Cellular Internet of Things

for

Industrial Automation, Wearables, and Smart Cities

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Content

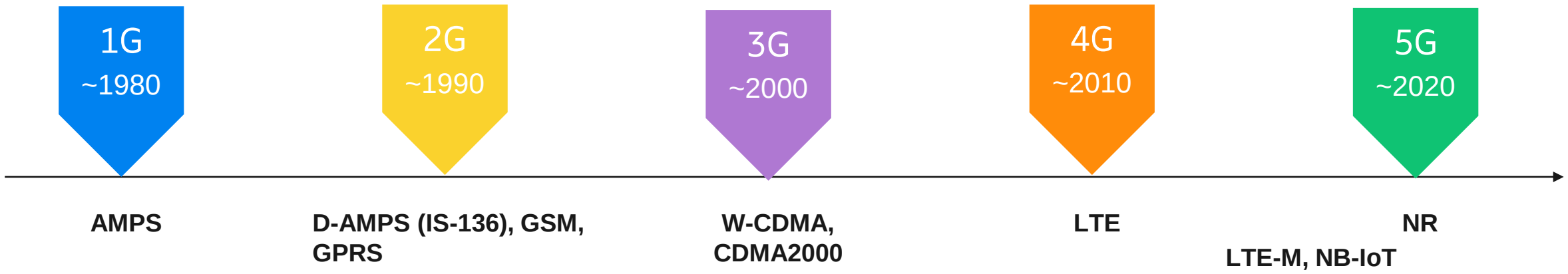
1 **5G & Cellular IoT**
Cellular technology evolution & 5G vision; 5G use cases;

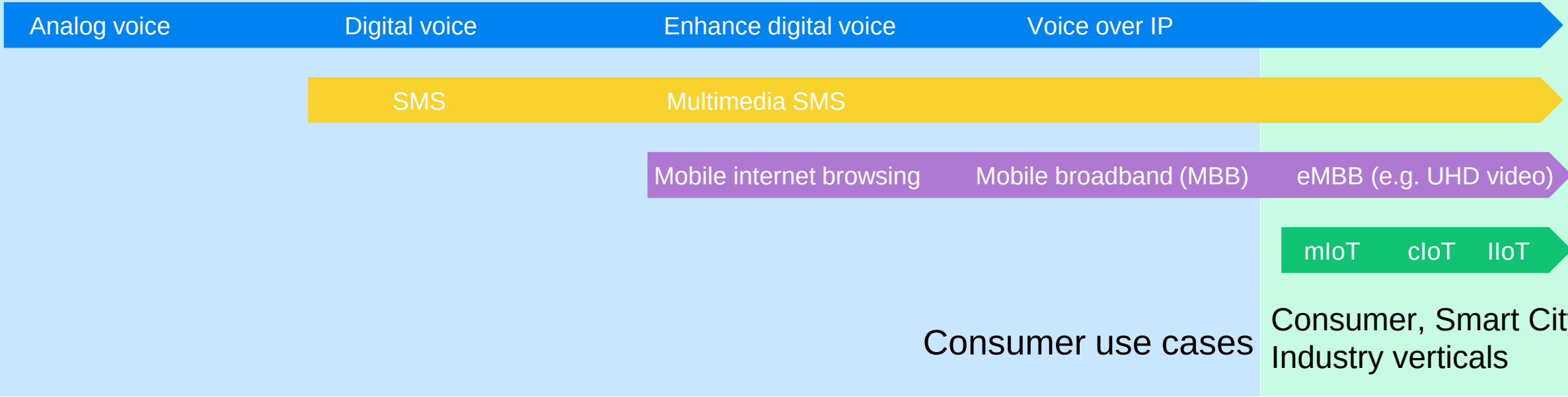
2 **Highlights of cellular IoT solutions**
LTE-M (a.k.a. Cat-M), NB-IoT, NR-URLLC, NR-IIoT, NR RedCap

3 **Continued 5G evolution and beyond 5G**
What are the remaining performance gaps to address?

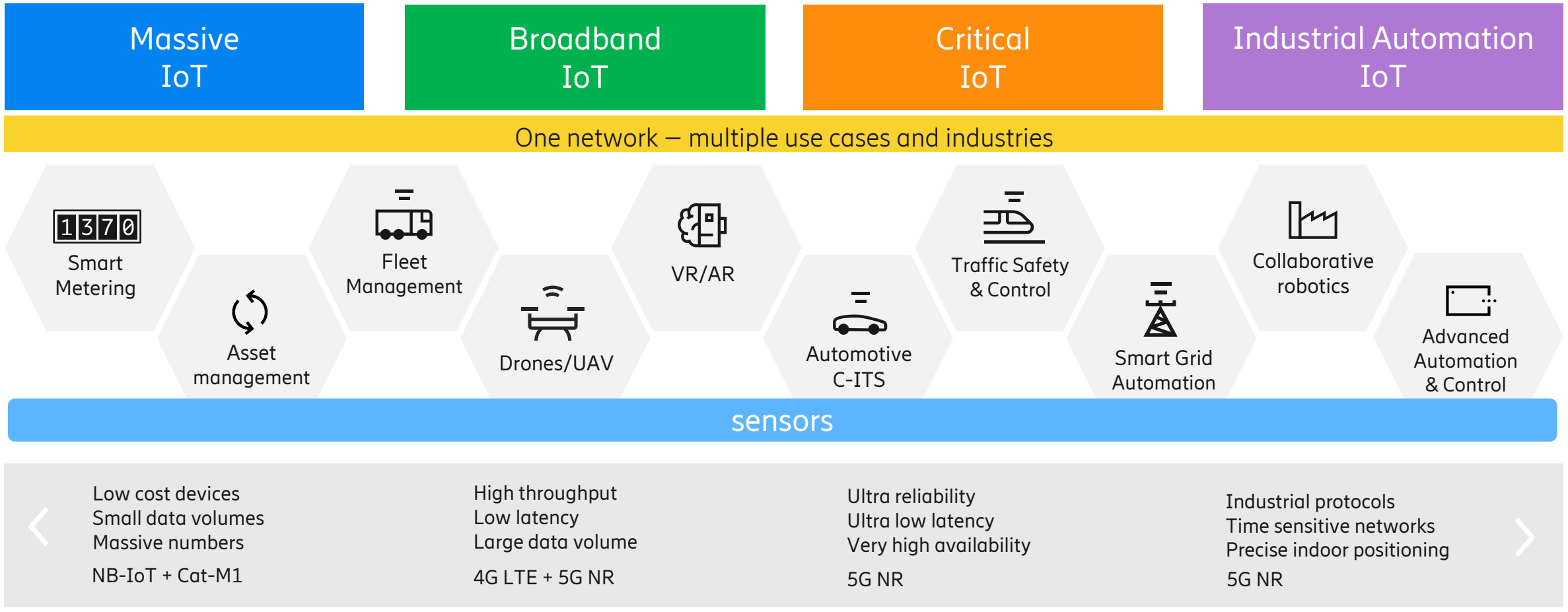
4 **Network deployment and ecosystem status**
Commercial network deployment status; UE device availability; Future network migration

Cellular Technology Evolution





Cellular IoT Segments



3GPP Cellular IoT Technologies

Performance Target

Coverage
20 dB better than smart phone coverage

Device Cost
(A) ultra-low, e.g. <$5
(B) low

Battery Life
(A) >10 years
(B) Multi-year

Connection Density
1M devices per km^2

Reliability & Latency
Up to 99.9999% within 0.5 ms

Bounded Low Latency
Time jitter in the order of us

LTE-M: 3GPP Rel-13 (2016) A A

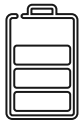
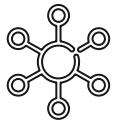
NB-IoT: 3GPP Rel-13 (2016) A A

NR URLLC: 3GPP Rel-15 (2018)

NR IIoT: 3GPP Rel-16 (2020)

NR RedCap: 3GPP Rel-17 (2022) B B

LTE-M & NB-IoT Overview

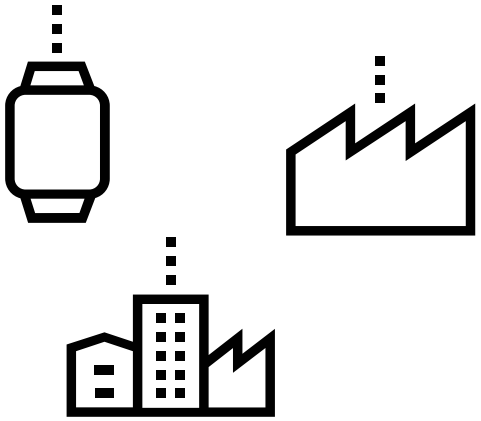
	 Carrier Bandwidth	 Coverage	 Battery life	 Capacity	 Peak Throughput DL/UL	 Mobility
LTE MTC	1.4-20 MHz	164 dB (+20 dB)	10+ Year	4.3 MHz/1M devices	300/375 kbps (0.8/1 Mbps)	Connected & idle mode mobility
NB-IoT	200 kHz	164 dB (+20 dB)	10+ Year	3 MHz/1M devices	21/63 kbps (227/250 kbps)	Idle mode mobility

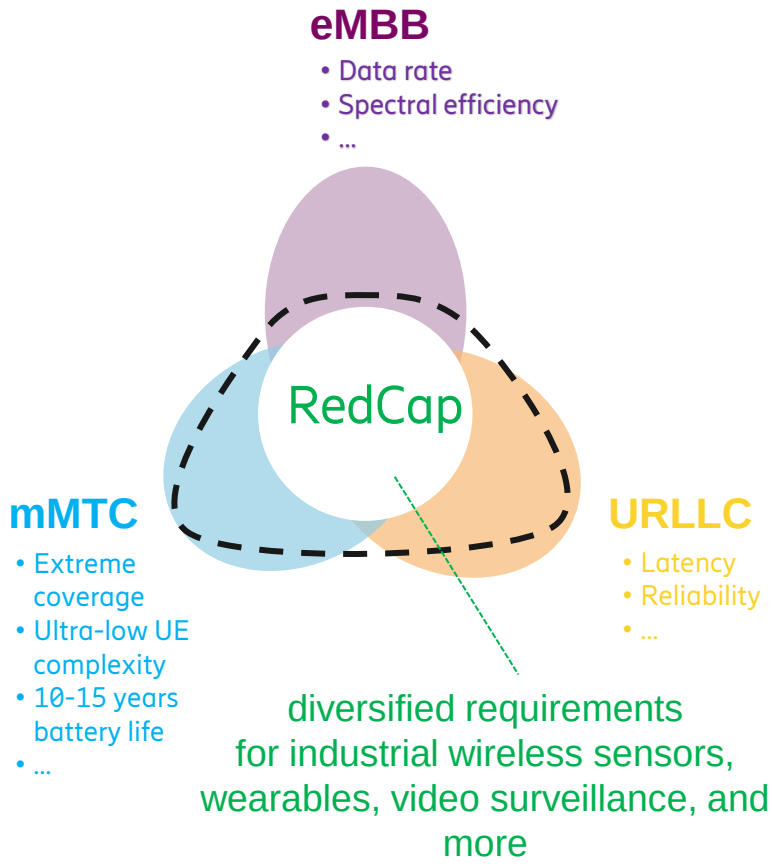
- Coverage enhancements essentially by time repetition
- Reduced UE complexity by narrow device BW, lower data rate requirements, and 1 Rx antenna
  - LTE-M device BW is 1.4 MHz for Cat-M1 and 5 MHz for Cat-M2.
  - NB-IoT device BW is 180 kHz for both Cat-NB1 and Cat-NB2.

NR RedCap Use Cases

- Intended to address use cases that are not best served by 3GPP Rel-16 specifications

- Main use cases
  - Wearables
  - Industrial wireless sensors
  - Video surveillance





3GPP Rel-17 RedCap

- Generic requirements
  - Device complexity: lower device cost and complexity as compared to high-end eMBB and URLLC devices of Rel-15/Rel-16.
  - Device size: 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:

Use case	Data rate	Latency	Reliability	Battery life
IWSN	2 Mbps	100 ms	99.99% (service availability)	Few years
Video Surveillance	2-4 Mbps, 7.5-25 Mbps (high-end)	500 ms	99%-99.9%	
Wearables	10-50 Mbps in DL, minimum 5 Mbps in UL. Peak bit rate: 150 Mbps for DL and 50 Mbps UL			Up to 1-2 weeks

Performance

- Modem cost reduction:
  - The reference is a UE supporting all mandatory features.

	FR1 FDD	FR1 TDD	FR2
Cost reduction	~65%	~71% (1 Rx) ~58% (2 Rx)	~48%

- Peak rate:
  - For TDD, a 3:1 DL:UL pattern is assumed in this table.

	FR1 FDD	FR1 TDD	FR2
DL peak rate	~80 Mbps	~60 Mbps (1 Rx) ~120 Mbps (2 Rx)	~300 Mbps
UL peak rate	~80 Mbps	~20 Mbps	~100 Mbps

- Battery life:
  - Using eDRX cycles of a few minutes in idle (or inactive) mode, a battery life of several years can be reached.
- Coverage impact:
  - Only a few DL channels need coverage recovery, and the losses can be compensated by legacy techniques
- Capacity impact:
  - Assuming low data volume for RedCap UEs, system-level simulations indicate small impact from RedCap UEs on spectral efficiency, capacity and eMBB UE performance.

3GPP Release-15 URLLC

- ITU requirements were adopted:
  - Latency requirement (one-way): Down to 1 ms
    - Layer 2/3 SDU ingress point to layer 2/3 SDU egress point of the radio interface
  - Reliability requirement: Up to $1 - 10^{-5}$
  - Packet size: 32 Bytes

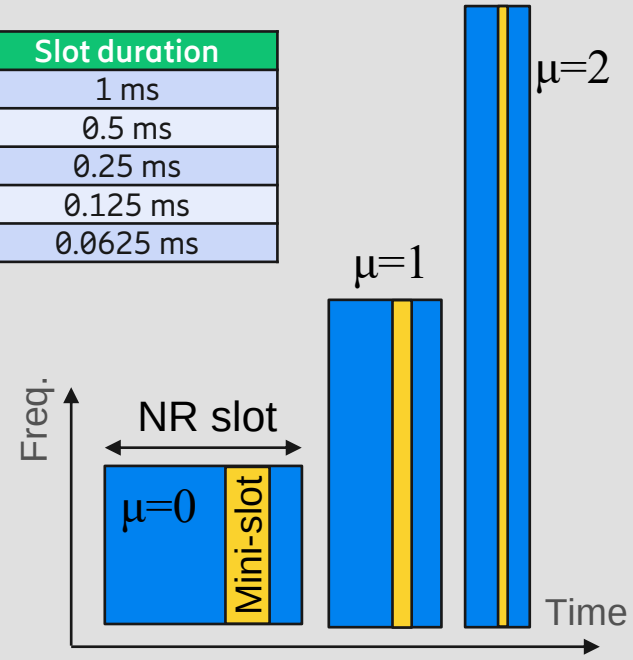
SDUs shall be correctly delivered within 1 ms (from ingress to egress) with an acceptable failure rate of 10^{-5}. *A late packet is a failure.*

3GPP URLLC/IIoT features

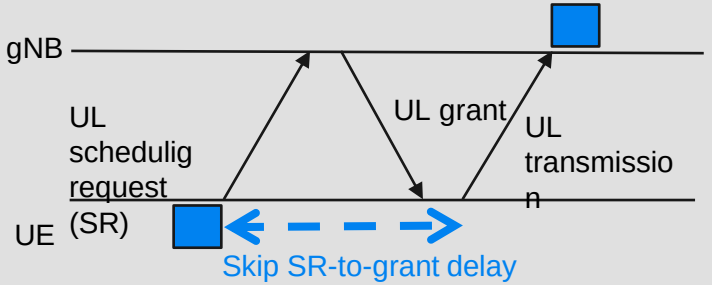
Low-latency features
High-reliability features
TSN feature

Numerology & mini-slot

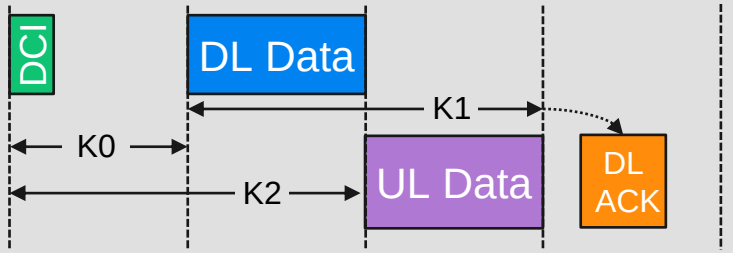
μ	SCS [kHz]	Slot duration
0	15	1 ms
1	30	0.5 ms
2	60	0.25 ms
3	120	0.125 ms
4	240	0.0625 ms



Pre-scheduling



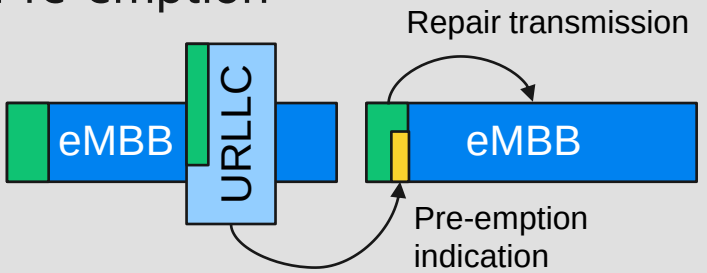
Fast HARQ



The fastest case is K0 = K1 = K2 = 0 slots

Fast UE processing

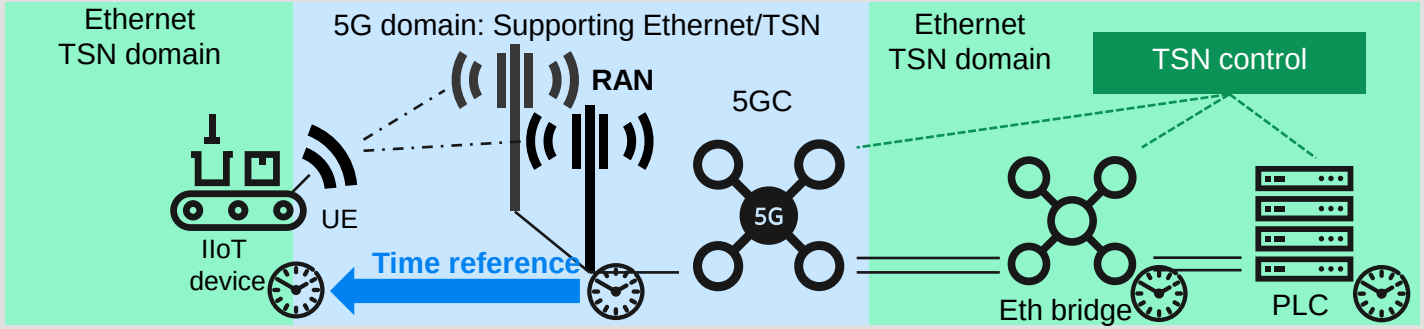
Pre-emption



Robust control and data

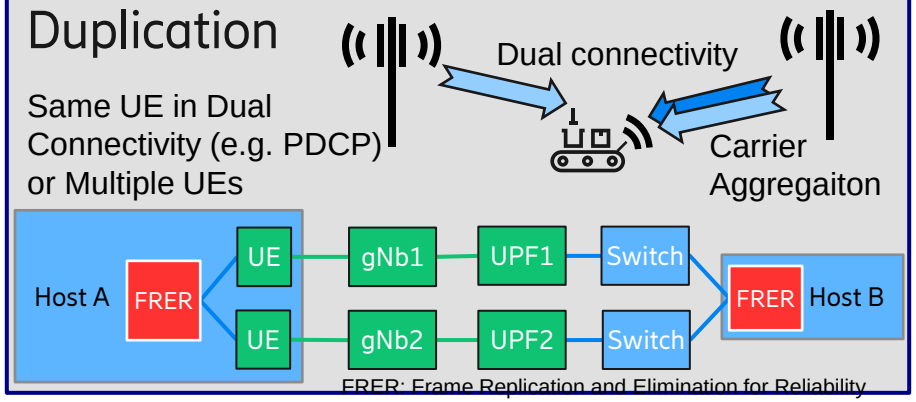
- Robust MCS tables
- CQI table for low BLER reporting
- Robust PDCCH/PUCCH

TSN integration



Duplication

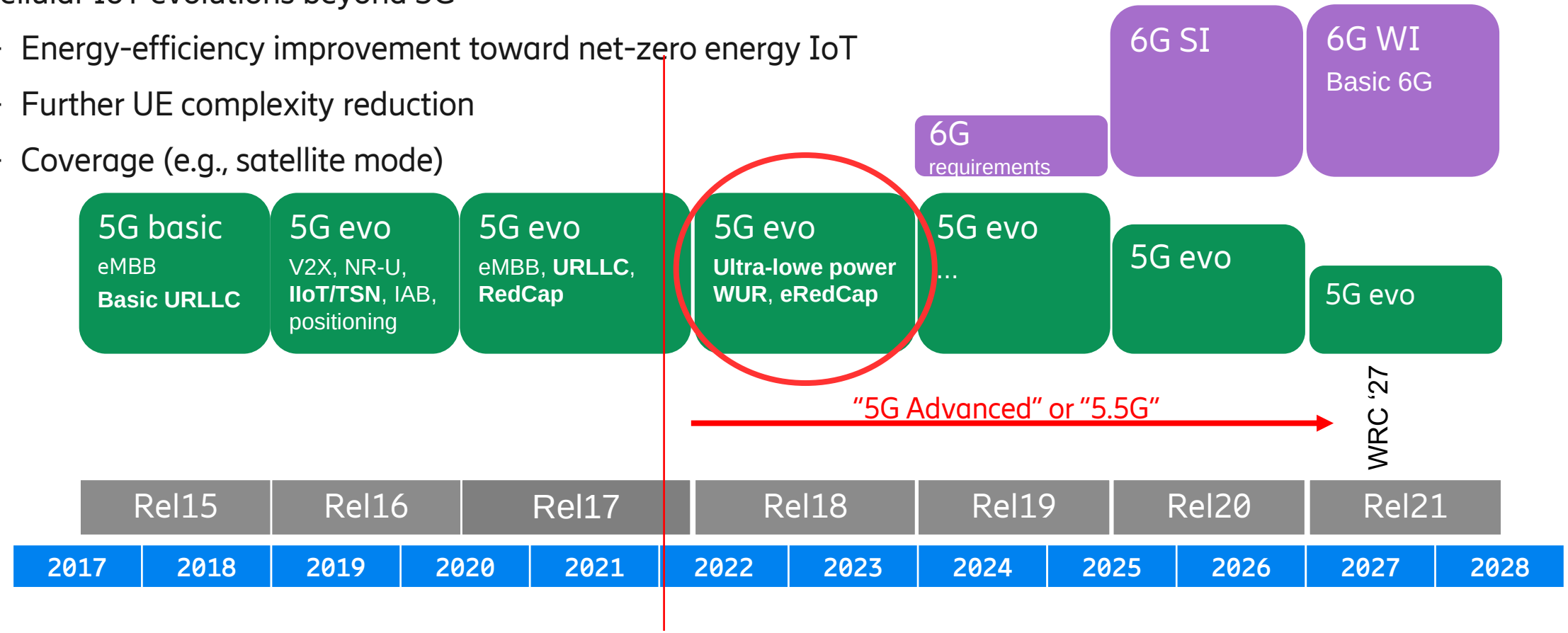
Same UE in Dual Connectivity (e.g. PDCP) or Multiple UEs



FRER: Frame Replication and Elimination for Reliability

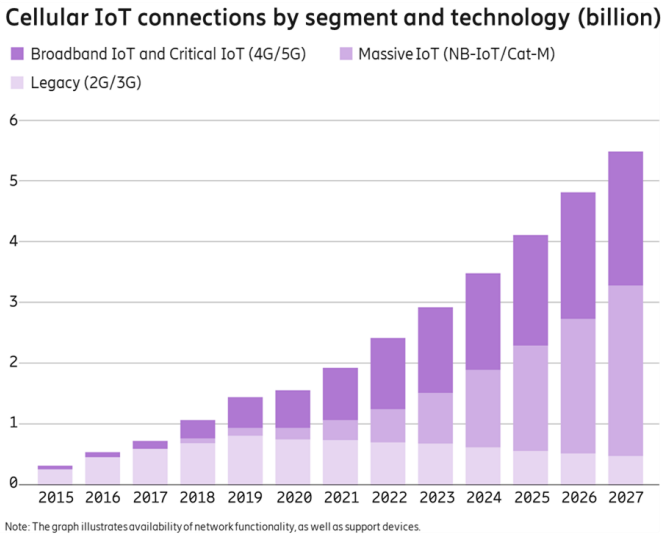
5G-Advanced and 6G

- 5G-Advanced starts in 3GPP Rel-18
  - Standardization work will start in 2022
- 6G work to start in Rel-19 (2024) with the 1st specification release in Rel-21 (~2028)
- Cellular IoT evolutions beyond 5G
  - Energy-efficiency improvement toward net-zero energy IoT
  - Further UE complexity reduction
  - Coverage (e.g., satellite mode)



LTE-M and NB-IoT Global ECO System and Market Status

139 operators in 64 countries have deployed/launched CIoT technologies



729 devices supporting either Cat-M1, Cat-NB1 or Cat-NB2

165 operators in 80 countries are known to be actively investing in NB-IoT networks

74 operators in 41 countries are known to be actively investing in NB-IoT networks

456 devices support Cat-NB1

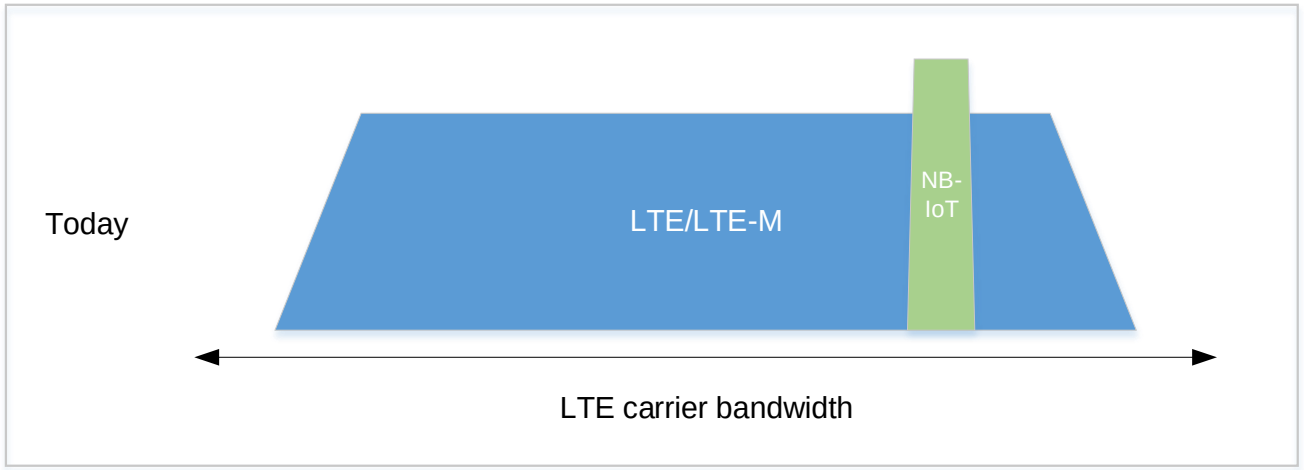
109 devices support Cat-NB2

536 devices support Cat-M1

References: NB-IoT & LTE-M: Global Ecosystem, September 2021https://gsacom.com/download.php?id=10774
Ericsson Mobility Report November 2021 https://www.ericsson.com/4ad7e9/assets/local/reports-papers/mobility-report/documents/2021/ericsson-mobility-report-november-2021.pdf

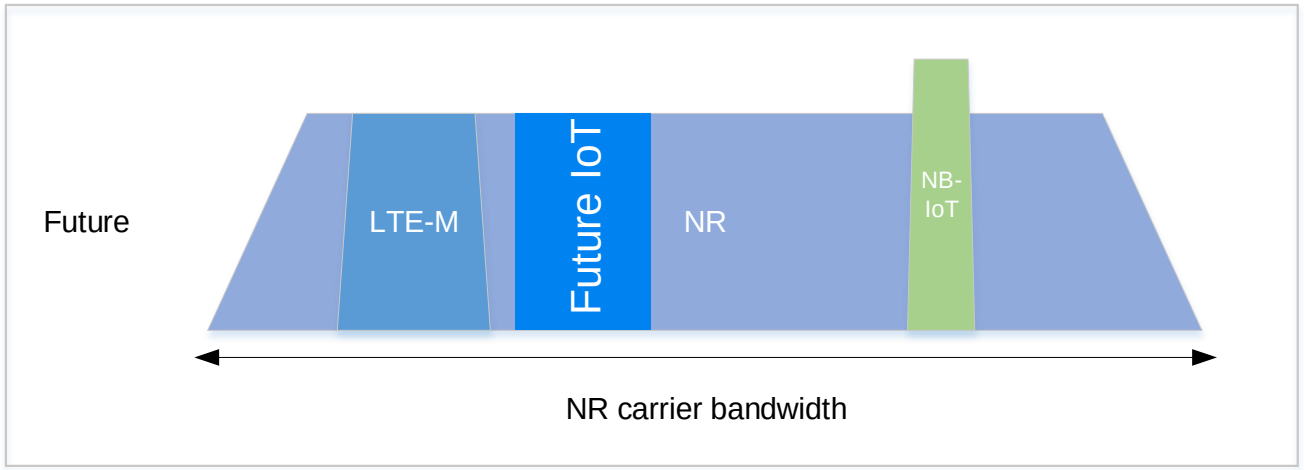
Future Network Migration

Spectrum re-farming



RAN software upgrade

NR built-in forward compatibility



Dynamic spectrum sharing

Cellular IoT service continuity ensured during eMBB driven network migration

Further Reading