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| 3GPP TR 38.875 V0.0.x (2020-yy) |
| 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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# 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:

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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-193238: "New SID on support of reduced capability NR devices".

# 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-M 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-M/NB-IoT) but lower than URLCC 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 coverage enhancements study is discussed and resolved in RAN#87 or later.

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

## 6.2 Evaluation methodology for UE power saving

## 6.3 Evaluation methodology for coverage recovery

## 6.4 Evaluation methodology for performance impacts

# 7 UE complexity reduction features

## 7.1 Introduction to UE complexity reduction features

## 7.2 Reduced number of UE Rx/Tx antennas

### 7.2.1 Description of feature

### 7.2.2 Analysis of UE complexity reduction

### 7.2.3 Analysis of performance impacts

### 7.2.4 Analysis of coexistence with legacy UEs

### 7.2.5 Analysis of specification impacts

## 7.3 UE bandwidth reduction

### 7.3.1 Description of feature

### 7.3.2 Analysis of UE complexity reduction

### 7.3.3 Analysis of performance impacts

### 7.3.4 Analysis of coexistence with legacy UEs

### 7.3.5 Analysis of specification impacts

## 7.4 Half-duplex FDD operation

### 7.4.1 Description of feature

### 7.4.2 Analysis of UE complexity reduction

### 7.4.3 Analysis of performance impacts

### 7.4.4 Analysis of coexistence with legacy UEs

### 7.4.5 Analysis of specification impacts

## 7.5 Relaxed UE processing time

### 7.5.1 Description of feature

### 7.5.2 Analysis of UE complexity reduction

### 7.5.3 Analysis of performance impacts

### 7.5.4 Analysis of coexistence with legacy UEs

### 7.5.5 Analysis of specification impacts

## 7.6 Relaxed maximum number of MIMO layers

### 7.6.1 Description of feature

### 7.6.2 Analysis of UE complexity reduction

### 7.6.3 Analysis of performance impacts

### 7.6.4 Analysis of coexistence with legacy UEs

### 7.6.5 Analysis of specification impacts

## 7.7 Relaxed maximum modulation order

### 7.7.1 Description of feature

### 7.7.2 Analysis of UE complexity reduction

### 7.7.3 Analysis of performance impacts

### 7.7.4 Analysis of coexistence with legacy UEs

### 7.7.5 Analysis of specification impacts

## 7.8 Combinations of UE complexity reduction features

### 7.8.1 Description of feature combinations

### 7.8.2 Analysis of UE complexity reduction

### 7.8.3 Analysis of performance impacts

### 7.8.4 Analysis of coexistence with legacy UEs

### 7.8.5 Analysis of specification impacts

# 8 UE power saving features

## 8.1 Introduction to UE power saving features

## 8.2 Reduced PDCCH monitoring

### 8.2.1 Description of feature

### 8.2.2 Analysis of UE power saving

### 8.2.3 Analysis of performance impacts

### 8.2.4 Analysis of coexistence with legacy UEs

### 8.2.5 Analysis of specification impacts

## 8.3 Extended DRX for RRC Inactive and/or Idle

### 8.3.1 Description of feature

In LTE / EPC, the UE may be configured with an extended DRX (eDRX) cycle. The UE may operate in extended DRX only if the UE is configured by upper layers and the cell indicates support for eDRX in System Information (no SI indication for NB-IoT). In RRC\_IDLE the eDRX cycle has maximum value of 2621.44 seconds (43.69 minutes) (for NB-IoT the maximum is 10485.76 seconds or 2.91 hours). Hyper SFN (H-SFN) is broadcasted by the cell and increments by one when SFN wraps around. Paging Hyperframe (PH) refers to the H-SFN in which the UE starts monitoring paging DRX during a Paging Time Window (PTW).

For RedCap UEs in NR, extended DRX cycles can be introduced at least up to 10.24 s for both RRC\_IDLE and RRC\_INACTIVE. For RRC\_IDLE, the baseline for possible extension of eDRX cycles is up to 2621.44 s and longer values (e.g. 10485.76 s) can be further considered.

If extension beyond 10.24 s is specified, similar mechanism as in LTE is expected to be feasible, at least for eDRX cycles longer than 10.24 s, including use of H-SFN, PH and PTW. For RedCap UEs in RRC\_IDLE or RRC\_INACTIVE, if the eDRX cycle is less than 10.24 s, paging monitoring does not use PTW and PH, if any. If the eDRX cycle is equal to 10.24 s in RRC\_IDLE, among the solution options the starting assumption is that the paging monitoring does not use PTW and PH.

Lower values than 5.12 s for eDRX cycle for UEs in RRC\_IDLE and RRC\_INACTIVE, such as 2.56 s, can be considered.

### 8.3.2 Analysis of UE power saving

### 8.3.3 Analysis of performance impacts

### 8.3.4 Analysis of coexistence with legacy UEs

### 8.3.5 Analysis of specification impacts

## 8.4 RRM relaxation for stationary devices

### 8.4.1 Description of feature

The study includes objective on RRM relaxation for stationary RedCap devices. Considering the mobility status of the target RedCap UE, the stationarity property is not limited to a strictly fixed UE, but such UE can also have low mobility even during periods of time it is “stationary”.

The RRM relaxation of RedCap UEs is triggered based on measurements, as a baseline. Other triggering conditions, for example for truly stationary devices at fixed location are not excluded, e.g. the possibility to signal “stationary property” explicitly can be studied further.

R16 NR RRM relaxation procedures are taken as a baseline to study further enhancements of neighbor cell RRM relaxation for RedCap UEs in RRC IDLE and RRC\_INACTIVE.

### 8.4.2 Analysis of UE power saving

### 8.4.3 Analysis of performance impacts

### 8.4.4 Analysis of coexistence with legacy UEs

### 8.4.5 Analysis of specification impacts

# 9 Coverage recovery features

## 9.1 Introduction to coverage recovery features

## 9.2 Coverage recovery feature X

### 9.2.1 Description of feature

### 9.2.2 Analysis of coverage recovery

### 9.2.3 Analysis of performance impacts

### 9.2.4 Analysis of coexistence with legacy UEs

### 9.2.5 Analysis of specification impacts

# 10 Definition and constraining of reduced capabilities

## 10.1 Definition of reduced capabilities

### 10.1.1 Description of feature

As a baseline, the existing UE capabilities framework is used to indicate the capabilities of reduced capability UEs. The UE reports its UE radio access capabilities which are static at least when the network requests.

Network should be able to control UE accesses and differentiate them from legacy 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 legacy R15/R16 and non-Redcap R17 UEs.

The RedCap UE capabilities can be categorized as:

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

For capability signaling of RedCap UEs, the following scenarios are possible, however feasibility and 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 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:

o Mandatory features for non-RedCap UE that are not supported for RedCap UE.

o Mandatory features for non-RedCap UE that are optional for RedCap UE.

o Mandatory features for non-RedCap UE that are supported for RedCap UE but with different value.

o Optional features for non-RedCap UE that are not supported for RedCap UE.

o Optional features for non-RedCap UE that are mandatorily supported for RedCap UE.

For a RedCap device type, define new signaling fields in UE Capability for the features that are mandatory w/o capability signaling for non-RedCap UEs but are optional for Redcap UEs, or mandatory with capability signaling for non-RedCap UEs but with different value for RedCap UEs.The possible new introduced signaling fields for RedCap UEs should not apply to non-RedCap or legacy UEs for mandatory features w/o capability signaling.

Alternative 2:

* Directly define the UE capabilities required for RedCap devices, including:

o Mandatory features for RedCap UEs (defined in specification).

o Optional features for Redcap UEs (introduce signaling 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 Section 11.1 on UE identification). The following options, which need not be mutually exclusive, can be considered for further analysis and down-selection:

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

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

Option 3: The network identifies RedCap UEs based on identification solution (see Section 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.

Editor’s note: FFS further changes to above options and possible options which are not yet captured.

Editor’s note: The details and numbers of device types is FFS and discussion should be coordinated between RAN1/RAN2.

### 10.1.2 Analysis of coexistence with legacy UEs

### 10.1.3 Analysis of specification impacts

## 10.2 Constraining of reduced capabilities

### 10.2.1 Description of feature

The study also includes objective on how to ensure RedCap UEs are only used for intended use cases. The following potential solutions can be considered (the solutions need not be mutually exclusive):

* Option 1: RRC Reject based approach

RAN can reject an RRC connection establishment attempt for a RedCap UE if the service the UE requested is not allowed for the RedCap UE. The rejection can be done, 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 RRC connection setup, UE indicates it is a RedCap UE to core network, e.g.

* + UE includes this indication in NAS signaling message to core network; or
	+ UE informs this indication during its RRC connection establishment procedure to RAN; RAN then informs core network of UE’s RedCap type in Initial UE Context message to core network.

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

The decision 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).

Editor’s note: FFS further changes to above options and possible options which are not yet captured.

### 10.2.2 Analysis of coexistence with legacy UEs

### 10.2.3 Analysis of specification impacts

# 11 UE identification and access restrictions

## 11.1 UE identification

### 11.1.1 Description of feature

The network needs to identify RedCap UEs in order to ensure such UEs can operate properly in the cell, to schedule messages properly and to possibly to restrict UE’s access to the network.

The feasibility of the different solutions on when such information should be available to the network depends on whether there is a need for network to have the information that the UE is a RedCap UE prior to scheduling a particular message.

The following options for including an indication of have been discussed:

- Option 1: Msg1 (Separate initial UL BWP or PRACH partitioning)

- Option 2: Msg3

- Option 3: Msg5

- Option 4: MsgA for 2 step RA

Analysis of Option 1: …

Analysis of Option 2: Whether it is needed for the network to identify a RedCap UE prior to or during reception of Msg3 depends on (FFS further details and pending RAN1 discussion) whether Msg4 and/or Msg5 need special handling and whether there is a need to provide opportunity for RRC to reject connection establishment based on that the UE is a RedCap UE.

Analysis of Option 3: …

Analysis of Option 4: …

### 11.1.2 Analysis of coexistence with legacy UEs

### 11.1.3 Analysis of specification impacts

## 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.

For RedCap UEs, an indication in broadcast system information can be used to indicate whether a RedCap UE can camp on the cell or not.

Unified access control framework is specified in TS 22.261 and it applies to all UEs in RRC\_IDLE, RRC\_CONNECTED and RRC\_INACTIVE for NR. This mechanism can also apply to RedCap UEs to control RedCap UEs accesses to the network.

Editor’s note: FFS on details of above, e.g. explicit or implicit indication in SI, details of UE access identifier and/or access categories for reduced capability UEs.

### 11.2.2 Analysis of coexistence with legacy UEs

### 11.2.3 Analysis of specification impacts

# 12 Conclusions

Annex <A>:
<Title>

# A.1 <Heading>

Annex <Y>:
Bibliography

The following material, though not specifically referenced in the body of the present document (or not publicly available), gives supporting information.

<Publication>: "<Title>".

Annex <Z>:
Change history

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| --- |
| **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 |