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RedCap

ADVANCE YOUR CAREER WITH 5G

Reduced Capability (RedCap) NR

RedCap NR

- RedCap is Reduced Capability.
- It is being used in the NR technology.
- NR-RedCap will start to appear in 5G networks i.e from Rel 16 and above.
- This will address the market segment of “Smart IoT” applications which will require mid-range speeds.

RedCap NR

- RedCap is initially known as NR-Lite.

RedCap NR

- This mid-range speed is corresponding to the current LTE capabilities.
- Devices connected to the NR-RedCap channels could enjoy similar bandwidth as standard 4G LTE connection without adding a significant load to the network.
- RedCap NR is helping to expand the NR device ecosystem which will enable the growth of even more 5G use cases.

RedCap NR

- The flexibility and scalability of 5G NR makes it possible to introduce timely enhancements to address the new use cases.
- It helps to extend the 5G ecosystem and connect more and more devices to the network.
- There is also a NR support for Reduced Capability devices.
- The introduction of RedCap NR devices can facilitate the expansion of the nR device ecosystem to cater various use cases that are not being served by the current NR specifications.

RedCap NR

- NR RedCap (Reduced Capability) will address mid-speed Smart IoT apps.
- These applications have higher connectivity demands.
- With the increasing demand for LPWA (Low Power wide area networks) for different industrial applications.
- LTE CatM and NB-IoT technologies emerged as the solution for many deployments.

RedCap NR

- NB-IoT technology is designed to keep the power consumption at a minimum and it can operate on the sub-GHz spectrum.

- LTE-M uses higher bands and also supports SMS and voice applications.

- Both NB-IoT and LTE-M are certified 5G technologies.

RedCap NR

- NR-RedCap will start to appear in 5G networks.
- It will address the market segment of “smart IoT” applications which requires mid-range speeds as compared to LTE capabilities.
- Devices connected to the NR-RedCap could enjoy the similar bandwidth as a standard 4G LTE connection without adding load to the network.

RedCap NR

- These new 5G standards applies to various devices like different wearables like smart watches, wearables medical devices etc.

- For different industrial applications, it allows for the different IoT sensors and various other industrial devices that require more bandwidth that catM and NB-IoT can provide.

UE type for RedCap

UE type for RedCap

- The existing UE features and the capability framework as the baseline, there are two alternatives which are defined as:

- Alternative 1: stick to the NR framework which would be just added NR features with the NR capability reporting framework.

- Alternative 2: it defines a field for reporting the device type and the corresponding set of capability parameters with the pre-defined parameters.

UE type for RedCap

- The RedCap framework may include both the traditional feature/ feature group description and all additional recommended features across Rel-15 to Rel-17.

- For this, various proposals are defined as:

UE type for RedCap

- Proposal 1: the reduced capabilities can base on existing UE capability signalling framework.

- Proposal 2: further discussion of the required changes to the existing UE capabilities, or need for the new components based on the output of the SI.

- Proposal 3: device type is used as an additional mechanism on top of explicitly signalling all the UE capabilities as in legacy NR.

UE type for RedCap

- Proposal 4: the signalling framework supports multiple UE types for future-proof in terms of extendibility.

- Proposal 5: A UE type is linked to a UE capability level, i.e a given set of reduced UE capabilities.

- Proposal 6: further discussion that whether a UE capability level can be linked to more than one UE types.

UE features for different use cases

Features list based on the UE type

Industrial sensors

list	General	Safety related sensors
Maximum number of (DL) MIMO layers	1	1
Tx antenna	1	1
Rx antenna	2	2
Maximum Modulation order	FFS	FFS

UE features for different use cases

Features list based on the UE type

Industrial sensors

list	General	Safety related sensors
Bandwidth	FFS	FFS
UE processing time	More Relaxed N1/N2	FFS
HD-FDD	FFS	FFS
Others, e.g	HARQ is baseline	Repetition is baseline

UE features for different use cases

Video Surveillance

list	Economic video	High-end video
Maximum number of (DL) MIMO layers	1	1
Tx antenna	1	1
Rx antenna	2	2
Maximum Modulation order	FFS	FFS

UE features for different use cases

Video Surveillance

list	Economic video	High-end video
Bandwidth	FFS	FFS
UE processing time	More Relaxed N1/N2	FFS
HD-FDD	FFS	FFS
Others, e.g	Consider BWP framework and CG	Mobility : stationary or low

UE features for different use cases

Wearables

list	Low-end	High-end
Maximum number of (DL) MIMO layers	1	2 for FR1, 1 for FR2
Tx antenna	1	1
Rx antenna	QPSK	64QAM for FR1 DL, QPSK or 16QAM for FR2 DL
Maximum Modulation order	FFS	FFS

UE features for different use cases

Video Surveillance

list	Low-end	High-end
Bandwidth	FFS	FFS
UE processing time	More Relaxed N1/N2	FFS
HD-FDD	FFS	FFS
Others, e.g	Consider Power savings features	

UE type for RedCap

UE type for RedCap

- Considering that a maximum UE bandwidth of 20 MHz is supported for FR1, the RedCap NR devices can support all the current CORESET#0 configuration.

- This configuration is explained in 3GPP TS38.213

- The default scheduling and feedback timing and low modulation order is used during the initial access.

UE type for RedCap

- All the RedCap UE's can realize initial access.
- With the capability report, gNB can provide UE specific configuration corresponding to its capability to realize low UE cost, low complexity etc.
- Another way is to define the explicit UE categories.
- By this way, gNB can distinguish UE capability in an early phase.

UE type for RedCap

- Both 50 Mhz and 100 MHz maximum UE bandwidth will be studied for FR2, the network can configure separate initial BWPs for RedCap devices with different capabilities.

- E.g for high-capability devices, the 100 MHz initial BWP of eMBB/URLLC can be reused for initial access.

- For devices with lower capabilities, they can access through a initial BWP with bandwidth of 50 MHz.

UE type for RedCap

- For the specification of device type, RedCap UE's can be defined through UE capability signaling, or based on UE feature sets.

- Two RedCap UE types are acceptable, with one type for low-end RedCap UE's and the other for high-end UE's.

- In NR, a UE is characterized by a set of capabilities and UE categories are not used to differentiate between the UE's.

UE type for RedCap

- For the specification of device type, RedCap UEs can be defined through UE capability signalling or based on the UE feature sets.
- Two RedCap UE types are accessible, with one type for low-end RedCap UEs and the other for high-end RedCap UE's.
- It is not desirable to have too many RedCap UEs types, which will bring specification complexity and market fragmentation.

UE type for RedCap

- In NR, a UE is characterized by a set of capabilities and UE categories are not used to differentiate between the UEs.

- Given the diverse set of requirements and use cases for RedCap UE’s, it may not be feasible to extend the NR framework to include all the capabilities for RedCap UEs.

UE type for RedCap

To define the RedCap UE's two options may be considered:

- Reuse the NR framework by introducing restrictions on the number of potential capability combinations.

- Define a new framework with new device types

Device types

Device types

Proposal 1: introduce two RedCap UE categories/types, one is to cover the low-end use cases, the other is to cover the high-end use cases:

- Type 1 RedCap UEs for industrial sensors, economic video, low-end wearables use cases

- Type 2 RedCap UEs for high-end wearables and high-end video surveillance use cases

Device types

Device type / Category	Use cases	Peak data rate	Rx/Tx antenna	Bandwidth
Type 1 (RedCap) Corresponding to LTECat1 bis)	Industrial sensors, economic video, low-end wearable	10 mbps in DL 5 mbps in UL	1Rx/1Tx	20 MHz
Type 2 (RedCap) Corresponding to LTE 4)	High-end video surveillance, high-end wearable	150 mbps in DL 50 mbps in UL	1Rx,2Rx,1Tx	20 MHz and above

Device types proposal

- Proposal 1: UE type for reduced capability NR devices can be defined based on the baseline maximum UE bandwidth for initial access.

- Proposal 2: for reduced capability NR devices

  For FR1, 20 MHz maximum UE bandwidth is considered for initial access. In connected mode, 20 MHz and another maximum UE bandwidth larger than 20 MHz can be considered.

Device types proposal

- Proposal 1: UE type for reduced capability NR devices can be defined based on the baseline maximum UE bandwidth for initial access.

- Proposal 2: for reduced capability NR devices

  For FR2, single UE category with 100 MHz UE bandwidth is considered for initial access and connected mode.

Reduced Device Capabilities

Reduced Device capabilities

- Bandwidth reduction, reducing the number of MIMO layers, and the relaxation of the maximum DL modulation order all help reduce the baseband complexity.

- Reducing the minimum number of required receive branches and allowing half-duplex (HD) operations in all bands help to reduce the bill of the material cost in terms of antenna and RF components.

Reduced Device capabilities

	FR 1	FR 1
	Baseline device	RedCap device
Maximum device bandwidth	100 MHz	20 MHz
Minimum number of device receive branches	2 or 4, depending on the frequency band	1 for bands where a baseline NR device is required to have 2 TBD: 1 or 2 for bands where a baseline NR device is required to have 4

Reduced Device capabilities

	FR1	FR1
	Baseline device	RedCap device
Maximum number of DL MIMO layers	2 or 4, depending on the frequency band	1 for RedCap device with 1Rx branch 2 for RedCap device with 2 Rx branches
Maximum DL modulation order	256 QAM	64 QAM
FD-FDD, TDD	FD-FDD, TDD	UE may implement HD-FDD, FD-FDD , TDD

Reduced Device capabilities

	FR 2	FR 2
	Baseline device	RedCap device
Maximum device bandwidth	200 MHz	100 MHz
Minimum number of device receive branches	2	1

Reduced Device capabilities

	FR2	FR2
	Baseline device	RedCap device
Maximum number of DL MIMO layers	2	1
Maximum DL modulation order	64 QAM	64 QAM
FD-FDD, TDD	TDD	TDD

Maximize device bandwidth

- A baseline NR device is required to support 100 MHz in frequency range (FR1), and 200 MHz in FR2, for transmission and reception.

- For RedCap, these requirements are reduced to 20 MHz and 100 MHz respectively.

- The BW reductions allows all the physical channels and signals specified for initial acquisition to be readily reusable for RedCap devices.

Maximize device bandwidth

- It minimizes the impact on network and device deployment when introducing RedCap to support the new use cases.

Minimum number of device receive branches

- The number of receive branches is related to the number of receive antennas.

- Reducing the number of receive branches therefore results in a reduction in the number of receive antennas and cost savings.

- The requiring on the minimum number of receive branches depends on frequency bands.

Minimum number of device receive branches

- Some frequency bands require a baseline NR device to be equipped with two receive branches, whereas some other frequency bands, mostly in the FR1 TDD bands, require the device to be equipped with four receive branches.

Minimum number of device receive branches

- For the bands where a baseline NR device is required to be equipped with a minimum number of two receive branches , a RedCap device is only required to have one receive branch.

- For the bands where a baseline NR device is required to be equipped with a minimum of four receive branches, it is yet to be decided whether a RedCap device is required to have one or two receive branches.

Reduced Device Capabilities

Maximum number of DL MIMO layers

- The maximum number of DL MIMO layers for a RedCap device is the same as the number of receive branches it supports.

- This is a reduction compared to the requirements for a baseline device.

Maximum DL Modulation order

- A baseline NR device is required to support 256 QAM in the DL in FR1.
- For a RedCap device, the support of DL 256QAM is optional.
- For FR1 uplink and FR2, both UL and DL, a RedCap device is required to support 64QAM, same as the requirement for a baseline device.

Duplex operation

- As per the duplex operations, the only relaxation is for operations in FDD bands.
- A baseline NR device is required to support a full duplex operation in FDD band.
- A typical full-duplex device incorporates a duplex filter to isolate the interference between the device’s transmit and receive paths.

Duplex operation

- In this, the same device may need to support multiple FDD bands, therefore, multiple duplex filters may be needed to support the FD-FDD operation.

- For a RedCap device, the support of FD-FDD is optional.

- It is not required to receive in the DL frequency while transmitting in the UL frequency, and vice-versa.

Duplex operation

- Such a duplex operation is referred to as half duplex FDD (HD-FDD). HD-FDD removes the need for the duplex filters.

- A RedCap device is expected to operate in a single band at a time and it will not support Carrier Aggregation and Dual connectivity.

- It can be seen that the cost and complexity reduction can be achieved with this.

Total reduction

For FR1 FDD

- Total reduction is approx 65%

Total reduction

For FR1 TDD

- Total reduction is approx 58% if a RedCap device supports 2 receive branches.

- Total reduction is approx 71% if a RedCap device supports 1 receive branches.

Total reduction

For FR2

- Total reduction is approx 48%

LTE-to-NR Migration path

LTE-to-NR Migration path

- The 3GPP Rel-17 work on the support for reduced capability NR devices is an imp step to expand the market of 5G NR.

- NR RedCap offers a path for migrating from LTE to NR for different use cases.

- Such a migration path is important as it can accelerate the spectrum re-farming from LTE to NR.

LTE-to-NR Migration path

- From the performance point of view, both network and device, there is also an incentive to take LTE-to-NR migration paths, as RedCap is a native NR technology.

- It includes all the key NR building blocks, which includes beamforming, scalable numerology, network energy efficiency etc.

- A RedCap device will support full co-existence on an NR carrier that is configured to be optimized for eMBB or time-critical communication performance.

LTE-to-NR Migration path

- It is important for industrial wireless sensors use cases as the network for enabling fully automated factories in Industry 4.0.

- It will have need to support both time-critical communications with more capable devices and lower-end sensor devices.

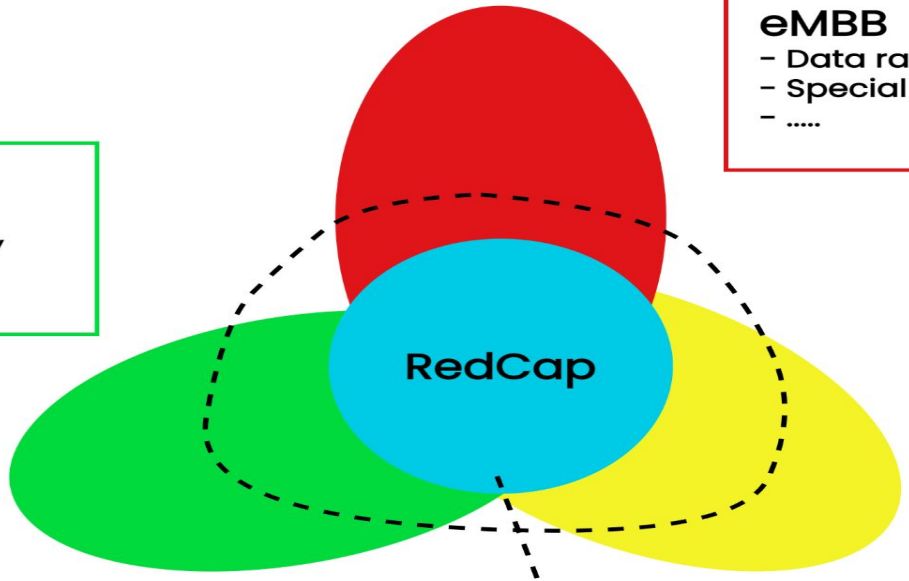
- The configuration of such networks may be optimized for ensuring the performance of time-critical communications while requiring the lower-end sensor devices to operate efficiently.

NR-RedCap UE features

RedCap

eMBB
- Data rate
- Special effeciency
- .....

LPWA (mMTC)
- Extreme Coverage
- Ultra-low UE complexity
- 18 to 15 year battery life
- .....



URLLC
- Latency
- Reliability
- ....

Diversified requirement for industrial wireless sensor, wearable, video surveillance and more

Reduced Capability New Radio

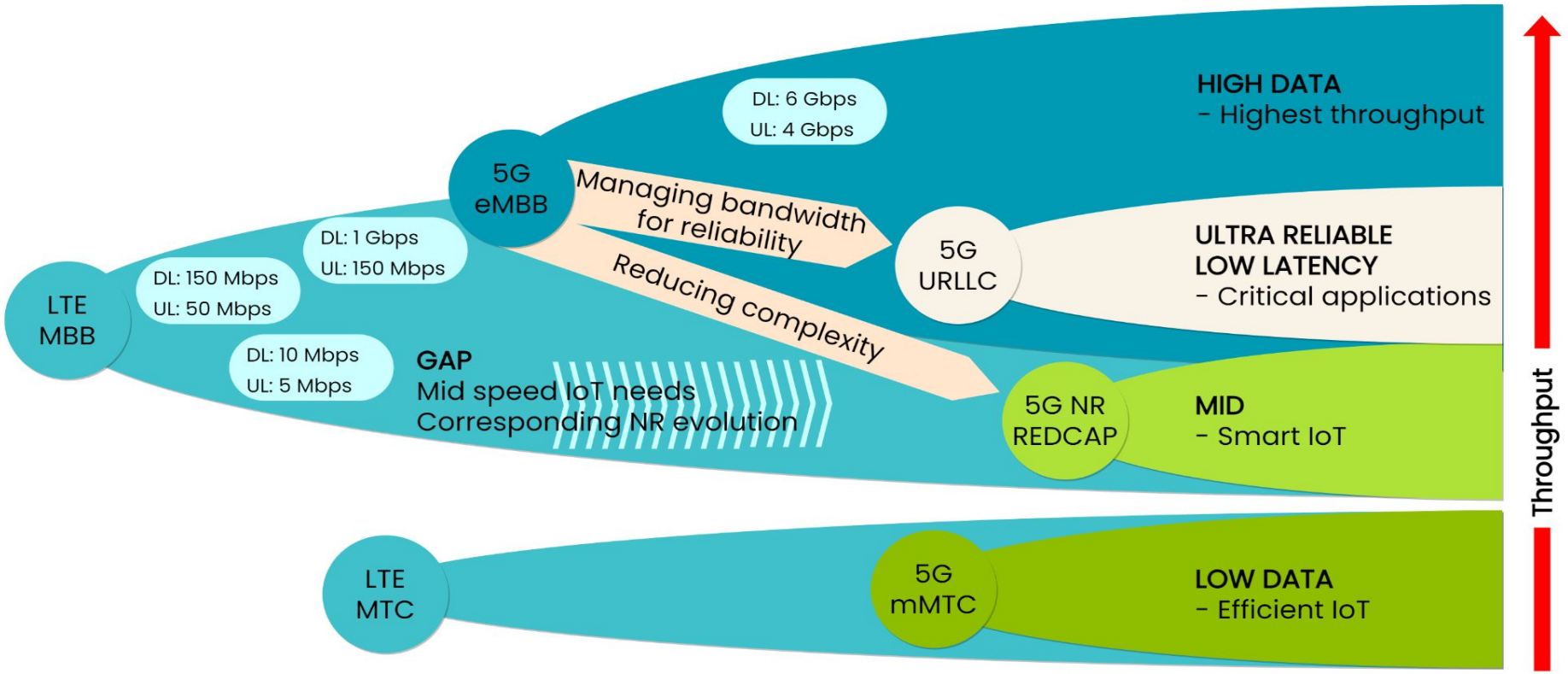
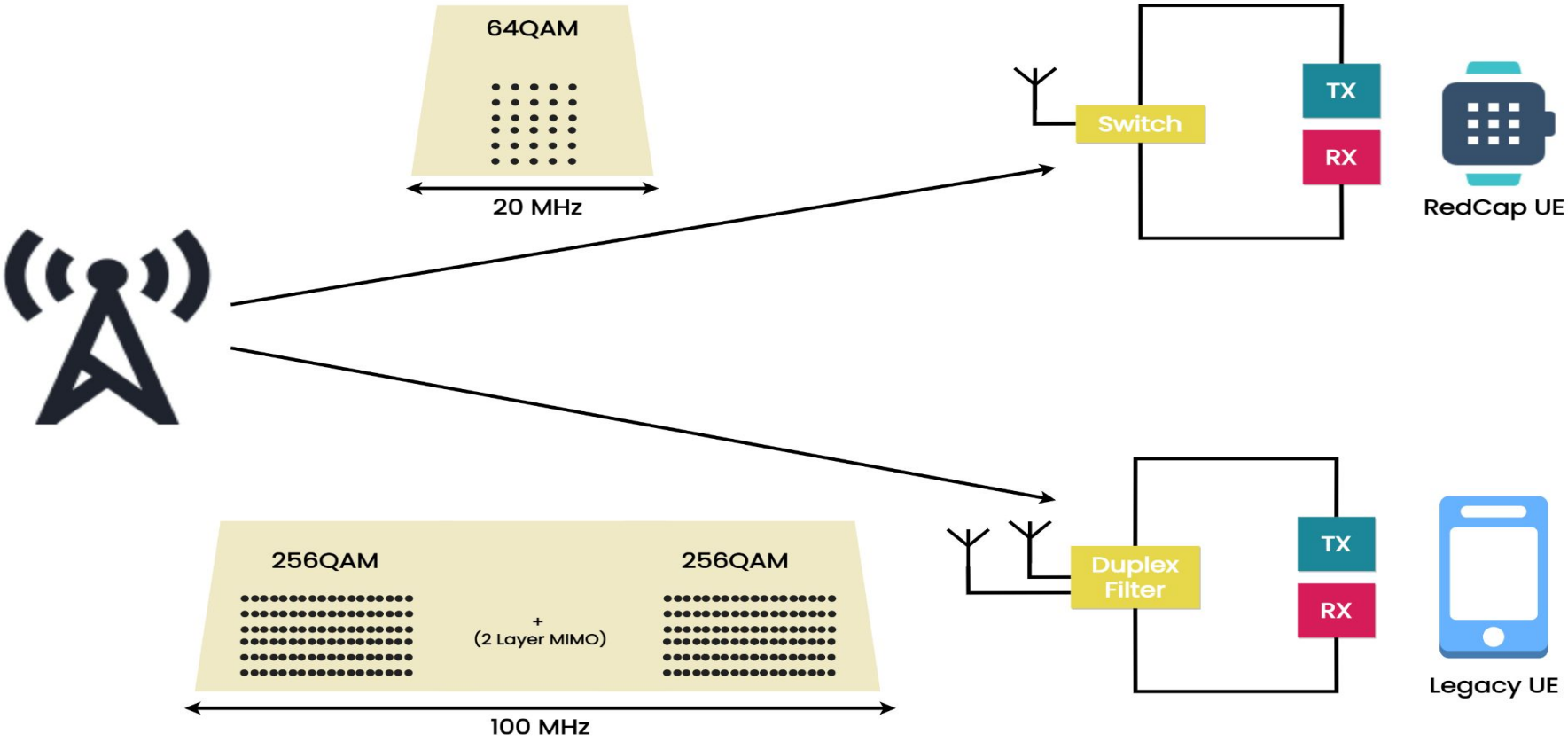


Illustration of the difference between RedCap device and baseline NR device capabilities



UE features

Requirements & Characteristics	Premium 5G UEs	Premium 5G UEs	Very low end
Requirements & Characteristics	eMBB	URLLC	LPWA mMTC
Latency	Low	Ultra Low	High
Reliability	High	Ultra high	Low
Data rate	High	low/high	Low
Device complexity	High	High	Very low
Coverage	Normal	Normal	Extreme

UE features

Requirements & Characteristics	Premium 5G UEs	Premium 5G UEs	Very low end
Requirements & Characteristics	eMBB	URLLC	LPWA mMTC
Coverage	Normal	Normal	Extreme
Battery life	Medium	Medium	Very long
Connection density	Medium	Medium	Very high
Bandwidth requirement	Wide	Wide	Narrow
Mobility	Yes	Yes	Nomadic

UE features

Requirements & Characteristics	Low tier 5G UEs	Low tier 5G UEs	Low tier 5G UEs
Requirements & Characteristics	Industrial sensors/ video monitoring	Low end wearables	Relaxed IoT
Latency	Medium	Medium	low/medium
Reliability	Medium	Medium/high	high/ultra high
Data rate	Medium	low/Medium	low/medium
Device complexity	Medium	Low	Low
Coverage	Normal	Normal	Normal

UE features

Requirements & Characteristics	Low tier 5G UEs	Low tier 5G UEs	Low tier 5G UEs
Requirements & Characteristics	Industrial sensors/ video monitoring	Low end wearables	Relaxed IoT
Coverage	Normal	Normal	Normal
Battery life	Medium	Long	long/medium/NA
Connection density	Medium	High	high/very high
Bandwidth requirement	Medium	Medium	Medium
Mobility	Yes	Yes	Yes

RedCap Enhancements : Rel-18 targets

RedCap Enhancements

For FR1

	Reference NR UE	RedCap (Rel-17)	RedCap (Rel-18)
Maximum BW	100 MHz	20 MHz	5 Mhz
Peak data rate		Approx 85 Mbps	10 mbps DL, 5 mbps UL
Antenna configuration	1Tx, 2Rx	1Tx,1 Rx,1Tx, 2Rx	1 Tx, 1Rx
DL MIMO Support	Yes	Yes for 2Rx	No
Duplex mode	FD-FDD/TDD	FD-FDD,HD-FDD/TDD	HD-FDD/TDD

RedCap Enhancements

For FR1

	Reference NR UE	RedCap (Rel-17)	RedCap (Rel-18)
Maximum modulations	256 QAM DL, 64 QAM UL	256 QAM DL (optional). 64 QAM DL (mandatory), 64 QAM UL	64 QAM DL, 16 QAM UL
Other complexity reduction techniques			Reduced number of HARQ processes, TBS limitation, relaed processing time (e.g cross subframe scheduling)

RedCap Enhancements

- Support high-end RedCap Device with flexible bandwidth larger than Rel-17 reduced BW(i.e FR1: 20 MHz, FR2: 100 MHz)

- Rel-17 leftovers: layer 1: UE processing time relaxation

  Relaxed PDSCH/PUSCH processing time in terms of N1/N2 e.g doubled

  Relaxed UE CSI computation time

  Benefit in both complexity reduction and power savings

RedCap Enhancements

- Rel-18 RedCap should aim to expand more use cases and applications in the market.
- More service types : support positioning in RedCap
- More diversified use cases : Sidelink RedCap
- More operation bands : Unlicensed RedCap

Reduced Capability NR devices

Reduced Capability NR devices

- Various use cases for RedCap include industrial wireless sensor network, video surveillance cameras and wearables (smart watches, rings, eHealth-related devices, medical-monitoring devices etc).

- The requirements differ significantly from the requirements for LPWAN use cases, addressed by LTE-M and NB-IoT.

- NR-RedCap is not intended for LPWAN use cases and is mainly intended ‘mid-range’ IoT market segment.

Reduced Capability NR devices

General requirements which are common to all RedCap use cases:

- Lower device cost and complexity
- Smaller device size and compact form factor
- Support deployment in all FR1/FR2 bands for FDD and TDD

Reduced Capability NR devices

Features considered in RedCap study:

- Reduced number of UE receiver (Rx) and/or transmitter (Tx) branches.
- UE bandwidth reduction
- Half-duplex FDD
- Relaxed UE processing time
- Relaxed UE processing capability

Reduced Capability NR devices

The complexity reduction features which are expected to have the largest impact on the coverage performance are:

- Reduced number of UE Rx/Tx branches
- UE bandwidth reduction

Reduced Capability NR devices

- The reduction of the minimum number of Rx and/or Tx branches relative to that of a reference Rel-15 NR UE will lower the cost and complexity of various RedCap UEs.

- The reference NR UE supports 2Rx/1Tx branches in FR1 FDD bands, 4Rx/1Tx branches in FR1 TDD bands, and 2Rx/1Tx branches in FR2 bands.

- For RedCap UE's, the configuration for Rx and Tx branches that were considered are 1Rx/1Tx and 2Rx/1Tx, in both FR1 and FR2.

Reduced Capability NR devices

- In FR1, the reduction of number of Rx branches is also beneficial in terms of reducing the device size.

- In FR2, the reduction of the number of Rx branches may not provide much benefit in terms of reducing the device size as the antenna separation is in the order of the wavelength.

- In addition to the reduction in the number of Rx branches, UE bandwidth reduction is an imp feature.

Reduced Capability NR devices

- The maximum bandwidth capability of the reference UE is assumed to be 100 MHz in FR1 and 200 MHz in FR2, for both uplink and downlink.|

- For RedCap UEs, the bandwidth reduction options considered during are 20 MHz in FR1 and 50 or 100 MHz in FR2.

Link Level Simulations

Link Level Simulations

- In order to evaluate the impact of the UE complexity reduction on coverage of RedCap physical channels.

- We have performed link-level simulations (LLS) to obtain the required SINR for the physical channels under performance target for both the Reference UEs and RedCap UEs.

- The outcomes of the LLSs are used to perform the link budget evaluation to find coverage limiting channels.

Link Level Simulations

We have performed the LLS for three different scenarios:

- FR1, Rural with the carrier frequency of 0.7 GHz
- FR1, Urban with the carrier frequency of 2.6 GHz
- FR2, Indoor with the carrier frequency of 28 GHz

Link Level Simulations

We have considered LLS for following messages and channels:

- Synchronized Signal Block (SSB): it includes primary SS (PSS), secondary SS(SSS) and Physical broadcast channel (PBCH), is periodically transmitted on DL to initial cell search and carries the information that UE needs to connect to the network.

- Physical Random Access channel (PRACH): it is used by UE for transmission of preamble over UL.

Link Level Simulations

We have considered LLS for following messages and channels:

- Message 2 or random access response: it is transmitted on DL for indicating reception of the preamble and sending time alignment information.

- Message 3: It is used by UE to transmit information such as a device identity that is needed for the next message over PUSCH.

- Message 4: it transfers the UE to the connected state.

Link Level Simulations

We have considered LLS for following messages and channels:

- Physical DL control channel (PDCCH): It is mainly used for transmission of control information such as scheduling decisions.
- Physical DL shared channel (PDSCH): it is mainly used as the main transmission of DL unicast data.
- Physical UL control channel (PUCCH): it is used by UE to send information such as acknowledgements and channel-state reports.

Link Level Simulations

We have considered LLS for following messages and channels:

- Physical DL Shared channel (PUSCH): it is the uplink counterpart of PDSCH.
-