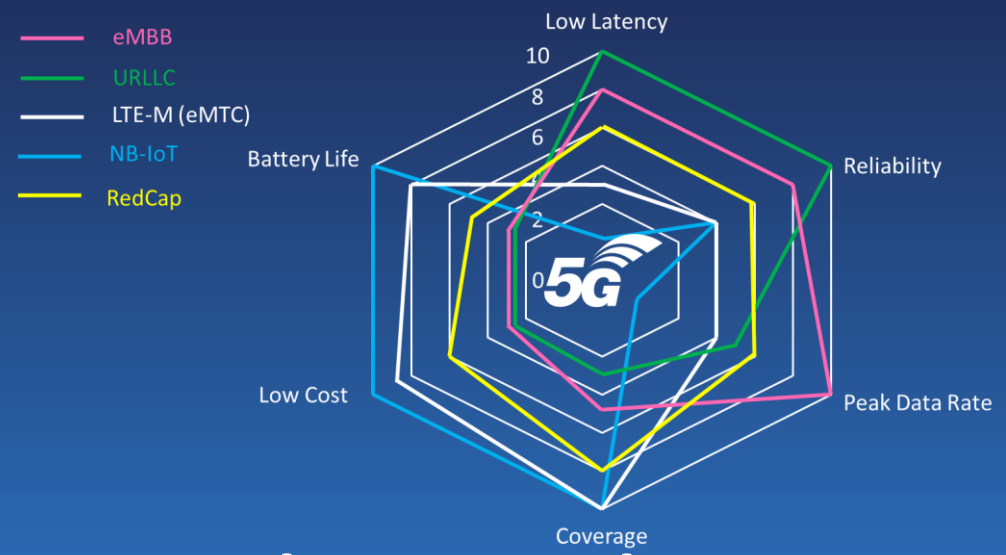


Beginners:

Introduction to 5G Reduced Capability (RedCap) Devices

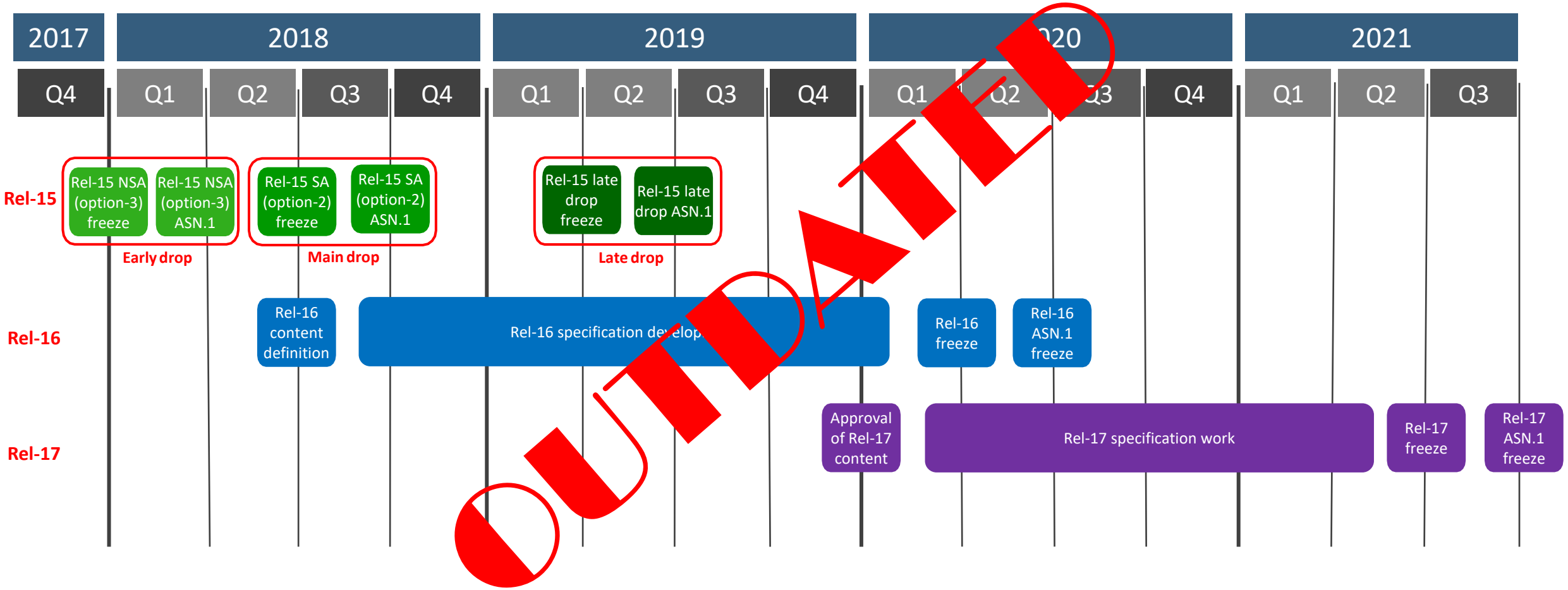
Previously known as NR-Lite / NR-Light

@3g4gUK

NR RedCap was initially called **NR-Lite** and then **NR-Light** before settling on **RedCap** (Reduced Capability).

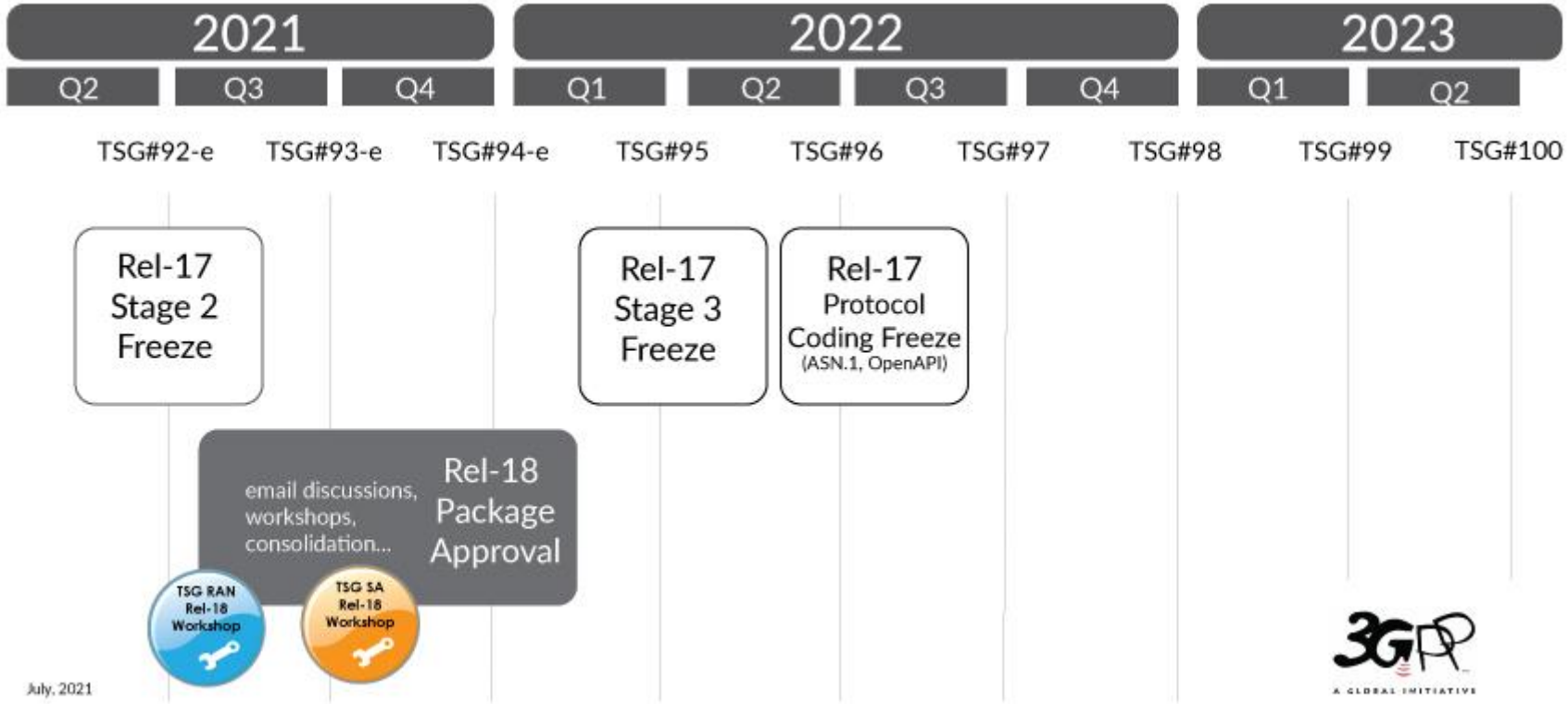
It was first introduced as a 3GPP Release-17 Study item in 3GPP RAN #84 at Newport Beach, California on 3-6 June 2019

3GPP Standards Timeline - Revised



Designed by 3G4G, based on roadmap from 3GPP, July 2019

3GPP Rel-17 Timeline as of July 2021



Source: 3GPP

3GPP Release and Features

Release 15

- **NR**
- **The 5G System – Phase 1**
- **Massive MTC and Internet of Things (IoT)**
- **Vehicle-to-Everything Communications (V2x) Phase 2**
- **Mission Critical (MC) interworking with legacy systems**
- **WLAN and unlicensed spectrum use**
- **Slicing – logical end-2-end networks**
- **API Exposure – 3rd party access to 5G services**
- **Service Based Architecture (SBA)**
- **Further LTE improvements**
- **Mobile Communication System for Railways (FRMCS)**

Release 16

- **The 5G System – Phase 2**
- **V2x Phase 3:** Platooning, extended sensors, automated driving, remote driving
- **Industrial IoT**
- **Ultra-Reliable and Low Latency Communication (URLLC) enhancements**
- **NR-based access to unlicensed spectrum**
- **5G Efficiency:** Interference Mitigation, SON, eMIMO, Location and positioning, Power Consumption, eDual Connectivity, Device capabilities exchange, Mobility enhancements
- **Enhancements for Common API Framework for 3GPP Northbound APIs (eCAPIF)**
- **FRMCS Phase 2**

Release 17 Content Approval*

TSG SA Work Areas under discussion at SA#85 (September 2019):

- 5G System Enhancement for Advanced Interactive Services (5G_AIS)
- Cellular IoT enhancement for the 5G System (5G_MCIoT)
- System enhancement for Proximity based Services in 5GS (5G_ProSe)
- Enhancement of support for 5G LAN-type service (5GLAN_enh)
- Integration of Satellite in 5G Systems (5GSAT_ARCH)
- Architectural enhancements for 5G multicast-broadcast services (5MBS)
- Study on enhancement of support for 5G Wireless and Wireline Convergence (5WWC_enh)
- Application Awareness Interworking between LTE and NR (AAI_LTE_NR)
- Extended Access Traffic Steering, Switch and Splitting support in the 5G system architecture (eATSSS)
- 5G Enhancement for unmanned aerial vehicles - UAVs (EAV)
- Enhanced IMS to 5GC Integration (eIMS5G)
- Enhancement to the 5GC LoCation Services-Phase 2 (eLCS_ph2)
- Enablers for Network Automation for 5G - phase 2 (eNA_Ph2)
- Enhancement of support for Edge Computing in 5GC (enh_EC)
- Enhanced support of Non-Public Networks (eNPN)
- Enhancement of Network Slicing Phase 2 (eNS_Ph2)
- Enhancement of 5G UE Policy (eUEPO)
- Architecture enhancements for 3GPP support of advanced V2X services - Phase 2 (eV2XARC_Ph2)
- Supporting Flexible Local Area Data Network (FLADN)
- Supporting Unmanned Aerial Systems Connectivity, Identification and Tracking (ID-UAS)
- Enhanced support of Industrial IoT - TSC/URLLC enhancements (IIoT)
- Support for Minimization of service Interruption (MINT)
- Multimedia Priority Service Phase 2 (MPS2)
- Support for Multi-USIM Devices (MUSIM)
- System architecture for next generation real time communication services (NG_RTC)
- Service-based support for SMS in 5GC (SB_SMS)
- Smarter User Plane (SUP)
- UPF enhancement for control and Service Based Architecture (UPCAS)
- Usage of User Identifiers in the 5G System (UUI5)

TSG RAN Work Areas under discussion For final decision at RAN#86 (December 2019):

- NR Light
- Small data transfer optimization
- Sidelink enhancements
- NR above 52.6 GHz (inlc 60GHz unlicensed)
- Multi SIM operation
- NR multicast broadcast
- Coverage enhancements
- NB-IoT and eMTC enhancements
- Industrial IoT & URLLC enhancements
- MIMO enhancements
- NR for Non Terrestrial Networks
- Integrated Access and Backhaul enhancements
- Generic enhancements to NR-U
- Power saving enhancements
- RAN data collection enhancements
- Positioning enhancements

* *Mainstream Rel-17 specification work will start at the beginning of 2020, with the functional freeze of physical layer aspects scheduled for the second quarter of 2021.*

The ASN.1 freeze should follow in September 2021.

There are a large number of work areas to be discussed. Realistically, we will only be able to take on board a sub-set of them within Rel-17.

3GPP Release-17 Features as of July 2021

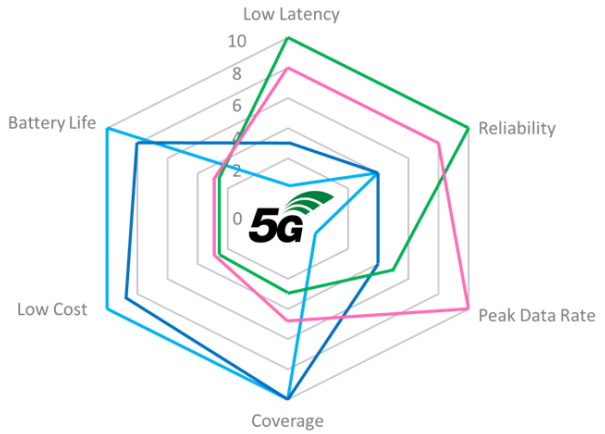
Release 17

- NR MIMO
- NR Sidelink enh.
- 52.6 - 71 GHz with existing waveform
- Dynamic Spectrum Sharing (DSS) enh.
- Industrial IoT / URLLC enh.
- IoT over Non Terrestrial Networks (NTN)
- NR over Non Terrestrial Networks (NTN)
- NR Positioning enh.
- Low complexity NR devices
- Power saving
- NR Coverage enh.
- NR eXtended Reality (XR)
- NB-IoT and LTE-MTC enh.
- 5G Multicast broadcast
- Multi-Radio DCCA enh.
- Multi SIM
- Integrated Access and Backhaul (IAB) enh.
- NR Sidelink relay
- RAN Slicing
- Enh. for small data
- SON / Minimization of drive tests (MDT) enh.
- NR Quality of Experience
- eNB architecture evolution, LTE C-plane / U-plane split
- Satellite components in the 5G architecture
- Non-Public Networks enh.
- Network Automation for 5G - phase 2
- Edge Computing in 5GC
- Proximity based Services in 5GS
- Network Slicing Phase 2
- Enh. V2x Services
- Advanced Interactive Services
- Access Traffic Steering, Switch and Splitting support in the 5G system architecture
- Unmanned Aerial Systems
- 5GC LoCation Services
- Multimedia Priority Service (MPS)
- 5G Wireless and Wireline Convergence
- 5G LAN-type services
- User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)

These are the Rel-17 headline features, prioritized during the December 2019 Plenaries (TSG#86)

Source: 3GPP

Video Link



5G Spider Diagrams

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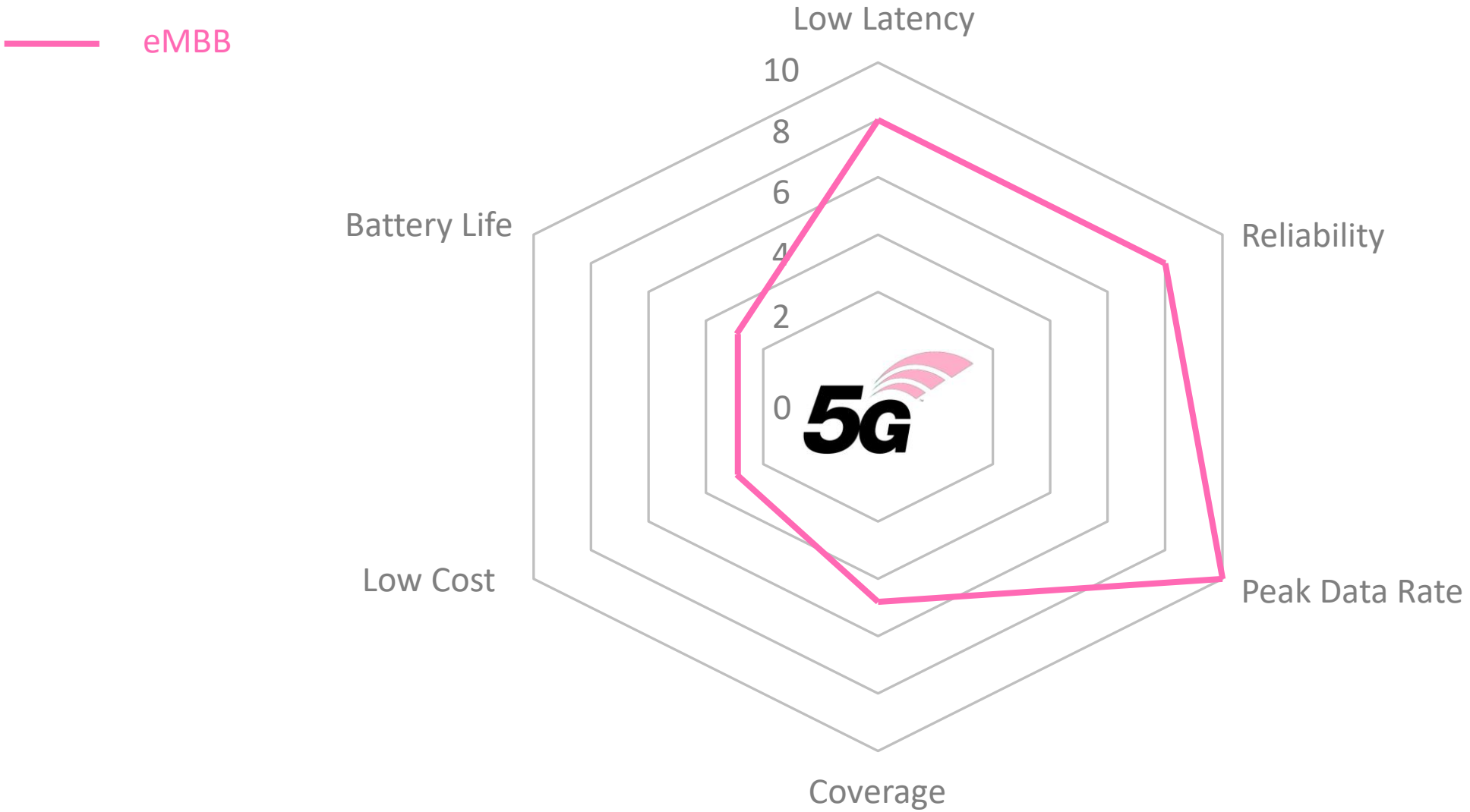
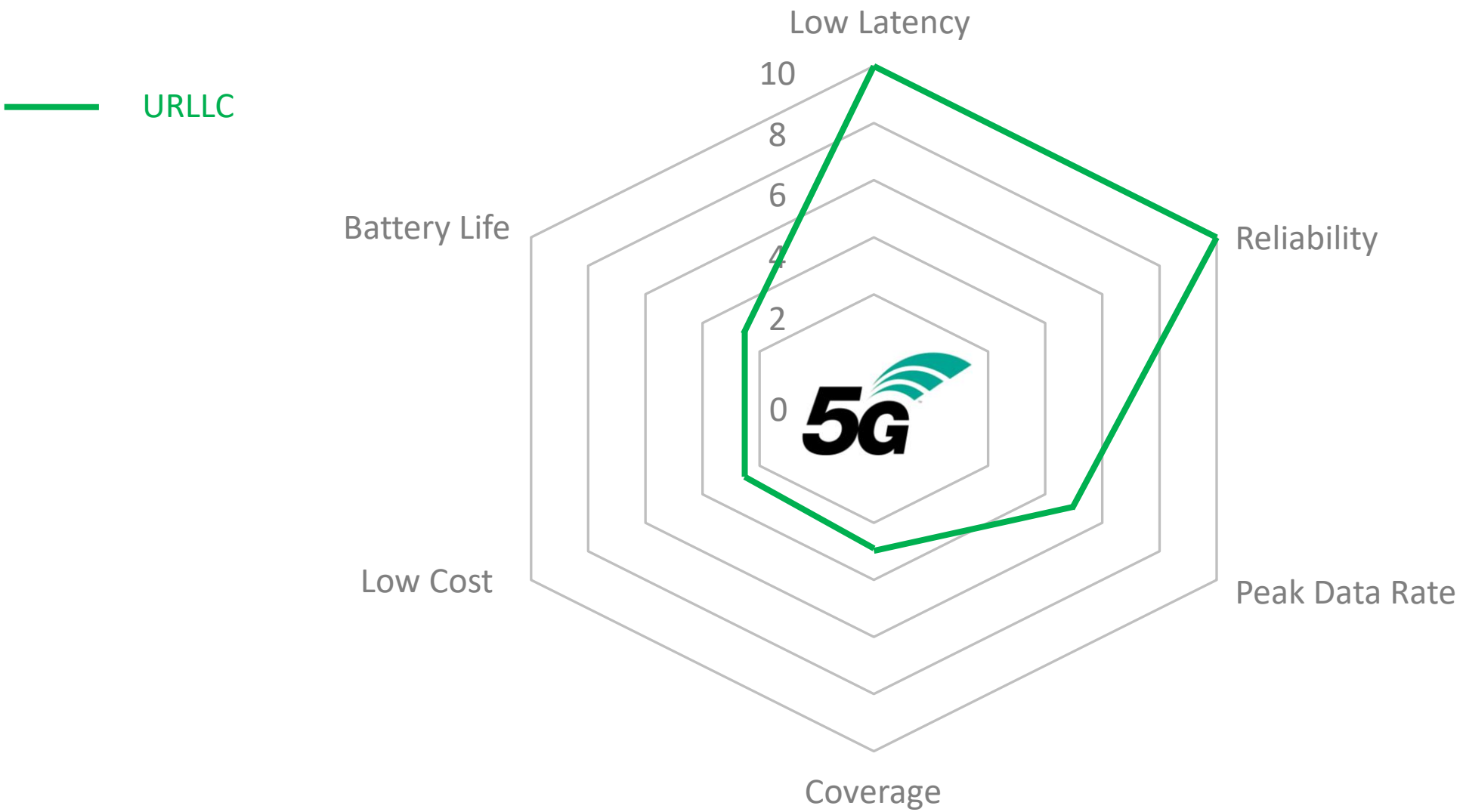
5G eMBB Spider Diagram



5G URLLC Spider Diagram

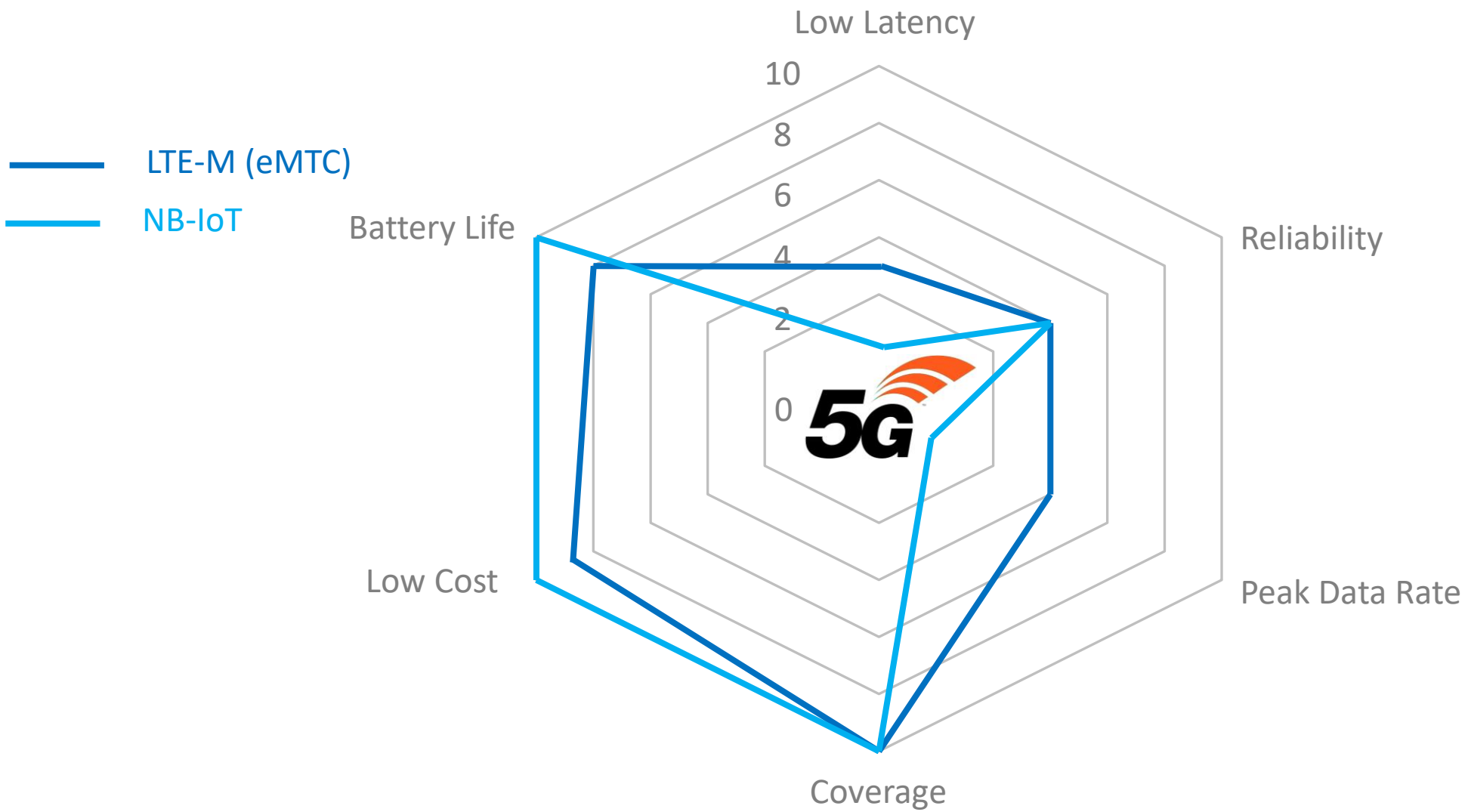


Requirements of Premiums 5G UEs

Requirements & Characteristics	Premium 5G UEs	
	eMBB	**URLLC**
Latency	Low	Ultra Low
Reliability	High	Ultra high
Data rate	High	Low/High
Device complexity	High	High
Coverage	Normal	Normal
Battery life	Medium	Medium
Connection density	Medium	Medium
Bandwidth requirement	Wide	Wide
Mobility	Yes	Yes

Table Source: Qualcomm

LTE-M (eMTC) & NB-IoT Spider Diagram

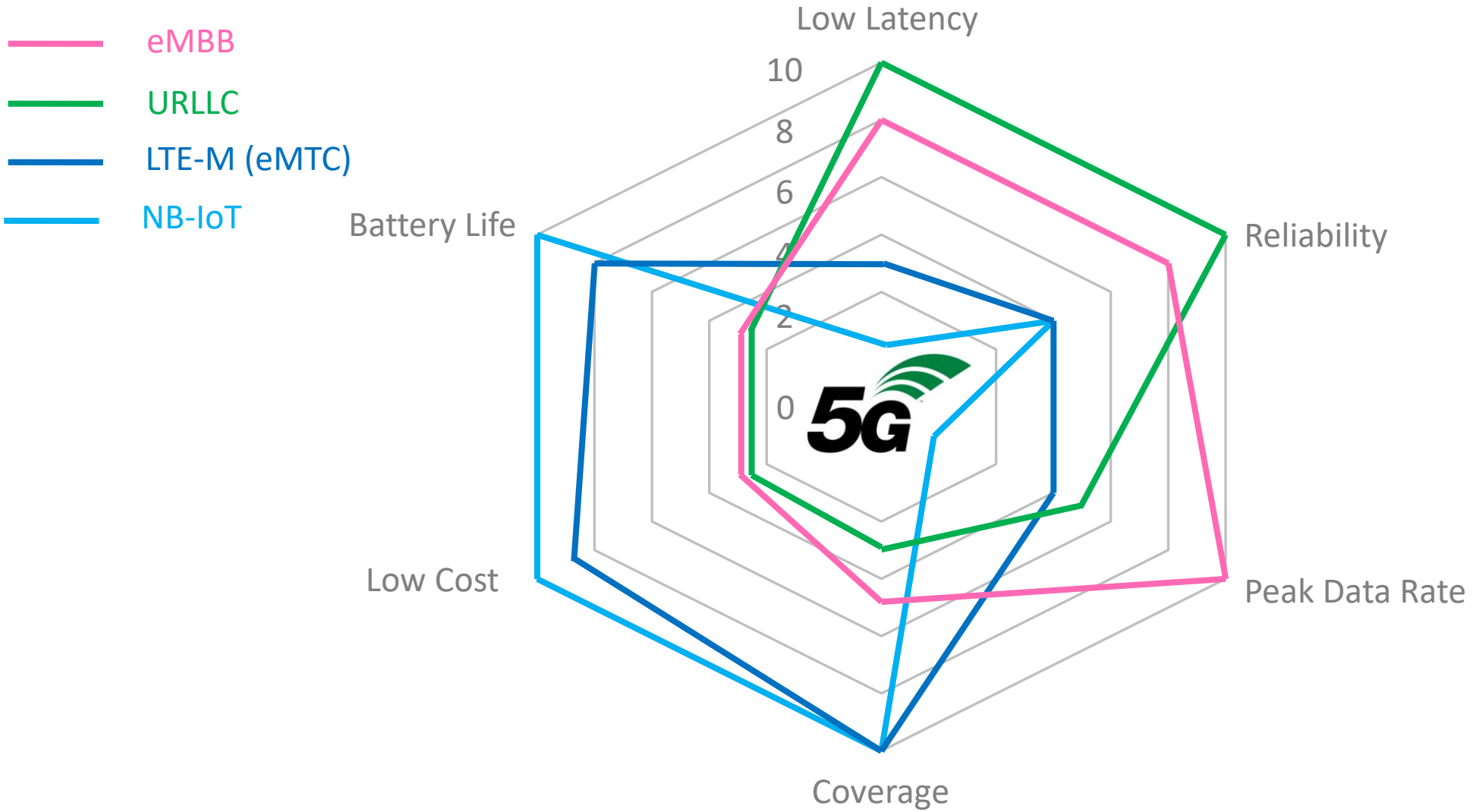


Requirements of Very Low End UEs

Requirements & Characteristics	Premium 5G UEs		Very low end
	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
Battery life	Medium	Medium	Very long
Connection density	Medium	Medium	Very high
Bandwidth requirement	Wide	Wide	Narrow
Mobility	Yes	Yes	Nomadic

Table Source: Qualcomm

5G Spider Diagram Combined



Scope of NR-Lite

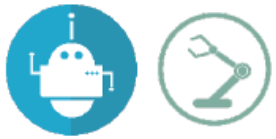
Expand the ecosystem

- What are Low Tier 5G UEs
  - Industrial sensors / video monitoring
  - Relaxed IOT devices
  - Wearables
  - May or may not be power constrained

Healthcare

Smart cities

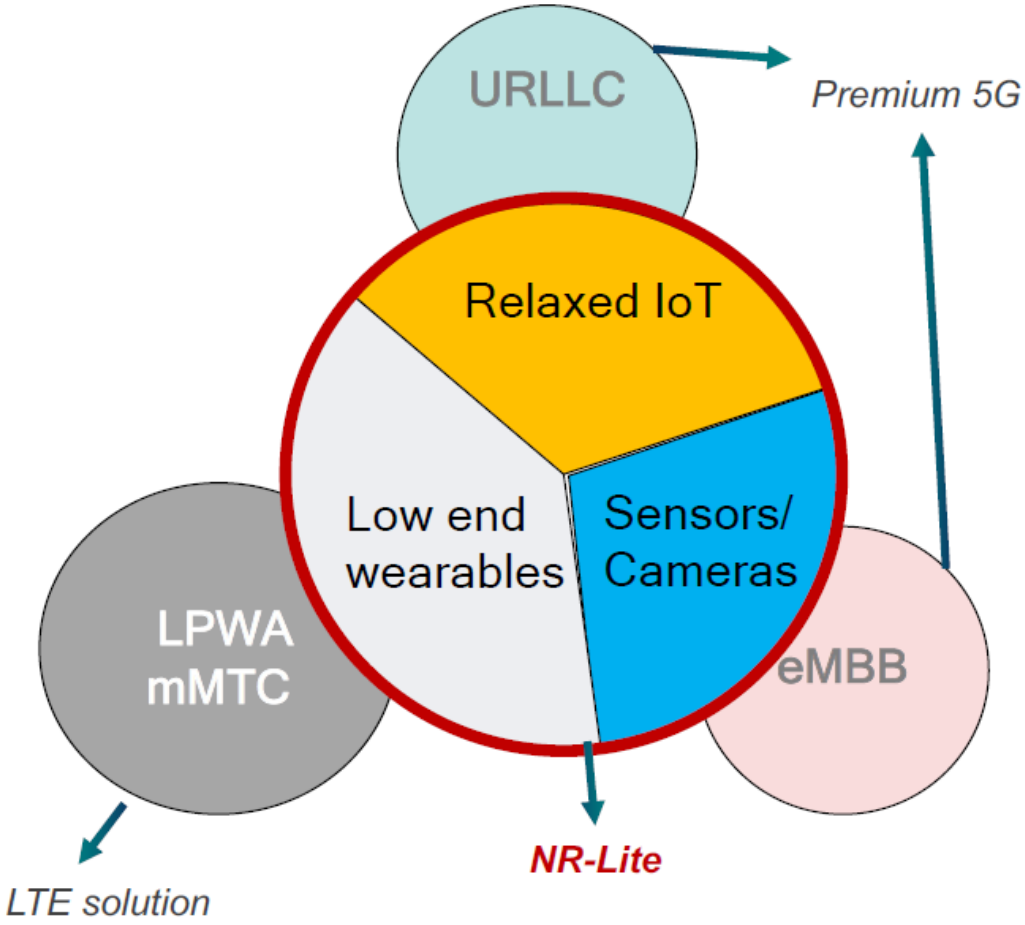
Transport and logistics



Process automation

Elec. distribution

Building automation



Characteristics	requirement
Latency	10-30ms
Reliability	1e-3/1e-4/1e-5
Data rate	10Mbps and below
Coverage	MCL=143dB

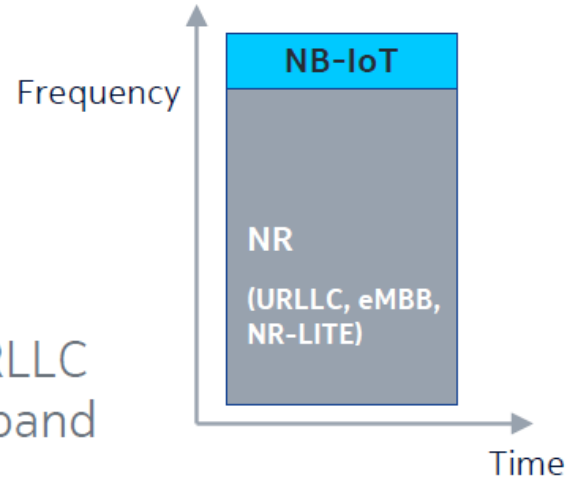
Different types of NR RedCap UEs / Devices

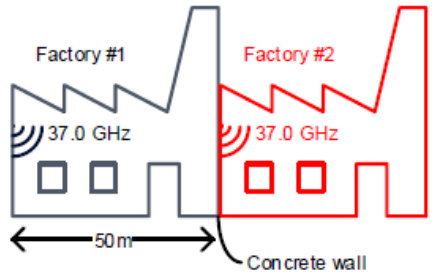
- IWSN: Industrial wireless sensor networks
  - Examples: microphones, CO2 sensors, pressure sensors, humidity sensors, thermometers, cameras, video cameras, motion sensors, accelerometers, laser scanners, fluid-level sensors, inventory sensors, electric voltage meter, electric current meter, actuators
- Wearables
  - Low-end Wearables
- Relaxed-IoT

- Other Terminology for NR-RedCap being used:
  - Low tier 5G UEs
  - IWSN & mid-end IoT

NR-Lite vs LTE

- Why introduce NR-Lite instead of reusing LTE?
- Motivation
  - No need to support 3 different networks – NR, eMTC/NB-IoT, and LTE
    - Operators can migrate their spectrum to NR which can support both URLLC & NR-Lite on the same carrier as well as deploy eMTC/NB-IoT either in-band or in guard-band.
  - Better system efficiency with NR compared to LTE
    - Utilize NR features like beam-formed operation, higher subcarrier spacing for latency reduction, massive MIMO for coverage, mixed numerology, higher positioning accuracy, low-overhead carriers, etc.
  - Deploy URLLC & NR-Lite in also FR2 and new spectrum
    - FR2 can be very attractive for private networks due to its limited range and high spatial reuse e.g. each building or floor can have its own network and they will not interfere with each other
  - Better integration and benefits from 5G core and architecture – network slicing, service based architecture, flow-based QoS, etc.





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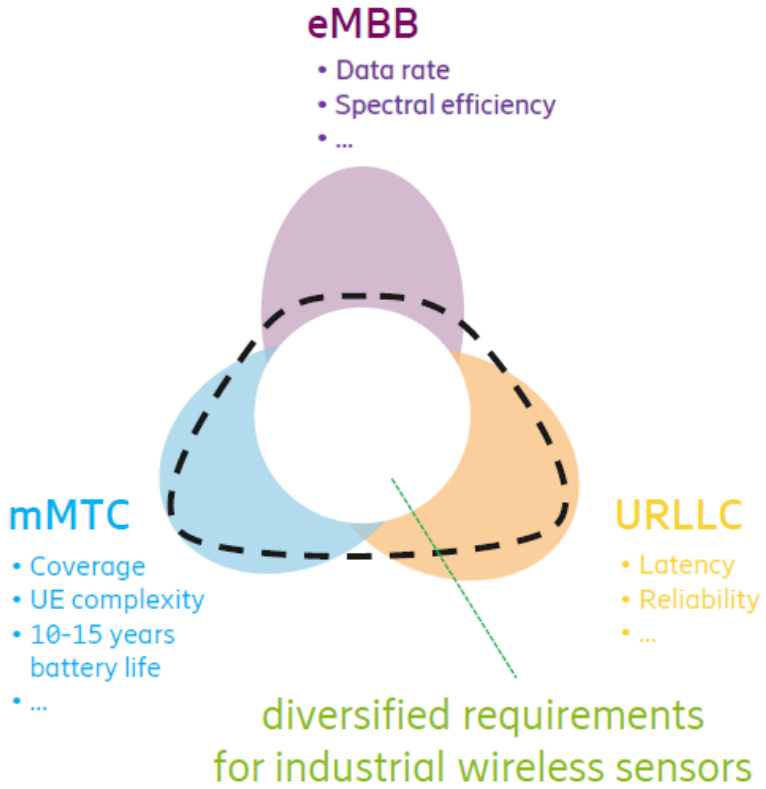
Use Case Requirements for Connected Industries

- Wide range of use cases and connectivity requirements for industrial verticals
  - cMTC type: remote driving, motion control for industrial automation, power distribution grid fault management
  - eMBB type: AR/VR for industrial automation
  - mMTC: LTE-M/NB-IoT for LPWA
  - IWSN: Industrial wireless sensor networks
    - Broadly speaking, sensors with connectivity requirements that cannot be addressed
      - by NR Rel-16 in terms of
        - battery lifetime
        - form factor
        - complexity
      - nor by LTE-M/NB-IoT in terms of
        - data rate
        - reliability and latency
    - Examples: microphones, CO2 sensors, pressure sensors, humidity sensors, thermometers, cameras, video cameras, motion sensors, accelerometers, laser scanners, fluid-level sensors, inventory sensors, electric voltage meter, electric current meter, actuators



Industrial Use Cases

Drone remote control (NR-Lite)

Voice (eMTC)

Crane remote control (NR-Lite)

Electricity distribution (URLLC/TSC)

AGV (URLLC)

Robotic control (URLLC/TSC)

Traffic light (eMTC/NB-IoT)

Industrial sensor (NR-Lite)

High-def video (NR-Lite)

Asset tracking (eMTC/NB-IoT)

NR-RedCap: New Feature in 3GPP Release-17

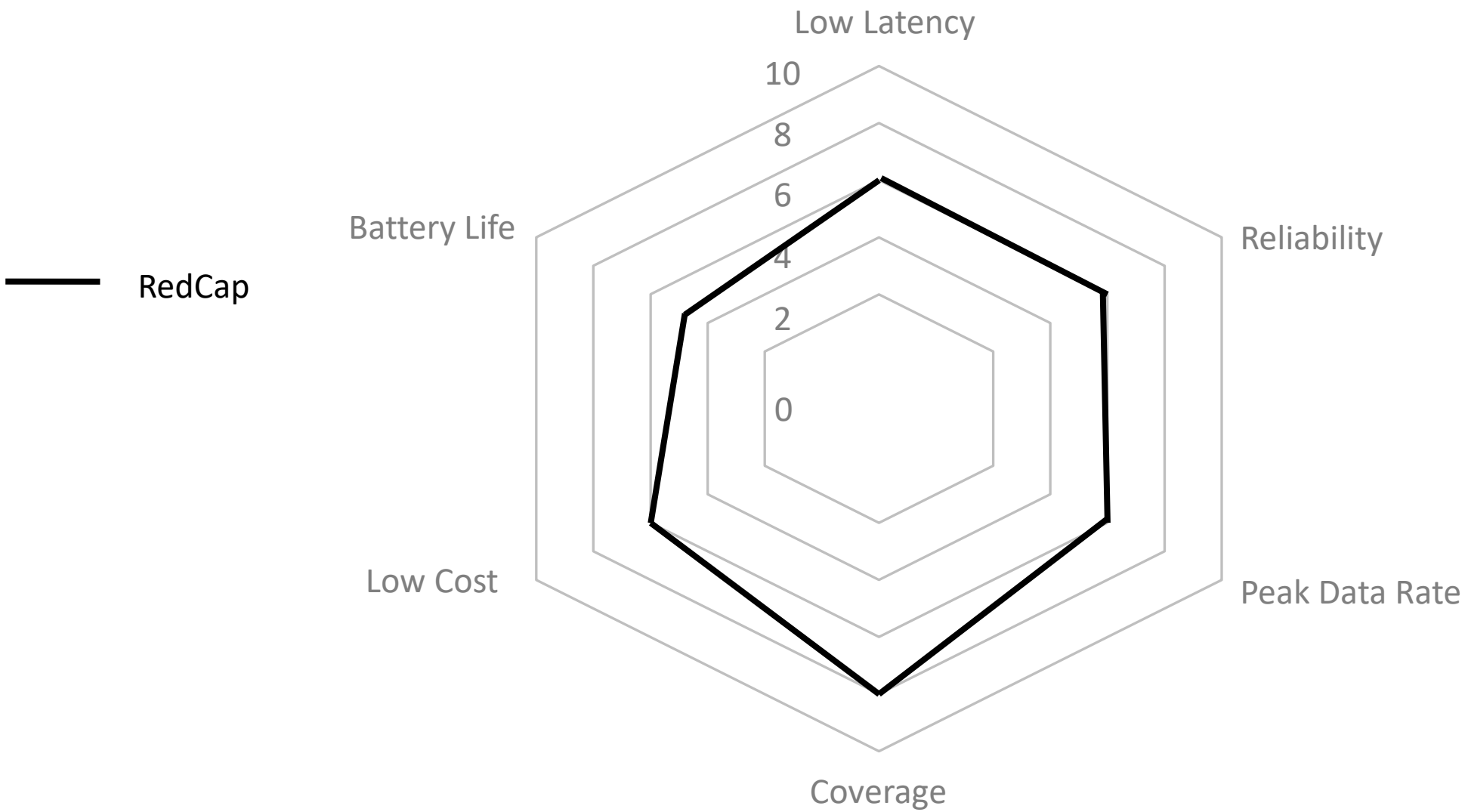
NR-RedCap addresses new use cases with IoT-type of requirements that cannot be met by eMTC and NB-IoT

Requirements & Characteristics	Premium 5G UEs		Low tier 5G UEs			Very low end
	eMBB	URLLC	Industrial sensors / video monitoring	Low end wearables	Relaxed IoT	LPWA mMTC
Latency	Low	Ultra Low	Medium	Medium	Low/medium	High
Reliability	High	Ultra high	Medium	Medium/High	High /ultra high	Low
Data rate	High	Low/High	Medium	Low -Medium	Low/medium	Low
Device complexity	High	High	Medium	Low	Low	Very low
Coverage	Normal	Normal	Normal	Normal	normal	Extreme
Battery life	Medium	Medium	Medium	Long	Long/Medium/NA	Very long
Connection density	Medium	Medium	Medium	High	High/very high	Very high
Bandwidth requirement	Wide	Wide	Medium	Medium	Medium	Narrow
Mobility	Yes	Yes	Yes	Yes	Yes	Nomadic

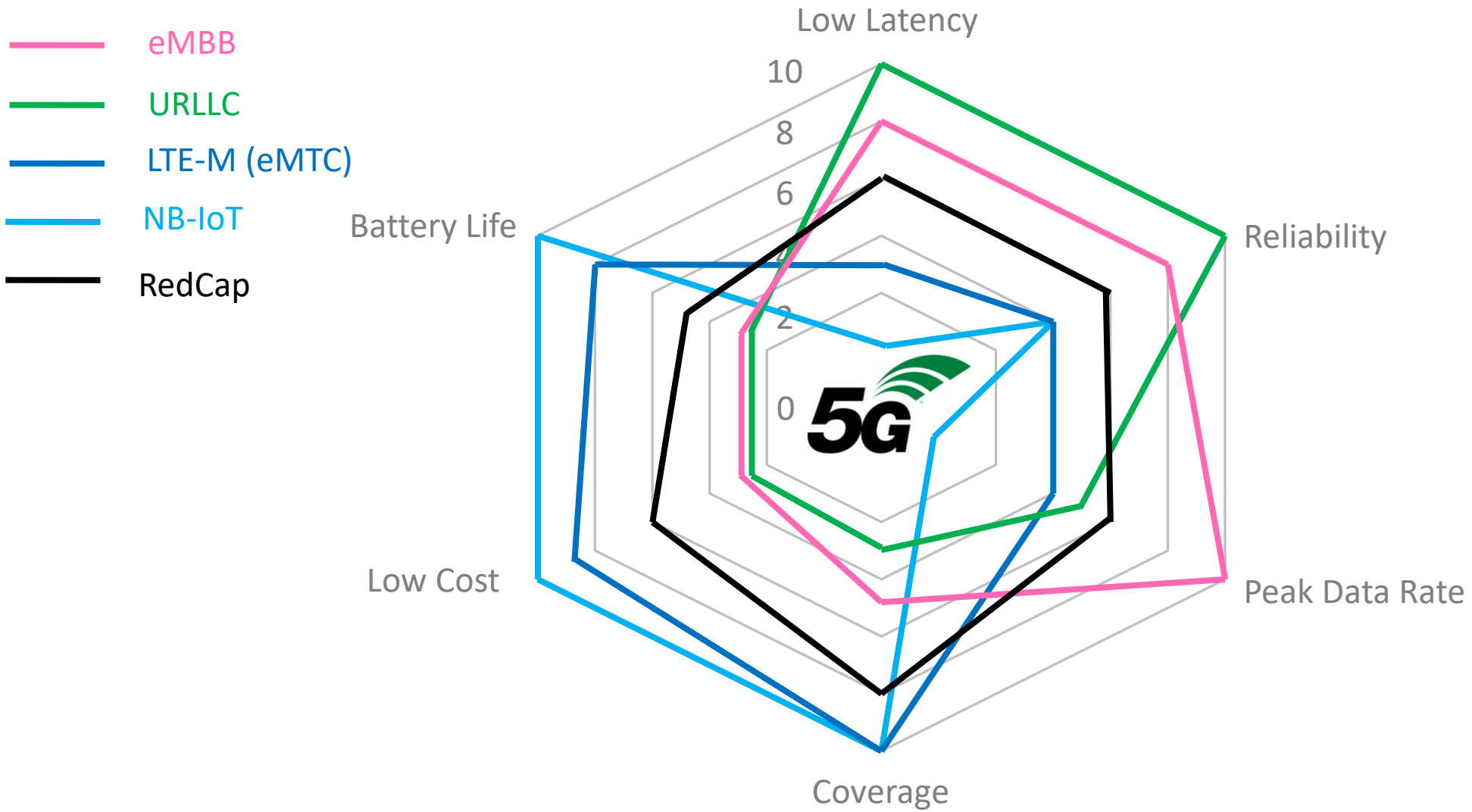
More details on 3G4G Blog

Table Source: Qualcomm

RedCap Spider Diagram



5G Spider Diagram Combined with RedCap



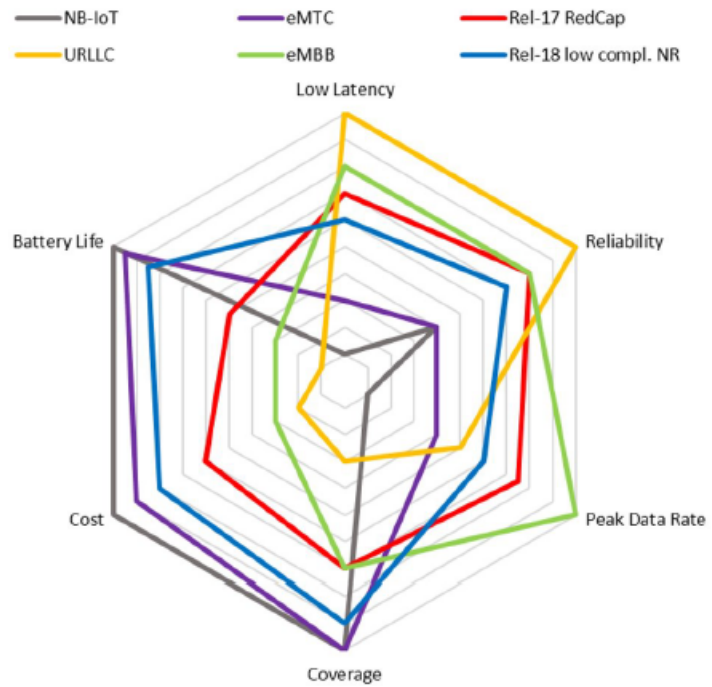
Rel-15 baseline NR devices v/s Rel-17 RedCap devices

	FR1		FR2	
	Baseline device	RedCap device	Baseline device	RedCap device
Maximum device bandwidth	100 MHz	20 MHz	200 MHz	100 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	2	1
Maximum number of downlink MIMO layers	2 or 4, depending on the frequency band	1 for RedCap device with 1 Rx branch; 2 for RedCap device with 2 Rx branches;	2	1
Maximum downlink modulation order	256QAM	64QAM	64QAM	64QAM
Duplex operation	FD-FDD, TDD	UE may implement HD-FDD, FD-FDD, TDD	TDD	TDD

Source: Ericsson

RedCap enhancements: Rel-18 targets

	FR1		
	Reference NR UE	RedCap (Rel-17)	RedCap (Rel-18)
Maximum Bandwidth	100 MHz	20 MHz	5 MHz
Peak data rate	-	~85 Mbps	[10] Mbps DL, [5] Mbps UL
Antenna configuration	1Tx-2Rx	1Tx-1Rx, 1Tx-2Rx	1Tx-1Rx
DL MIMO support	Yes	Yes for 2Rx	No
Duplex mode	FD-FDD / TDD	FD-FDD, HD-FDD / TDD	HD-FDD / TDD
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, relaxed processing time (e.g. cross-subframe scheduling)



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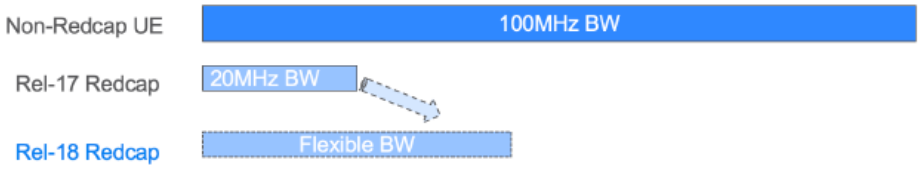
Enhanced Redcap | Flexible BandWidth and Rel-17 Leftovers

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



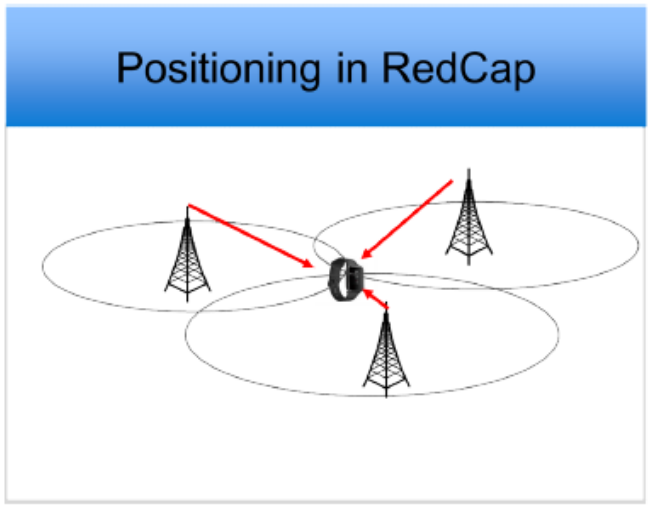
- Rel-17 leftovers
  - Layer-1 UE processing time relaxation
    - Relaxed PDSCH/PUSCH processing time in terms of N1/N2 e.g. doubled.
    - Relaxed UE CSI computation time
    - Benefit in both complexity reduction and power saving.

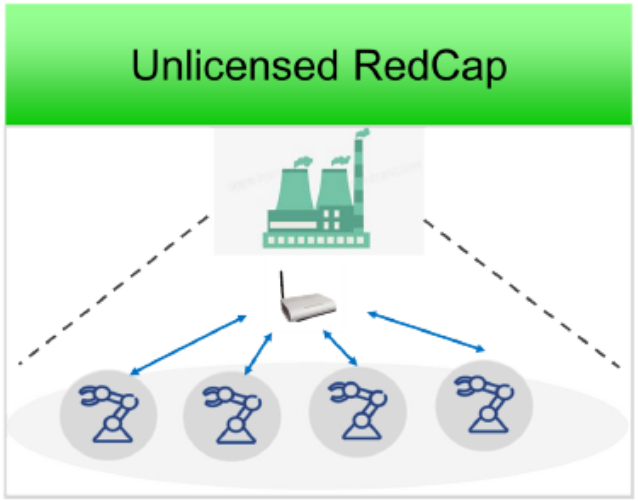
Table 7.5.2-1: Estimated relative device cost for relaxed UE processing time in terms of N_1 and N_2 [TR 38.875]

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%**

Potential evolution directions in Rel-18

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





References and Further Reading Links

- 3GPP TR 38.875: Study on support of reduced capability NR devices (link)
- RP-210918 : Support of reduced capability NR devices (NR_redcap) – Nokia, Ericsson
- Ericsson Blog: What is reduced capability (RedCap) NR and what will it achieve? (link)
- Thales view on 3GPP NR-REDCAP (link)
- The 3G4G Blog: New 3GPP Release-17 Study Item on NR-Lite (a.k.a. NR-Light) (link)
- RP 190831: Key directions for Release 17 – Nokia, Nokia Shanghai Bell
- RP-190844: NR-Lite for Rel-17 – Qualcomm views
- RP-191047: NR-Lite for Industrial Sensors and Wearables – Ericsson
- RP-191175: Motivation for NR-lite: IoT over NR – Samsung
- RP-1901227: New SID on NR-Lite devices and related technical enhancement – ZTE, Sanechips
- RWS-210116: RedCap/ NR-Light Enhancements in Rel-18 – Nokia (link)
- RWS-210504: Views on Redcap Enhancements for Rel-18 – Apple (link)
- RWS-210267: Evolution of RedCap in Release 18 – Xiaomi (link)

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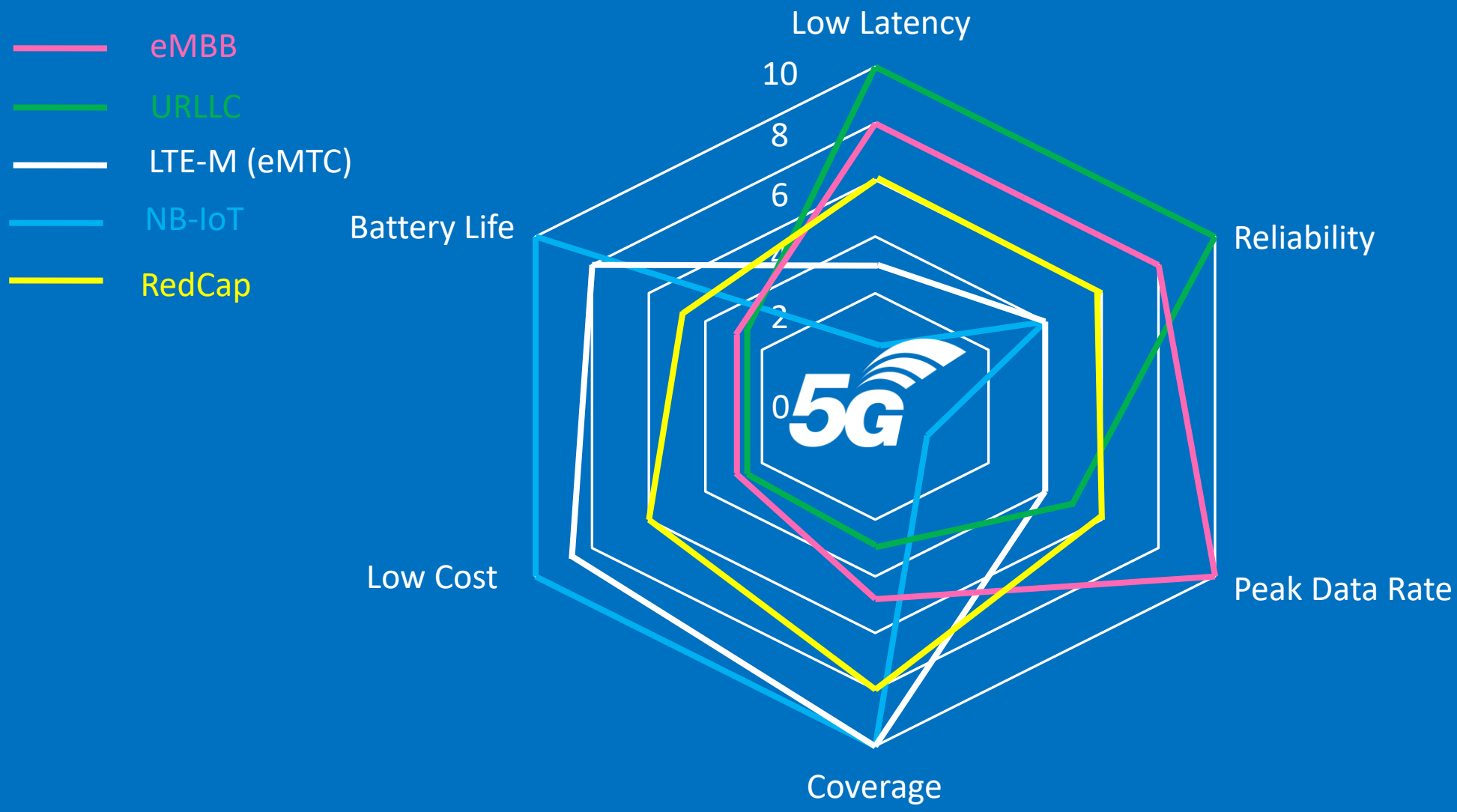
eMBB
URLLC
LTE-M (eMTC)
NB-IoT
RedCap
Low Latency
10
8
6
0
5G
Reliability
Peak Data Rate
Coverage
Low Cost
Battery Life