	162.55		160.6		156.6	144.9	152.87		144.9
	Margin (dB)	10.57	14.6	12.23	15.52	17.65		15.7		11.7	0.0	7.97		
Qualcomm	MIL (dB)	152.3		151.3	147.1	148.6				146.5	140.7	154.1		140.7
	Margin (dB)	11.6	-140.7	10.6	6.4	7.9				5.8	0.0	13.4		
Intel	MIL (dB)	156.3	157.4	152.7	157.0	154.7	156.3	161.5	160.3	157.7	140.0	147.0	156.3	140.0
	Margin (dB)	16.3	17.4	12.7	17.0	14.7		21.5	20.3	17.7	0.0	7.0	16.3	
Lenovo, Motorola Mobility	MIL (dB)	157.8		152.5	153.1	156.0		163.0	158.2	154.0	148.3	154.2		148.3
	Margin (dB)	9.5		4.2	4.8	7.7		14.7	9.9	5.7	0	5.9		

Note: 4 sources (Samsung, vivo, Nokia, Huawei) assume DL PSD 33 dBm/MHz and other sources use DL PSD 24 dBm/MHz.

Table C.3-2: Link budget performance (MIL) for the RedCap UE (20MHz BW, 2Rx)

Urban, 4GHz, 2Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	160.1	164.1	156.9	155.8	156.8		155.3	151.5	148.5	139.0	147.0		142.0
	Margin (dB)	18.0	22.0	14.8	13.7	14.7		13.3	9.5	6.5	-3.0	5.0		
OPPO	MIL (dB)	152.2	156.2	154.5	146.3	150.0		151.9	152.0	151.9	144.0	151.7		147.0
	Margin (dB)	5.1	9.1	7.5	-0.7	3.0		4.9	5.0	4.9	-3.0	4.7		
vivo	MIL (dB)	152.0	160.0	155.2	149.6	151.5	155.3	153.3	150.8	148.0	136.4	149.6	146.6	139.3
	Margin (dB)	12.7	20.7	16.0	10.3	12.3	16.0	14.0	11.5	8.8	-2.8	10.3	7.3	
Futurewei	MIL (dB)	150.3	152.3	150.1	146.3	149.1					149.6	150.5		152.6
	Margin (dB)	-2.4	-0.4	-2.6	-6.4	-3.6					-3.0	-2.1		
Nokia	MIL (dB)	162.5	162.5	158.6	163.4	160.0		148.7		147.2	137.8	144.3	152.1	140.8
	Margin (dB)	21.7	21.7	17.8	22.6	19.2		7.9		6.4	-3.0	3.5	11.3	
DOCOMO	MIL (dB)	150.9	154.9	150.8	143.9	147.0		158.2	161.8		143.8	151.6		146.8
	Margin (dB)	4.1	8.1	4.0	-2.8	0.2		11.5	15.1		-3.0	4.9		
Huawei	MIL (dB)	158.0	162.0	156.9	154.7	154.6		157.5		155.8	137.0	146.7		140.0
	Margin (dB)	18.0	22.0	16.9	14.6	14.6		17.5		15.7	-3.0	6.6		
Spreadtrum	MIL (dB)	149.8	154.0	151.8	148.8	148.8	151.8	155.2	153.2	155.0	142.4	150.5	152.6	145.4
	Margin (dB)	4.3	8.5	6.3	3.3	3.3	6.3	9.8	7.8	9.6	-3.0	5.1	7.1	
Ericsson	MIL (dB)	142.8	146.8	143.5	137.2	139.9	145.0	150.6	152.5	150.6	141.0	148.3	151.9	143.6
	Margin (dB)	-0.8	3.2	-0.1	-6.4	-3.7	1.4	7.0	9.0	7.1	-2.5	4.7	8.3	
InterDigital	MIL (dB)	149.77	153.8	151.30	153.83	156.80		157.1		152.8	141.9	149.87		144.9
	Margin (dB)	4.87	8.9	6.4	8.93	11.9		12.2		7.9	-3.0	4.97		
Qualcomm	MIL (dB)	146.8		145.6	140.8	143.1				143.5	137.0	144.0		140.7
	Margin (dB)	6.1		4.9	0.1	2.4				2.8	-3.7	3.3		
Intel	MIL (dB)	150.4	151.5	146.5	151.4	148.6	153.3	158.5	157.3	154.7	137.7	151.1	153.3	140.0

	Margin (dB)	10.4	11.5	6.5	11.4	8.6	13.3	18.5	17.3	14.7	-2.3	11.2	13.3	

Note: 4 sources (Samsung, vivo, Nokia, Huawei) assume DL PSD 33 dBm/MHz and other sources use DL PSD 24 dBm/MHz

Table C.3-3: Link budget performance (MIL) for the RedCap UE (20MHz BW, 1Rx)

Urban, 4GHz, 1Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	156.6	160.6	152.2	150.6	153.2		155.3	151.5	148.5	139.0	147.0		142.0
	Margin (dB)	14.5	18.5	10.1	8.5	11.1		13.3	9.5	6.5	-3.0	5.0		
ZTE	MIL (dB)	138.6	149.0	151.6	141.7	141.9		159.6	157.9	155.3	140.0	153.3		143.0
	Margin (dB)	-4.5	6.0	8.6	-1.3	-1.1		16.6	14.9	12.3	-3.0	10.3		
OPPO	MIL (dB)	148.2	152.2	151.9	140.8	146.2		151.9	152.0	151.9	144.0	151.7		147.0
	Margin (dB)	1.2	5.2	4.9	-6.2	-0.8		4.9	5.0	4.9	-3.0	4.7		
vivo	MIL (dB)	148.8	156.8	150.6	144.8	146.8	152.6	153.3	150.8	148.0	136.4	149.6	146.6	139.3
	Margin (dB)	9.6	17.6	11.4	5.6	7.5	13.4	14.0	11.5	8.8	-2.8	10.3	7.3	
Futurewei	MIL (dB)	146.7	148.7	145.3	139.3	143.0					149.6	150.5		152.6
	Margin (dB)	-6.0	-4.0	-7.4	-13.4	-9.7					-3.0	-2.1		
Nokia	MIL (dB)	158.5	158.5	154.8	159.6	156.5		148.7		147.2	137.8	144.3	152.1	140.8
	Margin (dB)	17.7	17.7	14.0	18.8	15.7		7.9		6.4	-3.0	3.5	11.3	
DOCOMO	MIL (dB)	147.6	151.6	146.8	138.3	142.9		158.2	161.8		143.8	151.6		146.8
	Margin (dB)	0.8	4.8	0.0	-8.5	-3.9		11.5	15.1		-3.0	4.9		
Huawei	MIL (dB)	154.5	158.5	153.1	150.4	150.8		157.5		155.8	137.0	146.7		140.0
	Margin (dB)	14.5	18.5	13.0	10.3	10.7		17.5		15.7	-3.0	6.6		
Spreadtrum	MIL (dB)	146.8	151.0	148.8	145.8	145.8	148.8	155.2	153.2	155.0	142.4	150.5	152.6	145.4
	Margin (dB)	1.3	5.5	3.3	0.3	0.3	3.3	9.8	7.8	9.6	-3.0	5.1	7.1	
Ericsson	MIL (dB)	139.7	143.8	139.8	132.4	136.0	141.4	150.6	152.5	150.6	141.0	148.3	151.9	143.6
	Margin (dB)	-3.9	0.2	-3.8	-11.2	-7.6	-2.2	7.0	9.0	7.1	-2.5	4.7	8.3	
InterDigital	MIL (dB)	146.57	150.6	148.23	149.29	153.67		157.1		152.8	141.9	149.87		144.9
	Margin (dB)	1.67	5.7	3.33	4.39	8.77		12.2		7.9	-3.0	4.97		
Qualcomm	MIL (dB)	143.5		142.4	136.9	139.8				143.5	137.0	144.0		140.7
	Margin (dB)	2.8		1.7	-3.8	-0.9				2.8	-3.7	3.3		
Lenovo, Motorola Mobility	MIL (dB)	146.3		145.7	140.2	145.4		160.0	155.2	154.0	145.3	151.2		148.3
	Margin (dB)	-2.0		-2.6	-8.1	-2.9		11.7	6.9	5.7	-3.0	2.9		

Note: 4 sources (Samsung, vivo, Nokia, Huawei) assume DL PSD 33 dBm/MHz and other sources use DL PSD 24 dBm/MHz

Table C.3-4: MPL (dB) results for Urban 4 GHz

Urban 2.6GHz													
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4
Samsung	Reference NR UE	132.1	136.3	131.8	131.5	131.6		124.8	121.0	118.1	111.3	119.3	
	2Rx RedCap	126.3	130.3	126.1	125.0	126.0		121.5	117.7	114.7	108.3	116.3	
	1Rx RedCap	122.8	126.8	121.4	119.8	122.4		121.5	117.7	114.7	108.3	116.3	
ZTE	Reference NR UE	114.0	124.4	126.6	117.6	117.8		128.8	127.1	124.5	112.3	125.6	
	2Rx RedCap							125.8	124.1	121.5	109.3	122.6	
	1Rx RedCap	104.8	115.2	120.9	111.0	111.2		125.8	124.1	121.5	109.3	122.6	
OPPO	Reference NR UE	124.6	128.6	128.1	122.7	125.5		121.2	121.2	121.4	116.3	124.0	
	2Rx RedCap	118.3	122.3	123.8	115.6	119.2		118.1	118.2	118.1	113.2	121.0	
	1Rx RedCap	114.4	118.4	121.2	110.1	115.5		118.1	118.2	118.1	113.2	121.0	
vivo	Reference NR UE	123.9	131.9	131.1	126.4	127.9	127.0	122.5	120.0	117.2	108.5	121.6	115.8
	2Rx RedCap	118.2	126.2	124.5	118.9	120.8	121.5	119.5	117.0	114.2	105.7	118.8	112.8
	1Rx RedCap	115.0	123.0	119.9	114.1	116.1	118.8	119.5	117.0	114.2	105.7	118.8	112.8
Futurewei	Reference NR UE	122.1	124.1	125.2	122.2	124.3					121.9	122.8	
	2Rx RedCap	116.5	118.5	119.3	115.5	118.3					118.9	119.8	
	1Rx RedCap	112.9	114.9	114.5	108.5	112.2					118.9	119.8	
Nokia	Reference NR UE	134.6	134.6	134.6	138.1	135.2		117.9		116.4	110.1	116.6	124.3
	2Rx RedCap	128.7	128.7	127.9	132.7	129.3		114.9		113.4	107.1	113.6	121.3
	1Rx RedCap	124.7	124.7	124.1	128.9	125.8		114.9		113.4	107.1	113.6	121.3
DOCOMO	Reference NR UE	123.0	127.0	126.8	120.7	122.9		127.4	131.0		116.0	123.9	
	2Rx RedCap	117.0	121.0	120.1	113.2	116.3		124.4	128.0		113.0	120.9	
	1Rx RedCap	113.8	117.8	116.0	107.5	112.2		124.4	128.0		113.0	120.9	
Huawei	Reference NR UE	130.2	134.2	133.5	130.4	130.2		126.7		124.9	109.3	118.9	
	2Rx RedCap	124.2	128.2	126.2	123.9	123.9		123.7		121.9	106.3	115.9	
	1Rx RedCap	120.7	124.7	122.3	119.6	120.0		123.7		121.9	106.3	115.9	
Spreadtrum	Reference NR UE	122.0	126.2	127.0	124.0	124.0	127.0	124.4	122.4	124.2	114.7	122.8	121.8
	2Rx RedCap	116.0	120.2	121.0	118.0	118.0	121.0	121.4	119.4	121.2	111.7	119.8	118.8
	1Rx RedCap	113.0	117.2	118.0	115.0	115.0	118.0	121.4	119.4	121.2	111.7	119.8	118.8
Ericsson	Reference NR UE	115.2	119.2	118.9	112.8	115.7	120.1	119.8	121.7	119.8	113.3	120.6	121.1
	2Rx RedCap	109.0	113.0	112.7	106.4	109.1	114.2	116.8	118.7	116.8	110.3	117.6	118.1
	1Rx RedCap	105.9	110.0	109.0	101.6	105.2	110.6	116.8	118.7	116.8	110.3	117.6	118.1
InterDigital	Reference NR UE	121.7	125.7	126.4	129.7	131.8		126.8		122.8	114.2	122.1	
	2Rx RedCap	116.0	120.0	120.6	123.1	126.1		123.3		119.0	111.2	119.1	
	1Rx RedCap	112.8	116.8	117.5	118.6	122.9		123.3		119.0	111.2	119.1	

Qualcomm	Reference NR UE	118.5		120.6	116.4	117.9				112.7	109.3	123.4	
	2Rx RedCap	113.0		114.9	110.1	112.4				109.7	106.3	120.4	
	1Rx RedCap	109.7		111.7	106.2	109.1				109.7	106.3	120.4	
Intel	Reference NR UE	122.5	123.6	122.0	126.2	123.9	125.6	127.7	126.5	123.9	110.0	123.4	122.5
	2Rx RedCap	116.6	117.7	115.8	120.6	117.8	122.6	124.7	123.5	120.9	107.0	120.4	119.5

Note: 4 sources (Samsung, vivo, Nokia, Huawei) assume DL PSD 33 dBm/MHz and other sources use DL PSD 24 dBm/MHz

C.4 Indoor scenario at 28 GHz

Link budget evaluation results for the Indoor scenario at 28 GHz from all the sourcing companies are captured in Tables C.4-1, C.4-2, C.4-3, C.4-4, and C.4-5. Tables C.4-1, C.4-2, C.4-3, and C.4-4 show the MIL results for reference NR UEs with 2 Rx branches (100MHz bandwidth), RedCap UEs with 1 Rx branch (100MHz bandwidth), RedCap UEs with 2 Rx branches (50MHz bandwidth), and RedCap UEs with 1 Rx branch (50MHz bandwidth), respectively. For every sourcing-company result, the values of the target MIL and the amount of compensation for each channel that has MIL below the target value are highlighted.

Additionally, the MPL results are provided Table C.4-5. The detailed link budget calculations from the sourcing companies can be found in [3].

Table C.4-1: Link budget performance (MIL) for the reference NR UE

Indoor, 28GHz, 100MHz, 2Rx Ref NR UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	146.5	146.5	141.3	145.1	142.5		157.8	153.8	150.9	133.3	149.4		133.3
	Margin (dB)	13.2	13.2	8.0	11.8	9.2		24.5	20.5	17.6	0.0	16.1		
ZTE	MIL (dB)	139.8	140.5	134.5	139.0	139.3		157.5	153.1	152.3	134.3	152.3		134.3
	Margin (dB)	5.5	6.2	0.2	4.6	4.9		23.1	18.8	18.0	0.0	18.0		
OPPO	MIL (dB)	145.9	145.9	142.9	144.6	144.2		160.0	159.7	160.0	141.9	160.2		141.9
	Margin (dB)	4.0	4.0	1.0	2.8	2.3		18.2	17.8	18.1	0.0	18.4		
vivo	MIL (dB)	135.5	140.5	136.0	133.7	135.1	139.8	153.9	152.3	149.0	131.4	142.8	142.6	131.4
	Margin (dB)	4.1	9.1	4.6	2.3	3.8	8.4	22.6	20.9	17.6	0.0	11.4	11.2	
Nokia	MIL (dB)	142.5	142.5	139.3	144.9	144.1		160.5		158.9	144.9	153.1	157.5	139.3
	Margin (dB)	3.3	3.3	0.0	5.6	4.8		21.2		19.6	5.6	13.8	18.2	
DOCOMO	MIL (dB)	148.6	148.6	143.0	143.3	142.0		158.6	164.0		147.3	160.3		142.0
	Margin (dB)	6.6	6.6	1.0	1.3	0.0		16.6	22.0		5.4	18.3		
Ericsson	MIL (dB)	132.1	133.1	128.4	128.2	128.0	134.3	150.5	150.9	148.4	138.7	146.3	149.1	128.0
	Margin (dB)	4.1	5.1	0.4	0.2	0.0	6.3	22.5	22.9	20.4	10.7	18.3	21.1	
InterDigital	MIL (dB)	147.3	147.3	142.67	143.32	142.47		166.3		160.7	143.4	159.35		142.47
	Margin (dB)	4.8	4.8	0.2	0.85	0.0		23.83		18.2	0.9	16.88		
Qualcomm	MIL (dB)	143.4	149.4	141.9	143.9	147.3	153.0	170.8	164.7	162.2	138.8	147.4	163.4	138.8
	Margin (dB)	4.6	10.6	3.1	5.1	8.5	14.1	32.0	25.8	23.3	0.0	8.6	24.6	

Intel	MIL (dB)	139.2	140.0	132.1	140.5	137.6	142.3	157.0	157.3	154.2	137.4	150.9	150.9	132.1
	Margin (dB)	1.8	2.6	0	3.1	0.2	4.9	19.6	19.9	16.8	5.3	13.5	13.5	

Note: Sourcing companies Samsung and Vivo use max TRP 12 dBm and other companies use max TRP 23 dBm

Table C.4-2: Link budget performance (MIL) for the RedCap UE (100MHz BW, 1Rx)

Indoor, 28GHz, 100MHz, 1Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	142.3	142.4	136.4	139.5	137.2		157.5	153.9	150.4	133.3	149.4		133.3
	Margin (dB)	9.0	9.1	3.1	6.2	3.9		24.2	20.6	17.1	0.0	16.1		
ZTE	MIL (dB)	136.5	137.2	129.2	134.1	134.7		157.5	153.1	152.3	134.3	152.3		134.3
	Margin (dB)	2.1	2.8	-5.2	-0.2	0.3		23.1	18.8	18.0	0.0	18.0		
OPPO	MIL (dB)	141.0	141.0	138.8	140.1	139.4		160.0	159.7	160.0	141.9	160.2		141.9
	Margin (dB)	-0.9	-0.9	-3.1	-1.7	-2.5		18.2	17.8	18.1	0.0	18.4		
vivo	MIL (dB)	131.8	136.8	130.8	127.3	130.5	134.3	153.9	152.3	149.0	131.4	142.8	142.6	131.4
	Margin (dB)	0.4	5.4	-0.6	-4.0	-0.8	2.9	22.6	20.9	17.6	0.0	11.4	11.2	
Nokia	MIL (dB)	139.5	139.3	136.0	142.5	141.5		160.5		158.9	144.9	153.1	157.5	139.3
	Margin (dB)	0.3	0.0	-3.3	3.2	2.2		21.2		19.6	5.6	13.8	18.2	
DOCOMO	MIL (dB)	144.9	144.9	138.4	137.1	137.0		158.6	164.0		147.3	160.3		142.0
	Margin (dB)	2.9	2.9	-3.5	-4.8	-5.0		16.6	22.0		5.4	18.3		
Ericsson	MIL (dB)	128.2	129.2	124.4	124.8	123.5	130.6	150.5	150.5	148.1	138.7	146.3	149.1	128.0
	Margin (dB)	0.2	1.2	-3.6	-3.2	-4.5	2.6	22.5	22.6	20.1	10.7	18.3	21.1	
InterDigital	MIL (dB)	143.5	143.5	138.56	138.0	137.90		166.3		160.7	143.4	159.35		142.47
	Margin (dB)	1.0	1.0	-3.9	-4.47	-4.57		23.9		18.2	0.9	16.88		
Qualcomm	MIL (dB)	140.1	146.1	137.7	138.5	143.8	149.7	170.8	164.7	162.2	138.8	147.4	163.4	138.8
	Margin (dB)	1.3	7.3	-1.2	-0.4	5.0	10.8	32.0	25.8	23.3	0.0	8.6	24.6	
Intel	MIL (dB)	135.1	135.9	128.0	137.1	134.0	137.8	157.0	157.3	154.2	137.4	150.9	150.9	132.1
	Margin (dB)	3.0	3.8	-4.1	5.0	1.9	5.7	24.9	25.2	22.1	5.3	18.8	18.7	

Note: Sourcing companies Samsung and Vivo use max TRP 12 dBm and other companies use max TRP 23 dBm

Table C.4-3: Link budget performance (MIL) for the RedCap UE (50MHz BW, 2Rx)

Indoor, 28GHz, 50MHz, 2Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	146.0	145.9	137.0	145.1	142.5		157.5	153.9	150.4	133.3	149.4		133.3
	Margin (dB)	12.7	12.6	3.7	11.8	9.2		24.2	20.6	17.1	0.0	16.1		
OPPO	MIL (dB)	145.7	145.7	137.2	144.6	144.2		160.0	159.7	160.0	144.8	160.2		141.9

	Margin (dB)	3.9	3.9	-4.6	2.8	2.3		18.2	17.8	18.1	3.0	18.4		
DOCOMO	MIL (dB)	144.8	144.8	137.4	143.3	142.0		158.6	164.0		145.9	160.3		142.0
	Margin (dB)	2.9	2.9	-4.6	1.3	0.0		16.6	22.0		4.0	18.3		
Ericsson	MIL (dB)	130.2	131.2	124.8	129.2	128.0	134.3	150.5	150.5	148.1	143.6	146.3	149.1	128.0
	Margin (dB)	2.2	3.2	-3.2	1.2	0.0	6.3	22.5	22.6	20.1	15.7	18.3	21.1	
Qualcomm	MIL (dB)			138.4	143.9	144.2	152.9	170.8	164.7	162.2	138.9	147.4	163.4	138.8
	Margin (dB)			-0.4	5.1	5.4	14.1	32.0	25.8	23.3	0.1	8.6	24.6	

Note: Sourcing companies Samsung and Vivo use max TRP 12 dBm and other companies use max TRP 23 dBm

Table C.4-4: Link budget performance (MIL) for the RedCap UE (50MHz BW, 1Rx)

Indoor, 28GHz, 50MHz, 1Rx RedCap UE														
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4	Target /Option3
Samsung	MIL (dB)	141.6	141.6	130.9	139.5	137.2		157.5	153.9	150.4	133.3	149.4		133.3
	Margin (dB)	8.3	8.3	-2.4	6.2	3.9		24.2	20.6	17.1	0.0	16.1		
OPPO	MIL (dB)	140.9	140.9	131.8	140.1	139.4		160.0	159.7	160.0	144.8	160.2		141.9
	Margin (dB)	-1.0	-1.0	-10.1	-1.7	-2.5		18.2	17.8	18.1	3.0	18.4		
DOCOMO	MIL (dB)	140.3	140.3	131.3	137.1	137.0		158.6	164.0		145.9	160.3		142.0
	Margin (dB)	-1.7	-1.7	-10.7	-4.8	-5.0		16.6	22.0		4.0	18.3		
Ericsson	MIL (dB)	126.1	127.1	120.1	124.8	123.5	130.6	150.5	150.5	148.1	143.6	146.3	149.1	128.0
	Margin (dB)	-1.9	-0.9	-7.9	-3.2	-4.5	2.6	22.5	22.6	20.1	15.7	18.3	21.1	
Qualcomm	MIL (dB)			133.4	138.5	140.2	149.9	170.8	164.7	162.2	138.9	147.4	163.4	138.8
	Margin (dB)			-5.4	-0.4	1.4	11.1	32.0	25.8	23.3	0.1	8.6	24.6	

Note: Sourcing companies Samsung and Vivo use max TRP 12 dBm and other companies use max TRP 23 dBm

Table C.4-5: MPL (dB) results for Indoor 28 GHz

Indoor, 28GHz													
		PDCCH CSS	PDCCH USS	PDSCH	Msg2	Msg4	PBCH	PUCCH 2bits	PUCCH 11 bits	PUCCH 22bits	PUSCH	Msg3	PRACH B4
Samsung	Ref UE, 100MHz BW, 2Rx	146.5	146.5	141.3	145.1	142.5		157.8	153.8	150.9	133.3	149.4	
	RedCap, 100MHz BW, 1Rx	142.3	142.4	136.4	139.5	137.2		157.8	153.8	150.9	133.3	149.4	
	RedCap, 50MHz BW, 2Rx	146.0	145.9	137.0	145.1	142.5		157.5	153.9	150.4	133.2	149.4	
	RedCap, 50MHz BW, 1Rx	141.6	141.6	130.9	139.5	137.2		157.5	153.9	150.4	133.2	149.4	
ZTE	Ref UE, 100MHz BW, 2Rx	139.8	140.5	134.5	139.0	139.3		157.5	153.1	152.3	134.3	152.3	

	RedCap, 100MHz BW, 1Rx	136.5	137.2	129.2	134.1	134.7		157.5	153.1	152.3	134.3	152.3	
	Ref UE, 100MHz BW, 2Rx	145.9	145.9	142.9	144.6	144.2		160.0	159.7	160.0	141.9	160.2	
	RedCap, 100MHz BW, 1Rx	141.0	141.0	138.8	140.1	139.4		160.0	159.7	160.0	141.9	160.2	
	RedCap, 50MHz BW, 2Rx	145.7	145.7	137.2	144.6	144.2		160.0	159.7	160.0	144.8	160.2	
OPPO	RedCap, 50MHz BW, 1Rx	140.9	140.9	131.8	140.1	139.4		160.0	159.7	160.0	144.8	160.2	
	Ref UE, 100MHz BW, 2Rx	127.0	132.0	130.8	128.5	129.9	131.3	145.4	143.8	140.5	126.2	137.6	134.1
vivo	RedCap, 100MHz BW, 1Rx	123.3	128.3	125.6	122.1	125.3	125.8	145.4	143.8	140.5	126.2	137.6	134.1
	Ref UE, 100MHz BW, 2Rx	134.1	134.1	134.1	139.7	144.1		152.0		150.4	139.7	147.9	152.3
Nokia	RedCap, 100MHz BW, 1Rx	131.1	130.8	130.8	137.3	141.5		152.0		150.4	139.7	147.9	152.3
	Ref UE, 100MHz BW, 2Rx	148.6	148.6	143.0	143.3	142.0		158.6	164.0		147.3	160.3	
	RedCap, 100MHz BW, 1Rx	144.9	144.9	138.4	137.1	137.0		158.6	164.0		147.3	160.3	
	RedCap, 50MHz BW, 2Rx	144.8	144.8	137.4	143.3	142.0		158.6	164.0		145.9	160.3	
DOCOMO	RedCap, 50MHz BW, 1Rx	140.3	140.3	131.3	137.1	137.0		158.6	164.0		145.9	160.3	
	Ref UE, 100MHz BW, 2Rx	132.1	133.1	128.4	129.2	128.0	134.3	150.5	150.9	148.4	138.7	146.3	149.1
	RedCap, 100MHz BW, 1Rx	128.2	129.2	124.4	124.8	123.5	130.6	150.5	150.5	148.4	138.7	146.3	149.1
	RedCap, 50MHz BW, 2Rx	130.2	131.2	124.8	129.2	128.0	134.3	150.5	150.9	148.1	143.6	146.3	149.1
Ericsson	RedCap, 50MHz BW, 1Rx	126.1	127.1	120.1	124.8	123.5	130.6	150.5	150.5	148.1	143.6	146.3	149.1
	Ref UE, 100MHz BW, 2Rx	138.8	138.8	142.7	143.3	142.5		166.3		160.7	143.4	159.3	
InterDigital	RedCap, 100MHz BW, 1Rx	135.0	135.0	138.6	138.0	137.9		166.3		160.7	143.4	159.3	
	Ref UE, 100MHz BW, 2Rx	143.4	149.4	141.9	143.9	147.3	153.0	170.8	164.7	162.2	138.8	147.4	163.4
	RedCap, 100MHz BW, 1Rx	140.1	146.1	137.7	138.5	143.8	149.7	170.8	164.7	162.2	138.8	147.4	163.4
	RedCap, 50MHz BW, 2Rx			138.4	143.9	144.2	152.9	170.8	164.7	162.2	138.9	147.4	163.4
Qualcomm	RedCap, 50MHz BW, 1Rx			133.4	138.5	140.2	149.9	170.8	164.7	162.2	138.9	147.4	163.4
Intel	Ref UE, 100MHz BW, 2Rx	139.2	140.0	132.1	140.5	137.6	142.3	157.0	157.3	154.2	137.4	150.9	150.9

	RedCap, 100MHz BW, 1Rx	135.1	135.9	128.0	137.1	134.0	137.8	157.0	157.3	154.2	137.4	150.9	150.9

Note: Sourcing companies Samsung and Vivo use max TRP 12 dBm and other companies use max TRP 23 dBm.

Annex D: System-level simulation evaluation results

Based on the latest available evaluation results in [3], the system-level simulation (SLS) evaluations of the impact of complexity reduction and antenna inefficiency to network capacity are summarized in Table D-1 to D-25. Table D-1 lists additional evaluation assumptions for capacity and spectral efficiency evaluation. Results for burst traffic are summarized in Table D-2 – Table D-19, for various deployment scenarios (Urban at 2.6 GHz, Urban at 4 GHz, and Indoor at 28 GHz), various loads (low and medium), and various RedCap UE complexity reduction options (2 Rx branches and 1 Rx branch). Both downlink and uplink results are summarized. Additionally, results for full-buffer traffic are summarized in Table D-22 – Table D-25.

Table D-1: Additional evaluation assumptions for capacity and spectral efficiency evaluation

	Traffic model	Scheduled BW	Modulation order	Options for UE modelling (Note)	Antenna efficiency loss for RedCap UE
Source 1 (Ericsson)	FTP mode 3 (0.5MB payload every 200ms) for eMBB UE IM model (0.1 MB payload every 2s) for RedCap UE	Max 100MHz for eMBB UE and 20 MHz for RedCap UE	Max 256 QAM in DL and 64 QAM in UL for eMBB UE Max 64QAM in DL and 16 QAM in UL for RedCap UE	Option 1	SLS results do not account for antenna efficiency loss
Source 2 (Huawei)	FTP model 3 for both eMBB and RedCap UEs. In each 20MHz frequency block within 100MHz bandwidth, packet size is 0.125 Mbytes for DL and 0.05 MB for UL and mean inter-arrival time is 200 ms	100MHz system bandwidth comprises five frequency blocks of 20MHz. Scheduled within one frequency block for both eMBB UE and RedCap UE	Max 256 QAM in DL and 64 QAM in UL for eMBB UE Max 64QAM in DL and 16 QAM in UL for RedCap UE	Option 2 For DL, a total number of UEs per cell is 4 for low-loading and 8 for medium loading For UL, a total number of UEs per cells is 2 for low-loading and 4 for medium loading	
Source 3 (vivo)	FTP model 3 (0.5MB payload every 200ms) for eMBB UE IM traffic (0.1 MB payload every 2s) for RedCap UE	Max 100MHz for eMBB UE and 20 MHz for RedCap UE	Max 256 QAM in DL and 64 QAM in UL for eMBB UE Max 64QAM in DL and 16 QAM in UL for RedCap UE	Option 1 For DL, 8 eMBB UE and 0/3/8 RedCap UE based on ratios for low loading; 12 eMBB UE and 0/4/12 RedCap UE based on ratios for medium loading For UL, 3 eMBB UE and 0/1/3 RedCap UE based on ratios for low loading; 5 eMBB UE and 0/2/5 RedCap UE based on ratios for medium loading	3dB antenna efficiency loss is modelled for all FR1 scenarios
Source 4 (MediaTek)	FTP model 3 for both eMBB and RedCap UEs. Packet size is 0.5 Mbytes and mean inter-arrival time 200 ms	Max 100MHz for eMBB UE and 20 MHz for RedCap UE	Max 256 QAM in DL for eMBB UE Max 64QAM in DL for RedCap UE		3dB antenna efficiency loss is modelled for all FR1 scenarios
Source 5 (Qualcomm)	FTP model 3 for eMBB UE (packet size is 0.5MB and the mean inter-arrival time changed with different RedCap UE ratios) IM model (0.1 MB payload every 2s) for RedCap UE	Max 100MHz for eMBB UE and 20 MHz for RedCap UE	Max 256 QAM in DL for eMBB UE Max 64QAM in DL for RedCap UE	Option 2 with a total 8 UEs per cell for DL	SLS results do not account for antenna efficiency loss
Source 6 (Nokia)	FTP model 3 for both eMBB and RedCap UEs (packet size is fixed, and packet arrival rate adapted to target RU)	Max 100MHz for eMBB UE and 20 MHz for RedCap UE	Max 256 QAM in DL and 64 QAM in UL for eMBB UE Max 64QAM in DL and 16 QAM in UL for RedCap UE	Option 2 with an average of 10 UEs per cell including both RedCap and reference NR UEs. The number of RedCap UEs in the entire system is based on the agreed percentages.	

Note: For burst traffic evaluation, the number of UEs including both eMBB and RedCap UEs can be based on the following options.

- Option 1: The number of UEs can be different for different RedCap UE ratios in the cell (e.g. using the target RU to determine the number of UEs for each RedCap UE ratio independently)
- Option 2: With respect to a target RU, the total number of UEs is same for all the RedCap UE ratios in the cell (e.g. firstly determine the number of UEs assuming 0% RedCap UE ratio for a target RU and use the same total number to other RedCap UE ratios)

Table D-2: Downlink capacity evaluation for burst traffic (2.6GHz, low loading, 2Rx RedCap UE)

2.6GHz, DL, 2Rx RedCap, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	634.00	636.00	630.00	\	317.00	315.00	313.00	\	6.30			\
	RedCap UE	\	86.00	85.00	83.00	\	38.00	37.00	37.00	\			4.10
	All UEs	634.00	634.00	625.00	83.00	317.00	306.00	272.00	37.00	6.30	6.30	6.20	4.10
Huawei	eMBB UE	86.96	58.82	39.22	\	33.33	21.98	16.95	\	5.76	5.68	4.87	\
	RedCap UE	\	29.41	30.77	46.51	\	10.93	9.09	14.81	\	3.20	3.17	2.87
	All UEs	86.96	50.41	35.72	46.51	33.33	19.22	14.02	14.81	5.76	5.44	3.65	2.87
vivo	eMBB UE	464.86	470.23	465.56		164.03	162.74	164.62		5.47	5.49	5.49	
	RedCap UE	\	39.00	38.13		\	16.03	15.34		\	2.64	2.61	
	All UEs	464.86	456.49	431.54		164.03	98.10	37.44		5.47	5.45	5.37	
MediaTek	eMBB UE	365.00			\	176.00			\	6.15			\
	RedCap UE	\			30.00	\			1.00	\			3.47
	All UEs	365.00			30.00	176.00			1.00	6.15			3.47
Qualcomm	eMBB UE	168.12	176.74	204.66	\	57.05	67.20	87.43	\	8.98	9.22	9.70	\
	RedCap UE	\	46.72	43.41	71.02	\	4.04	2.14	5.68	\	6.75	5.19	8.47
	All UEs	168.12	134.86	84.85	71.02	57.05	14.64	5.31	5.68	8.98	8.60	7.44	8.47
Nokia	eMBB UE	402.48	447.58	569.93	\	188.97	219.51	311.09	\	4.79	5.31	6.43	\
	RedCap UE	\	21.52	52.06	52.05	\	3.94	19.81	18.97	\	1.32	2.40	2.40
	All UEs	402.48	377.15	133.94	52.05	188.97	9.80	26.79	18.97	4.79	4.31	4.42	2.40

Table D-3: Downlink capacity evaluation for burst traffic (2.6GHz, low loading, 1Rx RedCap UE)

2.6GHz, DL, 1Rx RedCap, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	634.00	634.00	632.00	\	317.00	315.00	314.00	\	6.30			\
	RedCap UE	\	63.00	63.00	63.00	\	30.00	29.00	27.00	\			2.90
	All UEs	634.00	632.00	627.00	63.00	317.00	302.00	268.00	27.00	6.30	5.90	6.10	2.90
Huawei	eMBB UE	86.96	42.55	25.98	\	33.33	15.38	8.89	\	5.76	5.22	4.99	\
	RedCap UE	\	19.05	21.05	25.32	\	7.41	7.38	7.25	\	2.34	2.19	2.10
	All UEs	86.96	36.00	23.31	25.32	33.33	13.59	8.24	7.25	5.76	4.25	2.98	2.10
vivo	eMBB UE	488.09	471.06	471.38		177.71	162.54	165.98		5.75	5.49	5.53	
	RedCap UE	\	36.39	35.20		\	13.54	13.80		\	2.35	2.38	
	All UEs	488.09	456.73	436.73		177.71	95.10	34.73		5.75	5.43	5.39	
MediaTek	eMBB UE	365.00			\	176.00			\	6.15			\
	RedCap UE	\			16.00	\			2.00	\			2.50
	All UEs	365.00			16.00	176.00			2.00	6.15			2.50
Qualcomm	eMBB UE	168.12	176.95	212.95	\	57.05	71.71	98.93	\	8.98	8.95	9.63	\
	RedCap UE	\	36.20	31.15	41.79	\	1.13	0.92	2.28	\	3.95	3.13	3.98
	All UEs	168.12	132.78	61.29	41.79	57.05	10.61	2.48	2.28	8.98	7.70	6.38	3.98
Nokia	eMBB UE	402.48	447.58	569.93	\	188.97	219.51	311.09	\	4.79	5.31	6.43	\
	RedCap UE	\	18.93	41.51	41.51	\	3.88	14.47	14.73	\	1.19	1.72	1.72

	All UEs	402.48	377.17	133.97	41.51	188.97	7.72	18.24	14.73	4.79	4.28	4.08	1.72

Table D-4: Downlink capacity evaluation for burst traffic (2.6GHz, medium loading, 2Rx RedCap UE)

2.6GHz, DL, 2Rx RedCap, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	512.00	518.00	521.00	\	227.00	233.00	237.00	\	6.00			\
	RedCap UE	\	67.00	67.00	64.00	\	29.00	28.00	27.00	\			3.80
	All UEs	512.00	516.00	515.00	64.00	227.00	224.00	206.00	27.00	6.00	5.90	5.80	3.80
Huawei	eMBB UE	64.52	41.67	28.57	\	20.10	12.20	8.70	\	5.33	5.45	4.90	\
	RedCap UE	\	22.22	19.23	28.57	\	6.92	4.38	7.25	\	3.85	3.83	3.58
	All UEs	64.52	38.61	26.23	28.57	20.10	10.88	4.66	7.25	5.33	4.64	4.34	3.58
Vivo	eMBB UE	388.54	392.09	397.28		97.68	94.44	97.61		5.13	5.09	5.14	
	RedCap UE	\	27.10	27.56		\	7.82	7.74		\	2.53	2.61	
	All UEs	388.54	378.54	356.91		97.68	59.23	25.42		5.13	5.06	5.04	
MediaTek	eMBB UE	258.00			\	90.00			\	5.80			\
	RedCap UE	\			18.00	\			0.50	\			2.40
	All UEs	258.00			18.00	90.00			0.50	5.80			2.40
Qualcomm	eMBB UE	139.30	152.74	187.06	\	51.80	61.85	84.05	\	7.99	8.26	9.09	\
	RedCap UE	\	43.72	37.23	71.02	\	1.75	1.71	5.68	\	5.50	4.82	8.47
	All UEs	139.30	117.80	80.72	71.02	51.80	11.51	4.08	5.68	7.99	7.57	6.95	8.47
Nokia	eMBB UE	300.05	407.42	413.37	\	105.19	190.68	193.98	\	3.68	4.79	4.79	\
	RedCap UE	\	18.92	18.15	22.28	\	2.73	2.34	3.83	\	1.27	1.27	1.32
	All UEs	300.05	330.63	106.32	22.28	105.19	7.50	3.77	3.83	3.68	3.91	3.03	1.32

Table D-5: Downlink capacity evaluation for burst traffic (2.6GHz, medium loading, 1Rx RedCap UE)

2.6GHz, DL, 1Rx RedCap, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	511.00	515.00	511.00	\	227.00	236.00	231.00	\	6.00			\
	RedCap UE	\	52.00	52.00	51.00	\	20.00	20.00	19.00	\			2.80
	All UEs	511.00	512.00	504.00	51.00	227.00	224.00	200.00	19.00	6.00	5.90	5.60	2.80
Huawei	eMBB UE	64.52	27.78	18.18	\	20.10	7.25	4.52	\	5.33	5.25	5.23	\
	RedCap UE	\	14.49	13.70	16.13	\	4.03	2.44	2.73	\	2.41	2.72	2.96
	All UEs	64.52	26.07	16.86	16.13	20.10	6.55	3.67	2.73	5.33	3.75	3.32	2.96
vivo	eMBB UE	396.74	392.38	387.63		102.39	97.20	95.89		5.22	5.13	5.09	
	RedCap UE	\	25.54	24.37		\	7.73	7.24		\	2.36	2.31	
	All UEs	396.74	379.11	347.19		102.39	59.83	22.79		5.22	5.09	4.98	
MediaTek	eMBB UE	258.00			\	90.00			\	5.80			\
	RedCap UE	\			2.00	\			0.30	\			2.00
	All UEs	258.00			2.00	90.00			0.30	5.80			2.00
Qualcomm	eMBB UE	139.30	154.16	186.99	\	51.80	61.23	90.52	\	7.99	8.07	8.86	\
	RedCap UE	\	31.78	27.43	41.79	\	0.79	0.78	2.28	\	3.24	2.96	3.98
	All UEs	139.30	112.21	61.16	41.79	51.80	8.90	1.80	2.28	7.99	6.86	5.91	3.98
Nokia	eMBB UE	300.05	407.42	413.37	\	105.19	190.68	193.98	\	3.68	4.79	4.79	\
	RedCap UE	\	17.18	16.19	26.67	\	2.70	2.55	5.84	\	1.20	1.20	1.29
	All UEs	300.05	330.64	77.96	26.67	105.19	6.01	3.60	5.84	3.68	3.89	2.99	1.29

Table D-6: Uplink capacity evaluation for burst traffic (2.6GHz, low loading)

2.6GHz, UL, low loading (RU<30%)				
		50% UPT (Mbps)	5% UPT (Mbps)	Cell avg. SE (bps/Hz)

	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	47.000	47.000	47.000	\	3.000	3.000	3.000	\	0.40			\
	RedCap UE	\	12.000	12.000	11.000	\	2.700	2.700	2.400	\			0.40
	All UEs	47.000	46.000	46.000	11.000	3.000	3.000	3.000	2.400	0.40	0.40	0.40	0.40
Huawei	eMBB UE	8.420		3.430	\	0.220		0.220	\	1.66		1.65	\
	RedCap UE	\		1.940	4.300	\		0.210	0.230	\		0.84	0.82
	All UEs	8.420		2.880	4.300	0.220		0.220	0.230	1.66		1.16	0.82
vivo	eMBB UE	21.400	22.811	23.444		0.063	0.061	0.059		1.01	1.01	1.01	
	RedCap UE	\	0.556	0.473		\	0.070	0.004		\	0.24	0.24	
	All UEs	21.400	8.695	4.489		0.063	0.062	0.058		1.01	0.96	0.88	
MediaTek	eMBB UE	82.000			\	14.000			\	0.60			\
	RedCap UE	\			7.000	\			4.000	\			0.40
	All UEs	82.000			7.000	14.000			4.000	0.60			0.40
Nokia	eMBB UE	45.974	46.240	46.967	\	18.319	18.518	17.608	\	0.52	0.52	0.52	\
	RedCap UE	\	7.427	7.435	7.435	\	4.991	5.008	5.000	\	0.40	0.40	0.40
	All UEs	45.974	36.354	11.072	7.435	18.319	6.946	6.025	5.000	0.52	0.49	0.46	0.40

Table D-7: Uplink capacity evaluation for burst traffic (2.6GHz, medium loading)

2.6GHz, UL, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	37.000	37.000	37.000	\	1.700	1.700	1.600	\	0.40			\
	RedCap UE	\	11.000	11.000	11.000	\	1.500	1.600	1.400	\			0.50
	All UEs	37.000	37.000	36.000	11.000	1.700	1.700	1.600	1.400	0.40	0.40	0.40	0.50
Huawei	eMBB UE	7.340	5.230	3.400	\	0.220	0.220	0.230	\	2.04	2.20	2.22	\
	RedCap UE	\	2.470	2.010	3.600	\	0.190	0.220	0.240	\	0.73	0.97	1.34
	All UEs	7.340	4.410	2.900	3.600	0.220	0.200	0.220	0.240	2.04	1.82	1.59	1.34
vivo	eMBB UE	19.929	19.877	18.060		0.065	0.064	0.061		1.01	1.01	1.01	
	RedCap UE	\	0.328	0.398		\	0.034	0.032		\	0.25	0.25	
	All UEs	19.929	14.120	2.791		0.065	0.062	0.056		1.01	0.96	0.90	
MediaTek	eMBB UE	63.000			\	9.000			\	0.56			\
	RedCap UE	\			7.000	\			2.500	\			0.40
	All UEs	63.000			7.000	9.000			2.500	0.56			0.40
Nokia	eMBB UE	35.769	35.710	36.162	\	11.898	11.898	11.163	\	0.49	0.49	0.49	\
	RedCap UE	\	6.968	7.079	7.150	\	3.514	3.289	3.313	\	0.39	0.39	0.39
	All UEs	35.769	29.122	7.783	7.150	11.898	5.171	4.040	3.313	0.49	0.47	0.44	0.39

Table D-8: Downlink capacity evaluation for burst traffic (4GHz, low loading, 2Rx RedCap UE)

4 GHz, DL, 2Rx RedCap, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	506.00	507.00	504.00	\	152.00	153.00	153.00	\	3.80			\
	RedCap UE	\	64.00	63.00	64.00	\	16.00	15.00	15.00	\			2.30
	All UEs	506.00	506.00	497.00	64.00	152.00	129.00	98.00	15.00	3.80	3.80	3.70	2.30
Huawei	eMBB UE	62.50	41.17	27.56	\	19.05	12.09	9.63	\	5.02	4.95	4.63	\
	RedCap UE	\	19.16	16.93	30.57	\	6.01	5.09	8.77	\	3.85	2.96	3.15
	All UEs	62.50	35.29	23.35	30.57	19.05	10.27	7.58	8.77	5.02	4.63	3.86	3.15

vivo	eMBB UE	419.32	426.57	422.85		143.05	149.96	152.43		4.35	4.54	4.68	
	RedCap UE	\	33.70	33.33		\	9.71	12.22		\	1.86	1.95	
	All UEs	419.32	415.80	393.03		143.05	99.24	33.11		4.35	4.50	4.55	
Qualcomm	eMBB UE	118.95	155.56	189.03	\	44.27	52.85	77.25	\	7.62	8.54	9.30	\
	RedCap UE	\	20.64	28.90	34.61	\	1.63	1.51	1.81	\	5.55	5.19	8.47
	All UEs	118.95	118.55	82.69	34.61	44.27	5.85	2.29	1.81	7.62	7.46	7.02	8.47
Nokia	eMBB UE	371.06	488.87	494.21	\	173.15	255.53	273.74	\	4.34	5.50	5.50	\
	RedCap UE	\	44.28	44.76	44.36	\	15.36	17.94	16.79	\	2.07	2.07	2.07
	All UEs	371.06	431.70	95.22	44.36	173.15	28.19	22.97	16.79	4.34	4.64	3.79	2.07

Table D-9: Downlink capacity evaluation for burst traffic (4GHz, low loading, 1Rx RedCap UE)

4 GHz, DL, 1Rx RedCap, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	507.00	505.00	516.00	\	151.00	154.00	156.00	\	3.80			\
	RedCap UE	\	49.00	50.00	50.00	\	10.00	11.00	11.00	\			1.60
	All UEs	507.00	503.00	511.00	50.00	151.00	132.00	95.00	11.00	3.80	3.80	3.70	1.60
Huawei	eMBB UE	62.50	30.85	18.67	\	19.05	8.71	5.08	\	5.02	4.56	4.34	\
	RedCap UE	\	9.59	10.59	12.74	\	2.54	2.53	2.49	\	2.24	1.94	1.86
	All UEs	62.50	25.65	14.82	12.74	19.05	7.26	3.95	2.49	5.02	3.98	3.19	1.86
vivo	eMBB UE	422.64	420.15	413.95		146.07	141.29	150.78		4.51	4.50	4.45	
	RedCap UE	\	31.52	30.67		\	10.15	10.62		\	1.75	1.70	
	All UEs	422.64	409.41	383.94		146.07	84.44	29.75		4.51	4.45	4.31	
Qualcomm	eMBB UE	118.95	167.35	197.97	\	44.27	60.54	80.16	\	7.62	8.69	9.53	\
	RedCap UE	\	15.22	15.84	19.22	\	0.62	0.66	0.76	\	2.59	2.74	3.07
	All UEs	118.95	120.11	58.11	19.22	44.27	2.45	1.05	0.76	7.62	7.16	6.14	3.07
Nokia	eMBB UE	371.06	488.87	494.21	\	173.15	255.53	273.74	\	4.34	5.50	5.50	\
	RedCap UE	\	35.20	34.83	34.78	\	11.57	11.57	11.94	\	1.48	1.48	1.48
	All UEs	371.06	431.72	47.61	34.78	173.15	20.44	14.92	11.94	4.34	4.49	3.49	1.48

Table D-10: Downlink capacity evaluation for burst traffic (4GHz, medium loading, 2Rx RedCap UE)

4 GHz, DL, 2Rx RedCap, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	404.00	393.00	417.00	\	109.00	114.00	116.00	\	3.80			\
	RedCap UE	\	49.00	50.00	48.00	\	11.00	12.00	9.00	\			2.10
	All UEs	404.00	409.00	414.00	48.00	109.00	104.00	84.00	9.00	3.80	3.70	3.60	2.10
Huawei	eMBB UE	43.48	50.00	20.13	\	11.30	6.81	4.88	\	5.14	5.04	4.61	\
	RedCap UE	\	407.00	13.57	18.69	\	3.81	2.51	3.88	\	3.57	3.60	3.86
	All UEs	43.48	26.43	16.93	18.69	11.30	6.25	3.75	3.88	5.14	4.58	4.12	3.86
vivo	eMBB UE	336.94	337.24	339.47		78.86	82.85	82.10		4.12	4.24	4.25	
	RedCap UE	\	22.91	21.69		\	5.95	5.59		\	1.95	1.82	
	All UEs	336.94	323.63	305.21		78.86	45.98	20.18		4.12	4.20	4.14	
Qualcomm	eMBB UE		132.23	166.67	\		46.88	67.67	\		7.61	8.24	\
	RedCap UE		16.41	22.80	34.61		1.21	1.20	1.81		3.81	4.23	8.47
	All UEs		100.31	74.07	34.61		3.97	1.87	1.81		6.66	6.24	8.47
Nokia	eMBB UE	159.15	319.16	371.27	\	28.26	137.36	174.61	\	2.68	3.82	4.34	\
	RedCap UE	\	15.60	18.75	19.66	\	2.32	3.15	3.35	\	1.21	1.25	1.25
	All UEs	159.15	249.19	95.10	19.66	28.26	6.38	4.97	3.35	2.68	3.17	2.80	1.25

Table D-11: Downlink capacity evaluation for burst traffic (4GHz, medium loading, 1Rx RedCap UE)

4 GHz, DL, 1Rx RedCap, medium loading (30%<RU<50%)

		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	404.00	408.00	412.00	\	109.00	112.00	110.00	\	3.80			\
	RedCap UE	\	39.00	39.00	38.00	\	7.00	8.00	7.00	\			1.70
	All UEs	404.00	407.00	406.00	38.00	109.00	102.00	74.00	7.00	3.80	3.60	3.50	1.70
Huawei	eMBB UE	43.48	18.72	12.25	\	11.30	4.08	2.54	\	5.14	5.06	5.04	\
	RedCap UE	\	9.82	9.28	10.93	\	2.45	1.48	1.66	\	2.33	2.96	3.22
	All UEs	43.48	16.60	10.51	10.93	11.30	3.68	1.90	1.66	5.14	4.20	3.67	3.22
vivo	eMBB UE	343.43	337.71	341.72		83.67	79.37	81.73		4.32	4.15	4.25	
	RedCap UE	\	20.95	20.12		\	4.64	4.73		\	1.59	1.67	
	All UEs	343.43	324.09	306.91		83.67	42.09	18.41		4.32	4.09	4.13	
Qualcomm	eMBB UE		137.93	170.21	\		52.77	69.00	\		7.59	8.42	\
	RedCap UE		12.64	13.12	19.22		0.58	0.59	0.76		2.45	2.53	3.07
	All UEs		102.89	55.35	19.22		1.75	0.67	0.76		6.31	5.47	3.07
Nokia	eMBB UE	159.15	319.16	371.27	\	28.26	137.36	174.61	\	2.68	3.82	4.34	\
	RedCap UE	\	13.51	17.46	22.20	\	1.89	2.92	4.73	\	1.12	1.12	1.16
	All UEs	159.15	249.20	95.10	22.20	28.26	4.36	4.04	4.73	2.68	3.15	2.73	1.16

Table D-12: Uplink capacity evaluation for burst traffic (4GHz, low loading)

4 GHz, UL, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	52.000	52.000	52.000	\	0.900	0.900	0.900	\	0.40			\
	RedCap UE	\	16.000	16.000	16.000	\	0.800	0.900	0.700	\			0.50
	All UEs	52.000	52.000	51.000	16.000	0.900	0.900	0.900	0.700	0.40	0.40	0.40	0.50
Huawei	eMBB UE	9.850		4.240	\	0.210		0.240	\	1.48		1.45	\
	RedCap UE	\		2.330	5.110	\		0.200	0.240	\		0.75	0.78
	All UEs	9.850		3.290	5.110	0.210		0.200	0.240	1.48		1.07	0.78
vivo	eMBB UE	12.845	12.574	12.369		0.058	0.057	0.057		1.34	1.34	1.34	
	RedCap UE	\	0.582	0.635		\	0.065	0.070		\	0.32	0.32	
	All UEs	12.845	1.325	2.544		0.058	0.057	0.058		1.34	1.26	1.16	
Nokia	eMBB UE	63.987	61.527	63.484	\	11.134	27.863	28.981	\	0.73	0.72	0.73	\
	RedCap UE	\	11.065	11.141	9.399	\	7.803	8.291	7.987	\	0.58	0.59	0.59
	All UEs	63.987	51.601	13.084	9.399	11.134	9.623	8.852	7.987	0.73	0.69	0.66	0.59

Table D-13: Uplink capacity evaluation for burst traffic (4GHz, medium loading)

4 GHz, UL, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	43.000	43.000	43.000	\	0.600	0.600	0.600	\	0.60			\
	RedCap UE	\	15.000	15.000	15.000	\	0.500	0.500	0.500	\			0.60
	All UEs	43.000	42.000	41.000	15.000	0.600	0.600	0.600	0.500	0.60	0.60	0.60	0.60
Huawei	eMBB UE	8.450	6.110	4.070	\	0.200	0.220	0.220	\	1.86	2.20	2.05	\
	RedCap UE	\	2.840	2.410	3.790	\	0.200	0.200	0.220	\	0.73	0.89	1.25
	All UEs	8.450	5.220	3.260	3.790	0.200	0.200	0.200	0.220	1.86	1.67	1.42	1.25
vivo	eMBB UE	5.265	5.894	4.805		0.058	0.058	0.058		1.34	1.34	1.32	
	RedCap UE	\	0.505	0.513		\	0.034	0.037		\	0.32	0.32	

	All UEs	5.265	2.976	1.217		0.058	0.057	0.056		1.34	1.27	1.17	
Nokia	eMBB UE	54.438	54.020	53.324	\	22.083	20.970	20.970	\	0.70	0.70	0.70	\
	RedCap UE	\	10.469	10.527	10.538	\	5.873	6.004	5.873	\	0.58	0.58	0.58
	All UEs	54.438	42.751	12.042	10.538	22.083	8.429	7.260	5.873	0.70	0.67	0.64	0.58

Table D-14: Downlink capacity evaluation for burst traffic (28 GHz, low loading, 2Rx RedCap UE)

28 GHz, DL, 2Rx RedCap, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	441.00	444.00	442.00	\	192.00	199.00	198.00	\	8.80			\
	RedCap UE	\	338.00	336.00	356.00	\	153.00	146.00	155.00	\			7.00
	All UEs	441.00	442.00	440.00	356.00	192.00	199.00	195.00	155.00	8.80	8.70	8.60	7.00
MediaTek	eMBB UE	103			\	51			\	4.14			\
	RedCap UE	\			64.00	\			44.00	\			2.70
	All UEs	103			64.00	51			44.00	4.14			2.70
Qualcomm	eMBB UE	322.50	334.80	323.00	\	286.30	313.20	290.30	318.60	6.90	6.90	6.90	\
	RedCap UE	\	312.90	306.80	328.70	\	267.50	266.00	\	\	6.80	6.90	6.90
	All UEs	322.50	327.30	316.50	328.70	286.30	285.70	277.40	318.60	6.90	6.90	6.90	6.90

Table D-15: Downlink capacity evaluation for burst traffic (28 GHz, low loading, 1Rx RedCap UE)

28 GHz, DL, 1Rx RedCap, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	441.00	445.00	437.00	\	192.00	202.00	196.00	\	8.80			\
	RedCap UE	\	215.00	213.00	213.00	\	103.00	100.00	98.00	\			4.40
	All UEs	441.00	444.00	434.00	213.00	192.00	199.00	189.00	98.00	8.80	8.70	8.40	4.40
MediaTek	eMBB UE	103.00			\	51.00			\	4.14			\
	RedCap UE	\			48.00	\			22.00	\			2.2
	All UEs	103.00			48.00	51.00			22.00	4.14			2.2
Qualcomm	eMBB UE				\				\				\
	RedCap UE				177.30				172.00				3.50
	All UEs				177.30				172.00				3.50

Table D-16: Downlink capacity evaluation for burst traffic (28 GHz, medium loading, 2Rx RedCap UE)

28 GHz, DL, 2Rx RedCap, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	322.00	344.00	347.00	\	109.00	133.00	134.00	\	8.60			\
	RedCap UE	\	244.00	244.00	238.00	\	89.00	91.00	79.00	\			6.30
	All UEs	322.00	344.00	344.00	238.00	109.00	133.00	133.00	79.00	8.60	8.50	8.20	6.30
MediaTek	eMBB UE	84			\	38.00			\	3.75			\
	RedCap UE	\			54.00	\			32.00	\			2.60
	All UEs	84			54.00	38.00			32.00	3.75			2.60
Qualcomm	eMBB UE	249.50	284.00	237.80		207.70	238.10	189.00		6.80	6.80	6.70	
	RedCap UE	\	272.20	228.60		\	237.00	156.90		\	6.80	6.60	
	All UEs	249.50	283.00	234.80		207.70	238.60	167.40		6.80	6.80	6.60	

Table D-17: Downlink capacity evaluation for burst traffic (28 GHz, medium loading, 1Rx RedCap UE)

28 GHz, DL, 1Rx RedCap, medium loading (30%<RU<50%)

		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	322.00	343.00	346.00	\	109.00	130.00	132.00	\	8.60			\
	RedCap UE	\	172.00	171.00	173.00	\	64.00	63.00	65.00	\			4.40
	All UEs	322.00	342.00	342.00	173.00	109.00	128.00	128.00	65.00	8.60	8.40	8.00	4.40
MediaTek	eMBB UE	84.00			\	38.00			\	3.75			\
	RedCap UE	\			35.00	\			11.00	\			1.90
	All UEs	84.00			35.00	38.00			11.00	3.75			1.90

Table D-18: Uplink capacity evaluation for burst traffic (28 GHz, low loading)

28 GHz, UL, low loading (RU<30%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	62.00	62.00	61.00	\	16.00	16.00	16.00	\	1.10			\
	RedCap UE	\	54.00	53.00	49.00	\	14.00	14.00	10.00	\			0.90
	All UEs	62.00	62.00	61.00	49.00	16.00	16.00	16.00	10.00	1.10	1.10	1.00	0.90
MediaTek	eMBB UE	72.00			\	47.00			\	0.82			\
	RedCap UE	\			31.00	\			20.00	\			0.40
	All UEs	72.00			31.00	47.00			20.00	0.82			0.40

Table D-19: Uplink capacity evaluation for burst traffic (28 GHz, medium loading)

28 GHz, UL, medium loading (30%<RU<50%)													
		50% UPT (Mbps)				5% UPT (Mbps)				Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	25%	50%	100%	0	25%	50%	100%	0	25%	50%	100%
Ericsson	eMBB UE	31.00	31.00	31.00	\	0.60	0.60	0.60	\	1.10			\
	RedCap UE	\	27.00	27.00	18.00	\	0.50	0.50	0.10	\			0.80
	All UEs	31.00	31.00	31.00	18.00	0.60	0.60	0.60	0.10	1.10	1.00	1.00	0.80
MediaTek	eMBB UE	53.00			\	38.00			\	0.80			\
	RedCap UE	\			22.50	\			8.50	\			0.40
	All UEs	53.00			22.50	38.00			8.50	0.80			0.40

Table D-20: Downlink capacity evaluation for full buffer traffic (2.6 GHz, 2Rx RedCap UE)

2.6GHz, DL, 2Rx RedCap, full buffer, total 10 UEs/cell					
		Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	20%	50%	100%
Huawei	eMBB UE	15.10	14.92	14.48	\
	RedCap UE	\	9.63	9.84	10.50
	All UEs	15.10	14.18	12.80	10.50
Nokia	eMBB UE	4.49	4.47	4.43	\
	RedCap UE	\	2.67	2.77	2.84
	All UEs	4.49	4.11	3.60	2.84

Table D-21: Downlink capacity evaluation for full buffer traffic (2.6 GHz, 1Rx RedCap UE)

2.6 GHz, DL, 1Rx RedCap, full buffer, total 10 UEs/cell					
		Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	20%	50%	100%

Huawei	eMBB UE	15.10	15.03	14.87	\
	RedCap UE	\	7.68	7.80	7.87
	All UEs	15.10	13.65	11.49	7.87
Nokia	eMBB UE	4.49	4.47	4.43	\
	RedCap UE	\	2.09	2.17	2.21
	All UEs	4.49	3.99	3.30	2.21

Table D-22: Uplink capacity evaluation for full buffer traffic (2.6 GHz)

2.6 GHz, UL, full buffer, total 10 UEs/cell					
		Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	20%	50%	100%
Huawei	eMBB UE	2.73	2.70	2.61	\
	RedCap UE	\	1.41	1.49	1.54
	All UEs	2.73	2.47	2.14	1.54
Nokia	eMBB UE	2.03	2.01	2.00	\
	RedCap UE	\	1.79	1.78	1.79
	All UEs	2.03	1.97	1.89	1.79

Table D-23: Downlink capacity evaluation for full buffer traffic (4 GHz, 2Rx RedCap UE)

4 GHz, DL, 2Rx RedCap, full buffer, total 10 UEs/cell					
		Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	20%	50%	100%
Huawei	eMBB UE	14.02	13.96	13.66	\
	RedCap UE	\	9.14	9.43	9.68
	All UEs	14.02	14.18	12.80	9.68
Nokia	eMBB UE	4.74	4.73	4.75	\
	RedCap UE	\	2.98	2.89	2.89
	All UEs	4.74	4.38	3.82	2.89

Table D-24: Downlink capacity evaluation for full buffer traffic (4 GHz, 1Rx RedCap UE)

2.6GHz, DL, 1Rx RedCap, full buffer, total 10 UEs/cell					
		Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	20%	50%	100%
Huawei	eMBB UE	14.02	13.88	13.65	\
	RedCap UE	\	6.76	6.92	7.14
	All UEs	14.02	12.91	10.75	7.14
Nokia	eMBB UE	4.74	4.73	4.75	\
	RedCap UE	\	2.25	2.20	2.21
	All UEs	4.74	4.23	3.47	2.21

Table D-25: Uplink capacity evaluation for full buffer traffic (4 GHz)

2.6GHz, UL, full buffer, total 10 UEs/cell					
		Cell avg. SE (bps/Hz)			
	RedCap UE ratio	0	20%	50%	100%
Huawei	eMBB UE	2.54	2.49	2.41	\
	RedCap UE	\	1.35	1.41	1.47
	All UEs	2.54	2.47	2.14	1.47

Nokia	eMBB UE	1.94	1.93	1.93	\
	RedCap UE	\	1.76	1.76	1.75
	All UEs	1.94	1.90	1.84	1.75

Annex E: Company inputs to power saving evaluation in RAN2

E.1 Extended DRX for RRC Inactive and/or Idle

E.1.1 Power saving evaluation in [8]

In order to evaluate the additional power savings that could be achieved by introducing eDRX in NR compared to legacy I-DRX, we use a model based on TR 38.840, scaled to 20MHz for Idle mode operation. We consider two scenarios: 1) High SINR, and 2) Low SINR, as illustrated below:

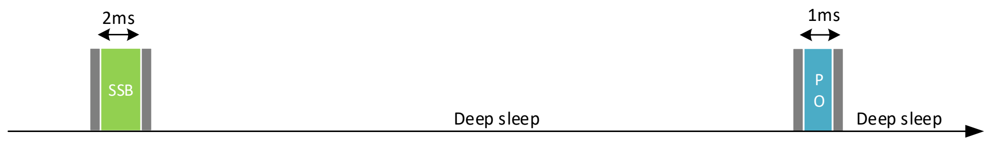

Figure E.1.1-1: Timeline for I-DRX with high SINR

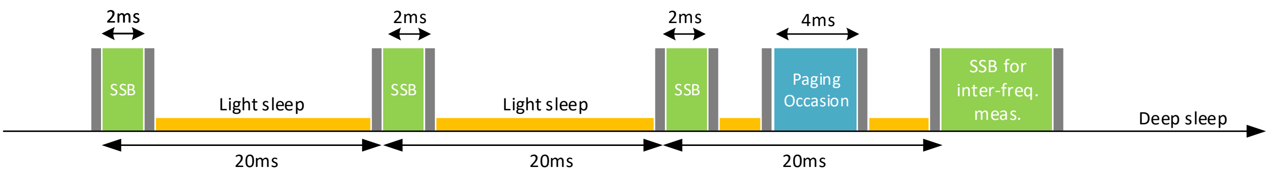

Figure E.1.1-2: Timeline for I-DRX with high SINR

Relative power during various states can be modelled as below:

Table E.1.1-1: Power state modelling for I-DRX

Component Description	Power notation	Relative power	Time notation	Time (ms)
SSB processing	P_{SSB}	50	T_{SSB}	2/4
Intra-frequency neighbor cell measurement	P_{IntraF}	60	T_{IntraF}	2
Paging occasion reception	P_{PO}	50/120 (without/ with PDSCH)	T_{PO}	1/4 (high/ low SINR)
Inter-frequency neighbor cell measurement	P_{Inter}	60	T_{InterF}	5
Micro sleep	P_{MS}	31	T_{MS}	(*)
Light sleep	P_{LS}	18	T_{LS}	(*)
Deep sleep	P_{DS}	0.8	T_{DS}	(*)

(*) The value depends on the power saving scenario adopted

We also define the following energy consumption for the state transition.

Component Description	Energy notation	Energy	Occurrence notation
Micro sleep transition	E_{MST}	0	N_{MST}
Light sleep transition	E_{LST}	100	N_{LST}
Deep sleep transition	E_{DST}	450	N_{DST}

Based on the above timeline and power model, the power consumption for I-DRX with high SINR is given by:

$$P_{IDRX,High\ SINR} = \frac{P_{SSB} \times T_{SSB} + P_{PO} \times T_{PO} + P_{DS} \times (T_{IDRX} - T_{SSB} - T_{PO}) + E_{DST} \times N_{DST}}{T_{IDRX}}$$

For low SINR, it is given by:

$$P_{IDRX,Low\ SINR} = \frac{\begin{array}{c} P_{SSB} \times T_{SSB} + P_{IntraF} \times T_{IntraF} + P_{PO} \times T_{PO} + P_{InterF} \times T_{InterF} + P_{LS} \times T_{LS} \\ +E_{LST} \times N_{LST} + P_{DS} \times (T_{IDRX} - T_{SSB} - T_{IntraF} - T_{PO} - T_{InterF} - T_{LS}) + E_{DST} \times N_{DST} \end{array}}{T_{IDRX}}$$

For eDRX, if we consider the UE to be in deep sleep outside of PTW and consuming power P_{IDRX} (in the formula above) during PTW, the formula for eDRX power consumption becomes:

$$P_{eDRX} = \frac{P_{IDRX} \times L_{PTW} + P_{DS} \times (T_{eDRX} - L_{PTW})}{T_{eDRX}}$$

Where, L_{PTW} is the PTW length.

Some example power savings by introducing eDRX, with different eDRX/I-DRX configurations are summarised in the table below:

Table E.1.1-2: Example power savings that can be achieved with eDRX

Scenario	**$T_{I\text{-}DRX}$ (ms)**	**T_{eDRX} (ms)**	**PTW length (ms)**	**% Savings with eDRX compared to I-DRX**
High SINR	2560	10,485,760	2560	33.83
High SINR	1280	10,485,760	1280	50.56
High SINR	320	10,485,760	320	80.36
Low SINR	2560	10,485,760	2560	56.08
Low SINR	1280	10,485,760	1280	71.86
Low SINR	320	10,485,760	320	91.08

From the evaluation above, it is clear that eDRX brings significant improvements to power consumption, and it is also clear that eDRX concepts and mechanisms such as PTW and extension of paging cycles to hyper-frames that were introduced for LTE/NB-IoT should be re-used in RedCap.

E.1.2 Power saving evaluation in [9]

Assumptions

To evaluate the power saving functionality for RedCap, we used assumptions based on the agreements made in RAN1 WG1 meeting#101e and #102e, see SID status report in RP-201676. We considered the power saving model described in TR 38.840 clause 8. We considered 20 MHz bandwidth in FR1. We assumed half-duplex RedCap devices that have 1 TX and 2 RX antennas with one MIMO layer in UL where MCS 0 is considered for MSG3 and MSG4. We assumed that the RedCap device is powered with 2 AA batteries (capacity is about 2x2000mAh depending on size current discharge) where self-discharging is negligible. It is assumed that the PDCCH monitoring periodicity is 1 ms. No power consumption due to RRM measurements was considered in the evaluation. Also, no coverage recovery is considered in the evaluation. We assumed the SSB synchronization time, i.e. if the sleep between two wakeup periods is extensively long, so there should be some power consumption accounted for to synchronize. We have taken an optimistic approach in determining the SSB period, MIB and SIB acquisition times, and average synchronization time, assuming the power consumption defined in 8.1.1 and 8.1.3 of TR 38.840 for SSB based synchronization tracking. We considered the packet inter-arrival time to model data traffic generation. In addition to the IAT specified in RP-201676, we have also evaluated battery lifetime for a number of IATs. The Inter-arrival rate is considered for uplink traffic.

Results

The evaluation results are shown in figure E.1.2-1. Figure E.1.2-1 shows the battery lifetime gain for different eDRX cycles and different inter-arrival times. The inter-arrival time in this figure is represented in the order of minutes. If one looks at the inter-arrival time of 1 min, when the eDRX cycle goes beyond 64 min, further extension of the eDRX cycle lengths does not significantly increase the lifetime. It is worth to note that the length of the eDRX cycle extension gain largely depends on the packet inter-arrival time. The IAT above 300 minutes also has nominal battery lifetime gain. Looking at the result, regardless of the payload's inter-arrival time, one can see that with a DRX cycle up to 10.24s a battery lifetime of around 6 to 8 months can be achieved for a device in RRC_IDLE. With an eDRX cycle above 10.24s, RRC_INACTIVE has 25% higher gain than the RRC_IDLE state due to the reduced signalling load between gNB and UE. It is worth to note that the presented power saving gains may be optimistic due to the simplistic assumptions made during the evaluation.

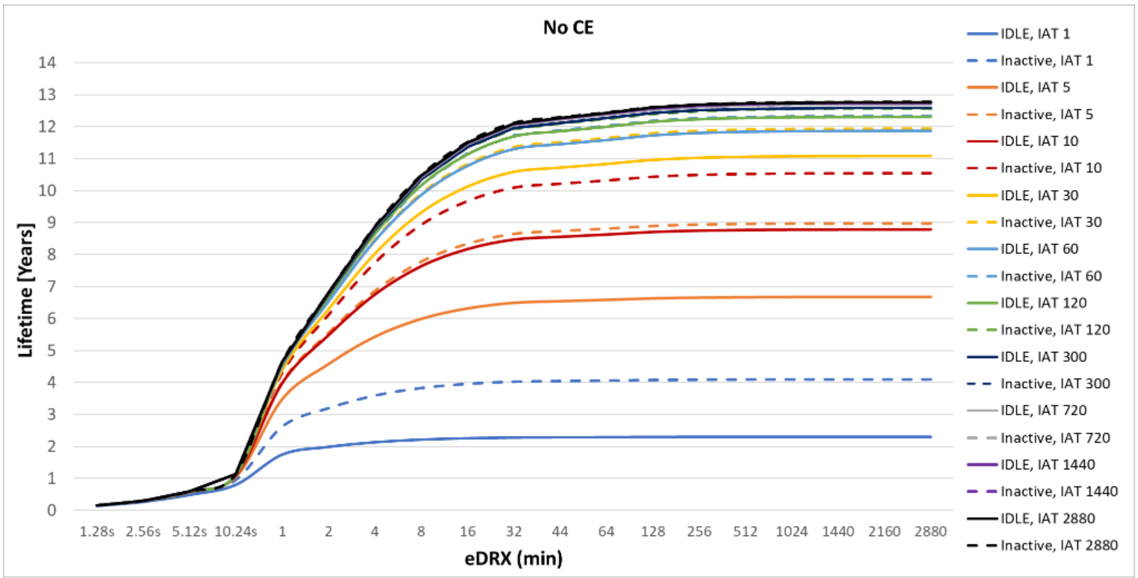

Figure E.1.2-1: RedCap UE battery lifetime in RRC_INACTIVE and RRC_IDLE state.

In the SID use case with Industrial Wireless Sensor Network (IWSN), the UE battery is expected to last at least a few years. From our result, one can see that eDRX longer than 10.24s is required to have a UE battery life of "at least a few years" for both RRC_IDLE and RRC_INACTIVE cases. Based on the results, we recommend RAN2 to extend the eDRX cycle for both RRC_IDLE and RRC_INACTIVE beyond 10.24 seconds.

Analysis

Length of extension for eDRX in RRC_IDLE

From the results we can see that it is reasonable to extend the eDRX duty cycle to 64 minutes (1.06 hours). In LTE a 10-bit H-SFN is defined in SI for eDRX. If we adopt the LTE-MTC mechanism for NR then the H-SFN signalling in SIB1 limits the eDRX cycle length to 10845.76 seconds or 2.91 hours, see table E.1.2-1.

Following agreement was made in RAN2#111-e,

For RRC_IDLE and/or RRC_INACTIVE, if the NR DRX cycle range is extended beyond 10.24s, the LTE eDRX mechanism beyond 10.24s (e.g., PTW, PH, etc.) is used as baseline when NR eDRX cycle is configured beyond 10.24s.

Table E.1.2-1: SFN and H-SFN bit mapping

Name	Range	Synchronization Method	Max Time in sec
SFN	0~1023	MIB(PBCH)r	10.24
H-SFN	0~1023	SIB1	10485.76 (=2.91 hour)

Hence, it is likely to introduce 10 H-SFN bits for NR RedCap as well. In this case, even if the exact use cases would be fine with eDRX extension up to 64 minutes. Unless there is a good technical reason, we should not limit the configuration possibility.

Length of extension for eDRX in RRC_INACTIVE

During the state transition RRC_INACTIVE state can reduce control signalling by 57%~63% compared to RRC_IDLE. In case the state transition occurs in a new gNB with in an assigned paging area then there is ~88% lower signalling cost with RRC_INACTIVE compared to RRC_IDLE (Hailu, Sofonias, Mikko Saily, and Olav Tirkkonen. "RRC State handling for 5G." IEEE Communications Magazine 57.1 (2018): 106-113). On top of that introducing eDRX in RRC_INACTIVE state can be very effective from battery lifetime perspective. As currently specified, RRC_INACTIVE with short DRX cycle cannot be considered as a good state if the UE wants to save power e.g., for some RedCap use cases such as IWSN. Moreover, the eDRX cycle length extension for RRC_INACTIVE beyond 10.24s may bring value for other WIs such as Small data enhancement and future WIs like LPWAN in NR. Hence, we should support the extension of the DRX cycle for RRC_INACTIVE mode.

Table E.1.2-2: RRC_INACTIVE battery life gain in different use cases.

Use case	Mean IAT	Payload Size	RRC_IDLE Battery Lifetime gain above 10.24s	RRC_INACTIVE Battery lifetime gain above 10.24s
Video Surveillance	≤1s	250 Bytes	up to 3.5%	up to 7%
Wearables	≤2s	72 Bytes	up to 7%	up to 16%
Industrial Wireless Sensor	100ms	72 Bytes	up to 0.38%	up to 1%
	1 min		up to 180%	up to 297%
	5 min		up to 340%	up to 419%

Table E.1.2-2 illustrates the battery life gain in RRC_IDLE and RRC_INACTIVE state, with 2 mins eDRX cycle compared to 10.24s eDRX, for the RedCap SID defined used cases and agreed traffic model in RP-201676. As shown in the table the battery life gain for eDRX above 10.24s in RRC_INACTIVE shows significant gain compared to RRC_INACTIVE with same eDRX cycle. For instance, in IWSN case, if we increase the IAT to 1 min up to 65% battery lifetime gain is possible in RRC_INACTIVE in comparison of RRC_IDLE with eDRX beyond 10.24s. Additionally, please note that IAT increment to 5 min also shows significantly better battery life gain in RRC_INACTIVE compared to RRC_IDLE.

E.2 RRM relaxation for stationary devices

E.2.1 RRM relaxation evaluation in [9]

Figure E.2.1-1 shows how the average device power consumption is reduced with increased interval between RRM measurements on neighbour cells. The power calculation is performed with the model in TR 38.840. At some point in time the effect of further Increase of the interval between measurements is insignificant. The red dashed line in Figure E.2.1-1 at one hour represents the condition where a device, which is not at cell edge and low mobility, may skip measurements for an hour. Note that even before an interval of one hour) the power consumption has almost reached its minimum. It is likely that the shape of the curve is not affected by UE's RRC state, however, the Rel-16 functionality mentioned only refers to a device in RRC_IDLE or RRC_INACTIVE.

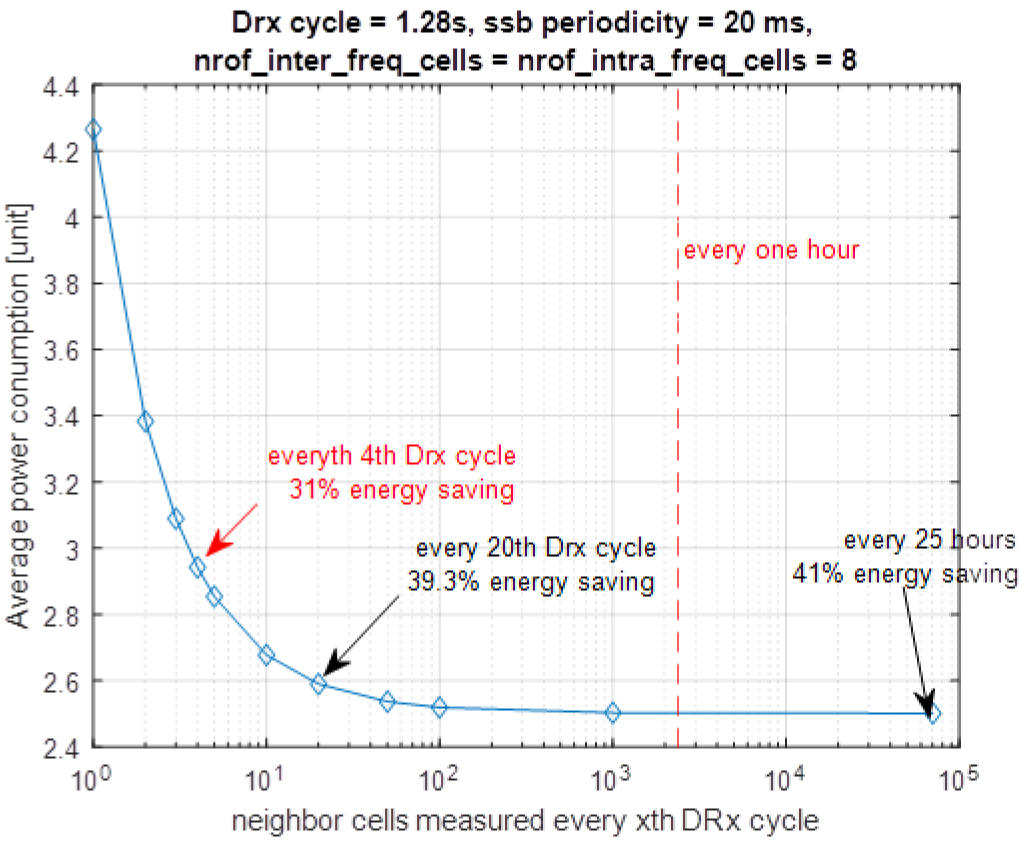

Figure E.2.1-1: Effect of relaxation on average power consumption.

E.2.2 RRM relaxation in idle/inactive mode for serving cell in [10]

Simulation cases:

To evaluate the power saving gain of serving cell RRM relaxation for RedCap UEs in idle and inactive mode, the following 6 cases are modeled and evaluated, which are classified as three scenarios: Rel-15/Rel-16 paging monitoring mechanism, WUS is applied for paging monitoring, including with or without gap between WUS and SSB.

Note: The intention to consider WUS together here is to provide the power saving gain in different scenarios (e.g. with or without WUS). As WUS in idle mode may be introduced in Rel-17 power saving, the following simulation results the power saving gain for RRM relaxation for use cases with and without WUS, which shows that there is still power saving gain even in the case with WUS.

Note 1: No neighbour cell RRM relaxation is performed in this simulation.

Note 2: FFS on whether WUS is applicable to Redcap devices.

- **Scenario 1**: When Rel-15/Rel-16 paging monitoring mechanism is adopted:
  - **Case1**: No relaxation on serving cell RRM is applied, i.e. UE needs to measure one SSB and monitor one Paging Occasion (PO) per DRX cycle as legacy.
  - **Case2**: RRM relaxation with 4x on serving cell, i.e. UE needs to measure one SSB every four DRX cycles and monitor one PO per DRX cycle. As a result, power consumption can be saved by skipping the monitoring of 75% SSBs and long deep sleep duration per DRX cycle can be achieved.
- **Scenario 2**: WUS is applied for paging monitoring, PO monitoring is only required when WUS is received, which occurs with low probability. It is assumed there is no time interval between WUS and SSB.
  - **Case3:** No relaxation on serving cell RRM is applied, i.e. UE needs to measure one SSB and monitor one WUS per DRX cycle.
  - **Case4:** RRM relaxation with 4x on serving cell, i.e. UE needs to measure one SSB every four DRX cycles and monitor one WUS per DRX cycle.
- **Scenario 3**: WUS is applied for paging monitoring, PO monitoring is only required when WUS is received, which occurs with low probability. The time interval between WUS and SSB is assumed as 3ms and micro sleep is performed between WUS and SSB.
  - **Case5:** No selaxation on serving cell RRM is applied, i.e. UE needs to measure one SSB and monitor one WUS per DRX cycle.
  - **Case6:** 4 RRM relaxation with 4x on serving cell, i.e. UE needs to measure one SSB every four DRX cycles and monitor one WUS per DRX cycle.

Simulation Assumptions:

- The paging rate is 10%, referring to that 10% POs indicating UE to receive paging PDSCH.
- The time interval between a SSB and its relative PO is 10ms.
- $P_{\mathrm{WUS}}= P_{\mathrm{PO}} = P_{\mathrm{SSB}}$ =50 power units/slot, where P_{WUS} , P_{PO} and P_{SSB} represent the power consumpation for each WUS, PO and SSB reception respectively. The power consumpation is scaled to a 20MHz receiving bandwidth from the 100MHz power model in TR 38.840.
- $T_{\mathrm{WUS}}= T_{\mathrm{SSB}}$ = 2ms, where T_{WUS} and T_{SSB} denote the duration of WUS and SSB.
- UEs are assumed as "true" stationary.
- More detailed power consumption model could be found in TR 38.840.

Simulation Results and Analysis:

The power saving gain are summarized in Table E.x.1.

Table E.x.1: Power saving gain of RRM relaxation for serving cell in high SINR case

Cases		**Average relative power per slot**	**Power saving gain or RRM relaxation**
w/o WUS	Case 1	1.6975	**13.4%** (case 2 over case 1)
	Case 2	1.4709	
w/ WUS **no gap between WUS and SSB**	Case 3	1.5367	**3.6%** (case 4 over case 3)
	Case 4	1.4814	

w/ WUS **the gap between WUS and SSB is 3ms**	Case 5	1.627	**8.3%** (case 6 over case 5)
	Case 6	1.4914	

Most of the gain are achieved by skipping SSB measurement with RRM relaxation. In addition, skipping SSB measurement extends the time interval between adjacent wake-up, leading to more energy efficient sleep, e.g. using one long deep sleep to replace serval micro sleeps.

3.6%~13.4% power saving gain is observed when 4 times RRM relaxation for serving cell is adopted by high SINR for idle/inactive UE.

Note: The impact on PDCCH and PDSCH decoding as a results of not monitoring SSBs are not captured in this simulation.

E.2.3 RRM relaxation in connected mode in [10]

RRC_Connected UEs is required to derive one L3 sample per 200ms at the maximum. Such frequent measurement may not be always necessary for stationary or low mobility RedCap UEs, e.g. some fixed industry sensors. In addition, UE is required to perform measurement on too many inter-frequency layers and cells per frequency layers. Related RRM relaxation enhancements has been evaluated in Rel-16 and the results come from Power saving SI TR [6]:

- By increasing measurement period 4 times for RRC_Connected UEs, 11.1% - 26.6% power saving gains are observed, at the cost of an increase of handover failure rate from 0% to 0.26% for stationary or low mobility (e.g., 3km/h) case.
- By reducing the number of measured cells for RRC_Connected UEs, 1.8% - 21.3% power saving gain can be observed. In addition, 26.43% - 37.5% power saving gain is shown by assuming that UE can limit the processing for measurement within a constrained time period and/or with reduced complexity.
- By reducing the number of measured inter-frequency layers can provide 21%~38% power saving gain for RRC_Connected UEs.

E.2.4 RRM relaxation evaluation in [11]

The following table shows the average power consumption and power saving gain when further expand the measurement interval from using three times scaling factor to stopping measurement for 1 hour. The power calculation is performed with the model in TR 38.840. For DRX cycle =1280ms, power saving gain of 25.17% can be achieved.

Table E.2.x-1 Power saving gain achieved by further expanding the measurement interval.

	DRX cycle = 1280ms
Relative power consumption: **3 times relax [unit]**	2.0374
Relative power consumption: **stop measurment for 1 hour [unit]**	1.5246
Power saving gain	25.17%

The measurement time reduction is further illustrated in Figure E.2.x-2 by reducing the measurement time duration discussed above, with the typical SMTC window with length 5ms (i.e. half frame) and periodicity 20ms. We assume that the maximum number of SS/PBCH blocks per half frame equals to 8, so the average time duration for detecting/measuring one SSB is 0.625ms. The time reduction and power saving gain are given in the Table E.2.x-3 as below. Moreover, the power saving gain can be obtained with few performance degrading since only unnecessary SSBs detection/measurement are avoided.

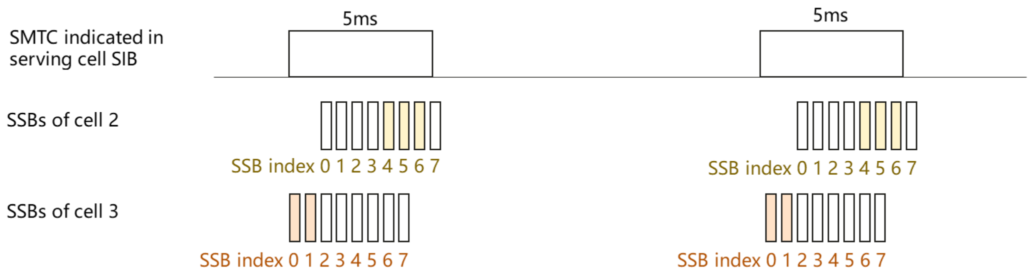

Figure E.2.x-2 The measurement time reduction

Table E.2.x-3 Time reduction and power saving gain

<table>
<tr><th colspan="2"></th><th>Time for measurement within 20ms</th><th>Time reduction</th><th>Power saving gain
According to the power model in TR 38.840, the power consumption is calculated during one DRX cycle = 1280ms</th></tr>
<tr><td colspan="2">Mapping between serving SSB index and the associated measurement time pattern during the SMTC window is not configured
Full SMTC window are measured</td><td>5ms</td><td>Baseline</td><td>The baseline power consumption is 2284.5 unit (NOTE)</td></tr>
<tr><td rowspan="2">Mapping between serving SSB index and the associated measurement time pattern during the SMTC window is configured</td><td>UEs with only 3 neighbor SSBs (Cell 2) to be measured</td><td>1.875ms</td><td>62.5%</td><td>Power consumption is 1975.125 unit
Power saving gain is 13.54%</td></tr>
<tr><td>UEs with only 2 neighbor SSBs (Cell 3) to be measured</td><td>1.25ms</td><td>75%</td><td>Power consumption is 1913.25 unit
Power saving gain is 16.25%</td></tr>
<tr><td colspan="5">NOTE: Considering one slot for synchronization, one slot for paging reception, and time duration for serving SSB measurement. The time interval between synchronization and serving SSB measurement is 20ms. The average light sleep time is 19ms. Considering the neighbor SSB measurement is right after the serving SSB measurement, the measurement time is 5ms. The deep sleep time is 1280-0.5-0.5-19-0.5-5=1254.5ms. The power consumption for synchronization, paging reception, serving SSB measurement and measurement for SMTC window is 100 unit per millisecond. The power consumption for light sleep and deep sleep are 20 unit and 1 unit per millisecond respectively.</td></tr>
</table>

The following table shows the average power consumption and power saving gain when further expand the measurement interval from using three times scaling factor to stopping measurement for 1 hour. The power calculation is performed with the model in TR 38.840. For DRX cycle =1280ms, power saving gain of 25.17% can be achieved. Therefore, it is proposed to further enhance RRM measurement relaxation by expanding the scenario of performing "stop measurement for 1 hour" for stationary UEs.

Table E.2.x-4 Power saving gain achieved by further expand the measurement interval.

	DRX cycle = 1280ms
Relative power consumption: 3 times relax [unit]	2.0374
Relative power consumption: stop measurment for 1 hour [unit]	1.5246

Power saving gain	25.17%

Annex F: Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2020-06	RAN1#101-e	R1-2004962				Skeleton	0.0.1
2020-08	RAN1#102-e	R1-2005233				Updated skeleton with endorsed clauses 4 & 5 (R1-2005233) and RAN2-led changes (agreed in R2-2007366)	0.0.2
2020-11	RAN1#103-e	R1-2009490				Updated skeleton with RAN1 endorsed changes (R1-2009490)	0.0.3
2020-11	RAN1#103-e	R1-2009850				Updated with RAN1 endorsed changes (R1-2009850)	0.1.0
2020-12	RAN#90-e	RP-202705				Presented to RAN#90-e (RP-202705)	1.0.0
2021-03	RAN1#104-e	R1-2102270				Updated with RAN1 endorsed changes (with change tracking in R1-2102269) including RAN2 endorsed changes (R2-2102056)	1.1.0