Privátní sítě 5G

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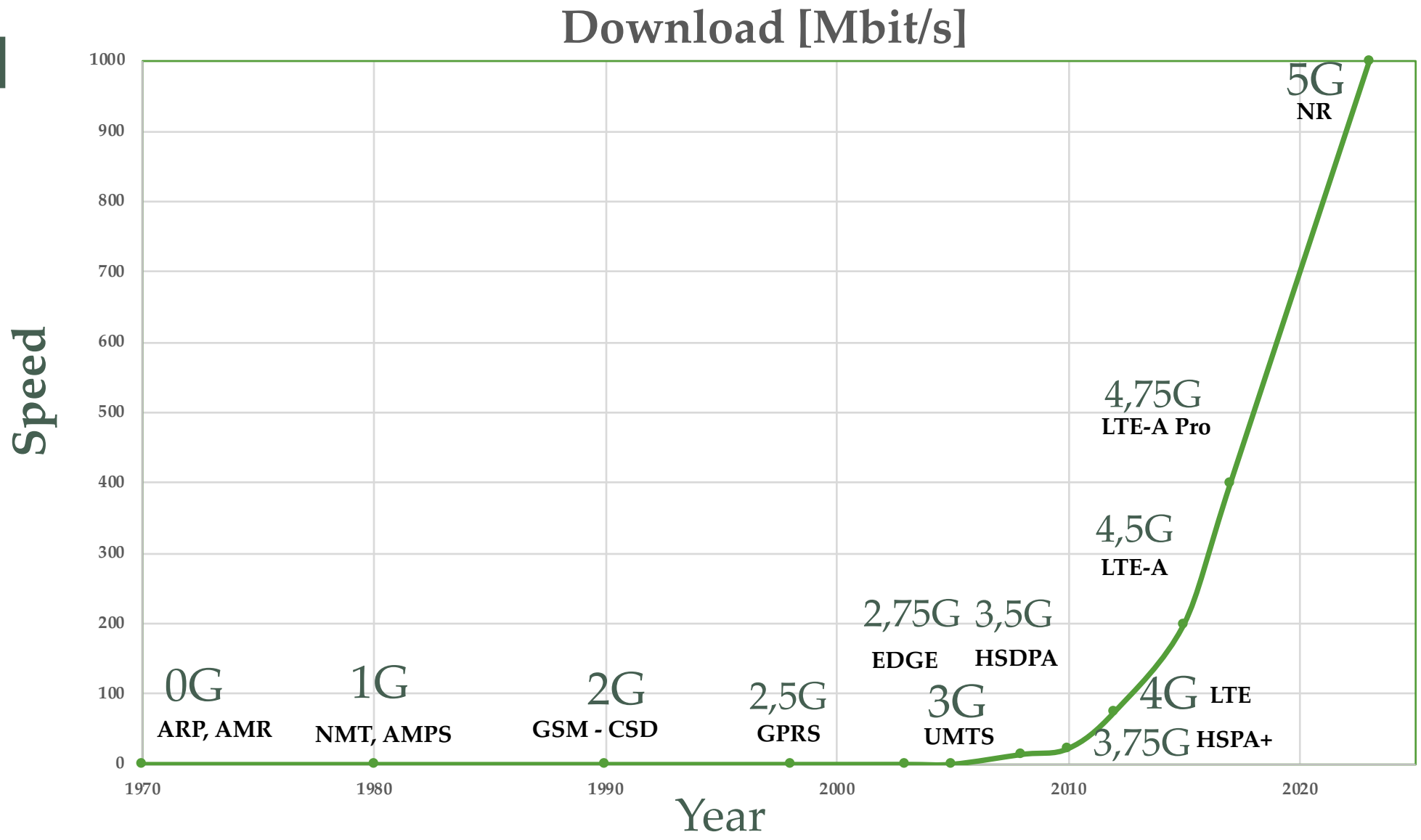
Data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0G
ARP, AMR
1G
NMT, AMPS
2G
GSM - CSD
2,5G
GPRS
2,75G
EDGE
3,5G
HSDPA
3G
UMTS
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HSPA+
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LTE-A
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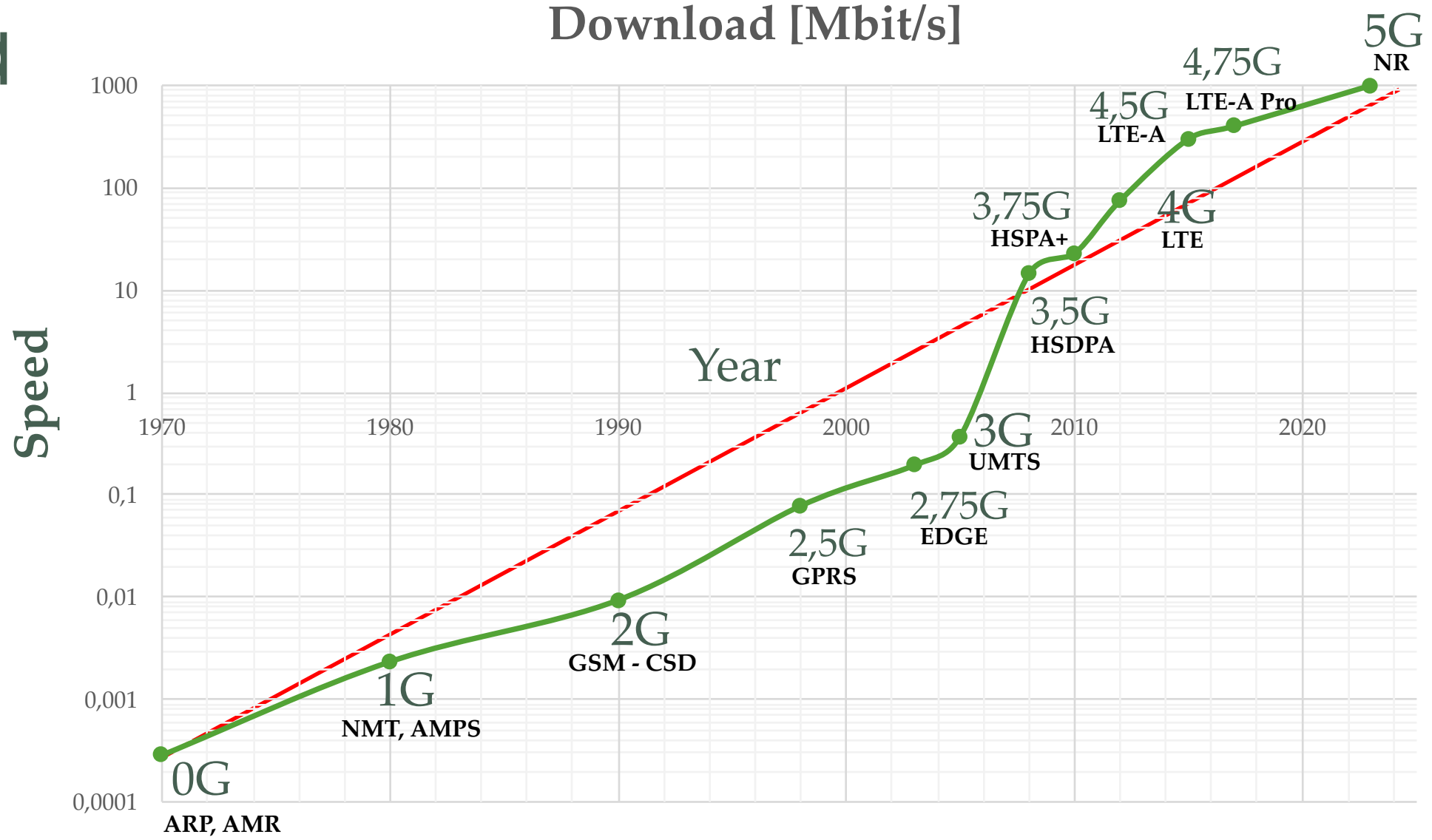
LTE-A Pro
5G
NR

Data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Speed
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HSDPA
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HSPA+
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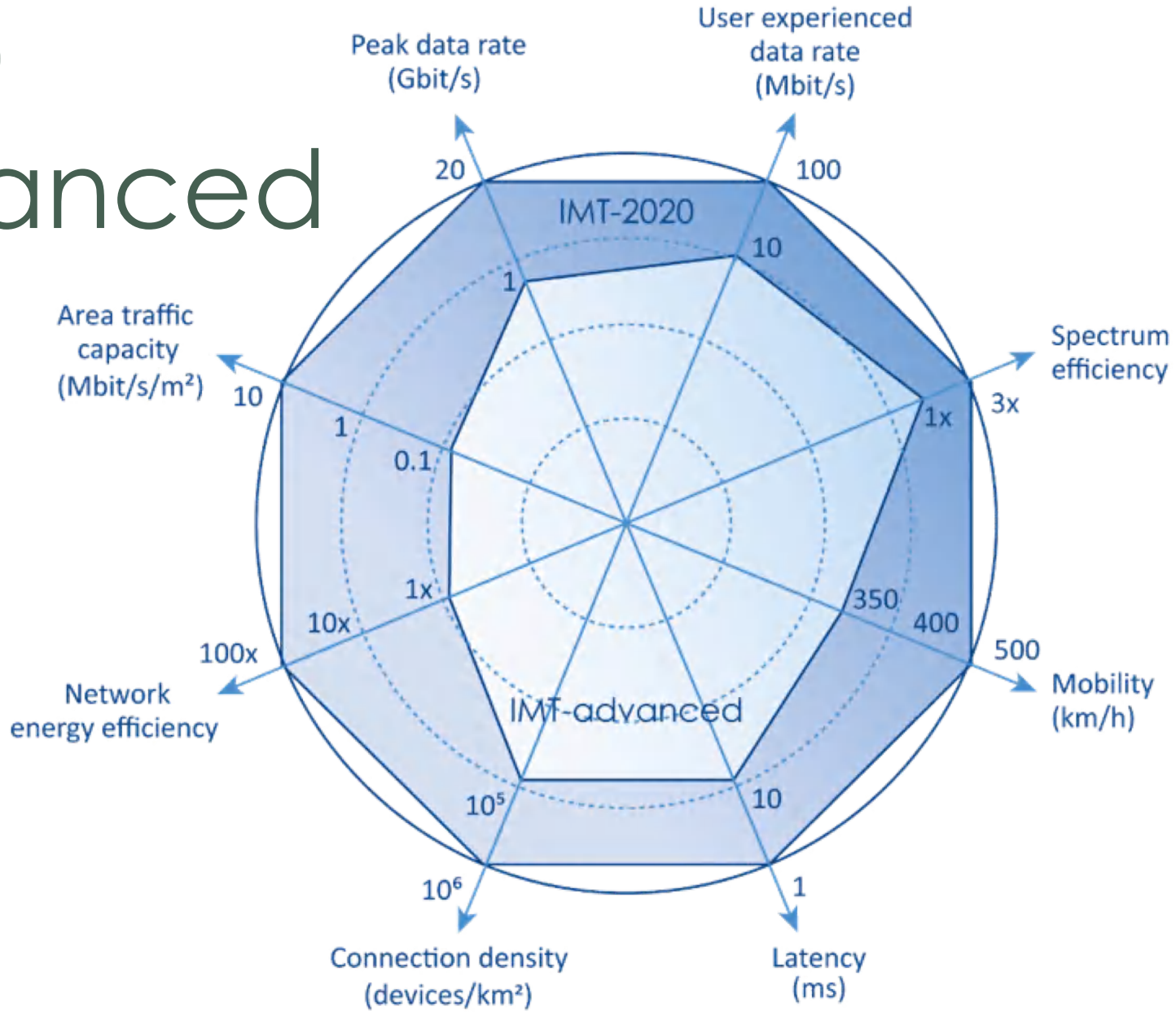
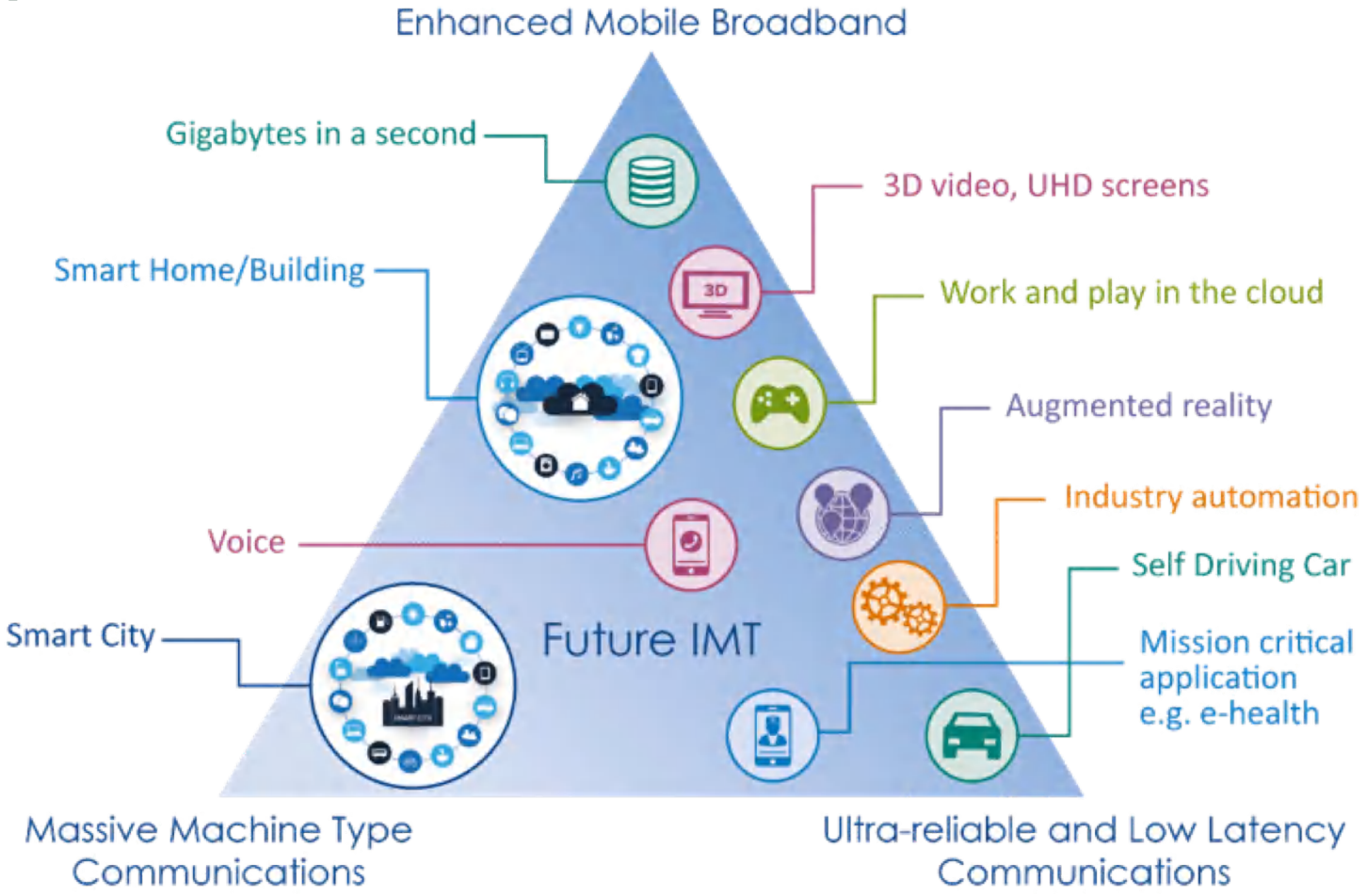
LTE-A Pro
5G
NR

CZ Speeds 03/2023

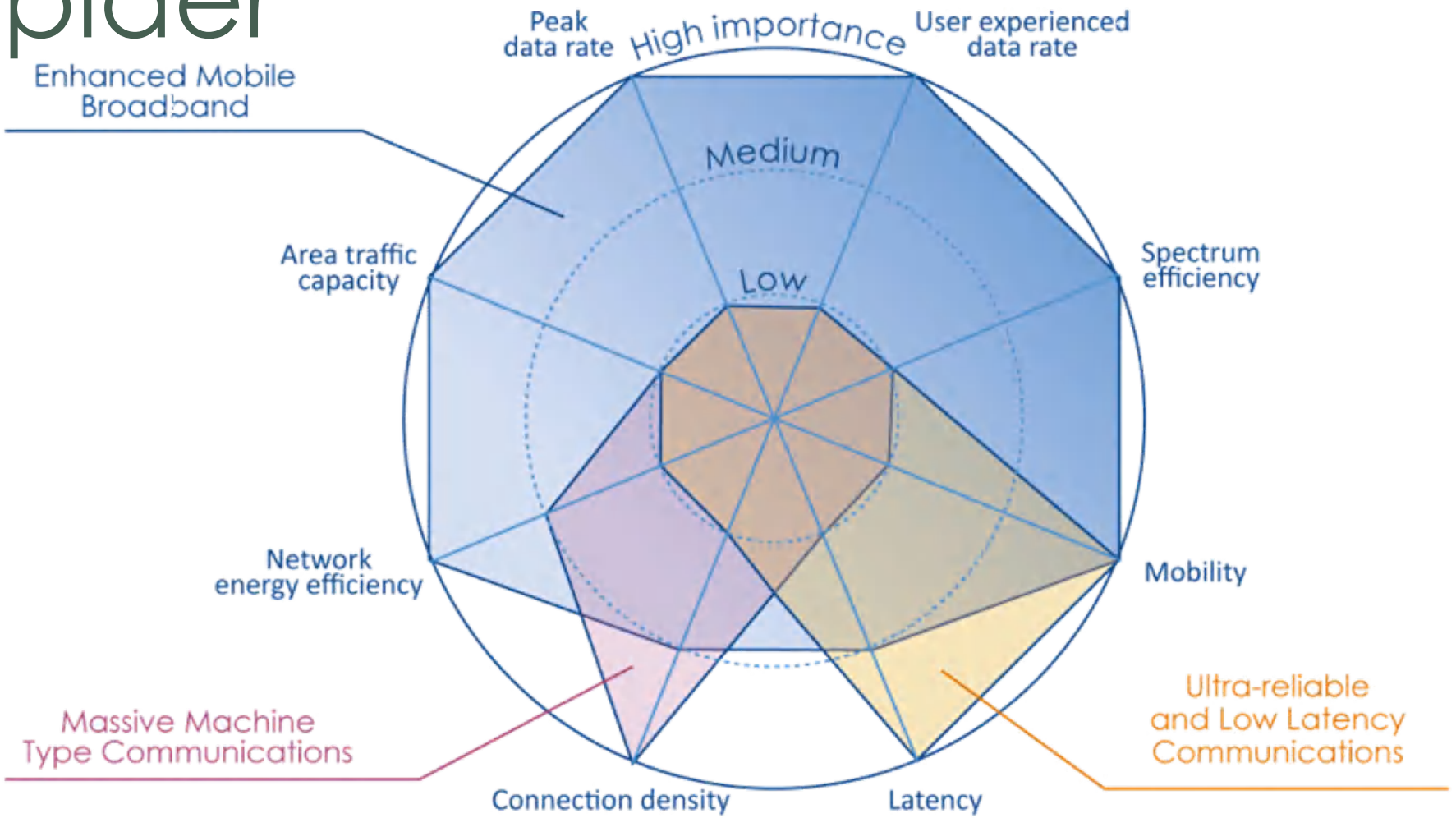
IMT-2020
IMT-advanced



5G – Type Of Communication



5G – Spider


Peak data rate
High importance
User experienced data rate
Enhanced Mobile Broadband
Medium
Area traffic capacity
Low
Spectrum efficiency
Network energy efficiency
Mobility
Massive Machine Type Communications
Ultra-reliable and Low Latency Communications
Connection density
Latency

5G Cases according ITU-R

- **Enhanced Mobile Broadband (eMBB**) to deal with hugely increased data rates, high user density and very high traffic capacity for hotspot scenarios as well as seamless coverage and high mobility scenarios with still improved used data rates
- **Massive Machine-type Communications (mMTC)** for the IoT, requiring low power consumption and low data rates for very large numbers of connected devices
- **Ultra-reliable and Low Latency Communications (uRLLC)** to cater for safety-critical and mission critical applications

5G NR – Radio frequencies

The air interface defined by 3GPP for 5G is known as **New Radio (NR)**

2 frequency bands, FR1 (below 6 GHz) and FR2 (mmWave), each with different capabilities.

Frequency Range 1 (< 6 GHz)

- The maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3 – 4.2 GHz and 2G, 3G, 4G frequency bands

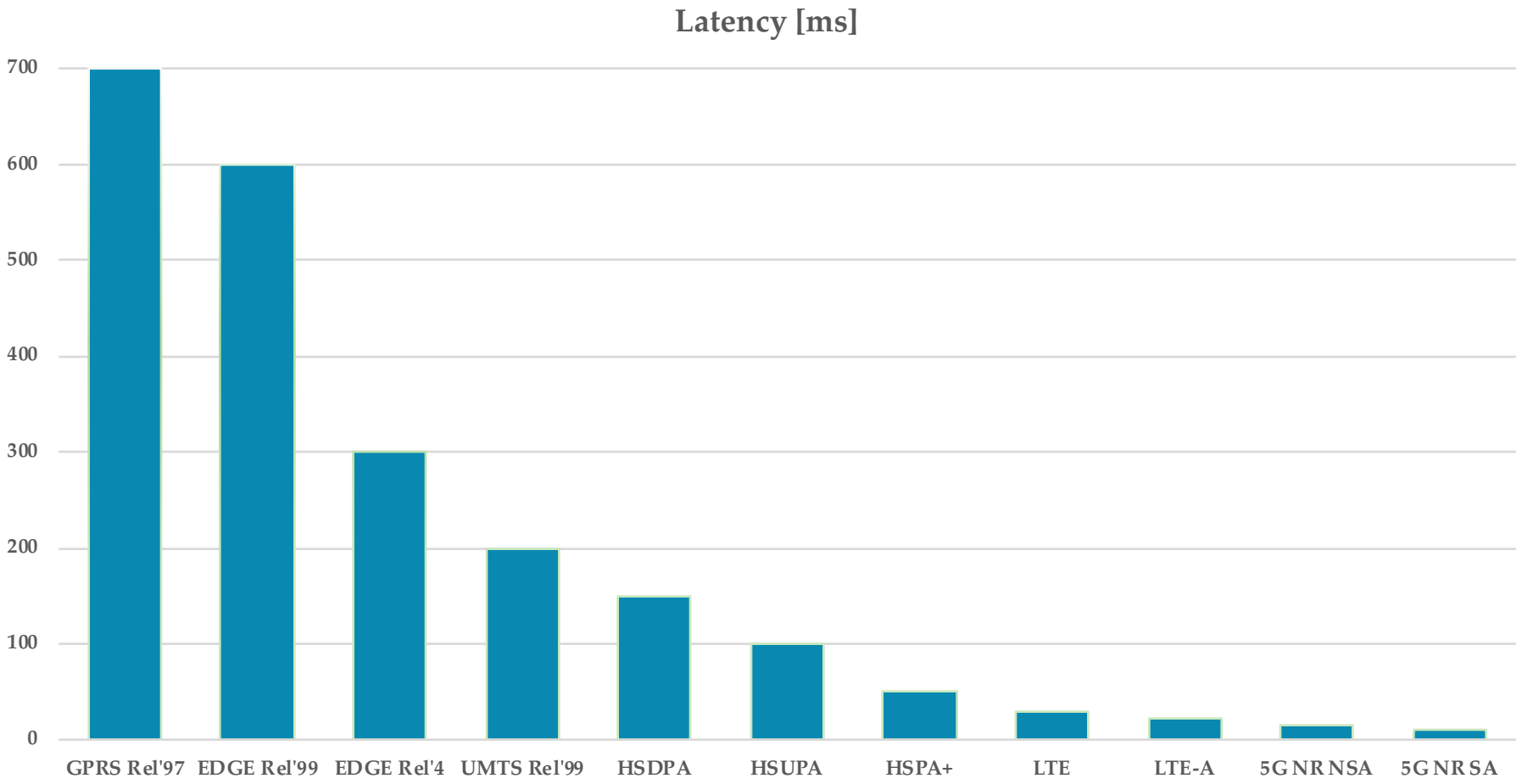
Frequency Range 2 (> 24 GHz) mmWave

- The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. The higher the frequency, the greater the ability to support high data-transfer speeds.

5G current state

- Current 5G / NSA – 4G LTE SAE/EPC core & new gNB 5G NR (BTS)
- Standalone (SA) x Non-Standalone (NSA) x Hybird 5G
- Standalone only private – 5G campus network
- 5G core x 4G EPC core
- Band FR1 – 700 MHz; 2 GHz; 3,5 GHz; 5 , 6 & 7 GHz
- Bands over existing 2G, 3G and 4G networks (operators only)
- Dynamic Spectrum Sharing (DSS) 4G LTE & 5G NR
- New Bands FR2 – 26, 28, 39 & 41 GHz
- Carrier aggregation & Dual connectivity

Latency in mobile network



Ultra Low Latency?

- < 20 ms – Current Virtual Reality (VR)
- < 10 ms – Extended Reality (XR)
- < 5 ms – Augmented Reality (AR)

Motion–To–Photon

Optical See–Through Head–Mounted Displays (OST-HMD)

Jitter

Jitter is a variation in packet transit delay caused by queuing, contention and serialization effects on the path through the network. In general, higher levels of jitter are more likely to occur on either slow or heavily congested links. It is expected that the increasing use of „QoS“ control mechanisms such as „class based“ queuing, bandwidth reservation and of higher speed links.

ping & jitter SA network / local

```
PACKET JITTER v1.5 & RFC 1889
PING 10.81.40.97 (10.81.40.97): 56 data bytes
64 bytes from 10.81.40.97: seq=0 ttl=254 time=10.862 ms
64 bytes from 10.81.40.97: seq=1 ttl=254 time=10.233 ms jitter=0.629 ms avg=0.629 ms rfc_jitter=0.676 ms
64 bytes from 10.81.40.97: seq=2 ttl=254 time=9.686 ms jitter=0.547 ms avg=0.588 ms rfc_jitter=0.668 ms
64 bytes from 10.81.40.97: seq=3 ttl=254 time=10.278 ms jitter=0.592 ms avg=0.589 ms rfc_jitter=0.663 ms
64 bytes from 10.81.40.97: seq=4 ttl=254 time=9.654 ms jitter=0.624 ms avg=0.598 ms rfc_jitter=0.661 ms
64 bytes from 10.81.40.97: seq=5 ttl=254 time=10.263 ms jitter=0.609 ms avg=0.600 ms rfc_jitter=0.657 ms
64 bytes from 10.81.40.97: seq=6 ttl=254 time=9.681 ms jitter=0.582 ms avg=0.597 ms rfc_jitter=0.653 ms
64 bytes from 10.81.40.97: seq=7 ttl=254 time=10.289 ms jitter=0.608 ms avg=0.599 ms rfc_jitter=0.650 ms
64 bytes from 10.81.40.97: seq=8 ttl=254 time=9.685 ms jitter=0.604 ms avg=0.599 ms rfc_jitter=0.647 ms
64 bytes from 10.81.40.97: seq=9 ttl=254 time=10.331 ms jitter=0.646 ms avg=0.605 ms rfc_jitter=0.647 ms

--- 10.81.40.97 ping statistics ---
9 jitters count
jitter min/avg/max = 0.547/0.605/0.646 ms, RFC1889 jitter 0.647 ms
rtt-1 min/avg/max = 9.654/10.011/10.331 ms
10 packets transmitted, 10 packets received, 0% packet loss
round-trip min/avg/max = 9.654/10.096/10.862 ms
```

ping & jitter SA network / 1.1.1.1

```
PACKET JITTER v1.5 & RFC 1889
PING 1.1.1.1 (1.1.1.1): 56 data bytes
64 bytes from 1.1.1.1: seq=0 ttl=56 time=12.369 ms
64 bytes from 1.1.1.1: seq=1 ttl=56 time=10.522 ms jitter=1.847 ms avg=1.847 ms rfc_jitter=0.840 ms
64 bytes from 1.1.1.1: seq=2 ttl=56 time=9.786 ms jitter=0.736 ms avg=1.292 ms rfc_jitter=0.834 ms
64 bytes from 1.1.1.1: seq=3 ttl=56 time=11.488 ms jitter=1.702 ms avg=1.428 ms rfc_jitter=0.888 ms
64 bytes from 1.1.1.1: seq=4 ttl=56 time=10.677 ms jitter=0.811 ms avg=1.274 ms rfc_jitter=0.883 ms
64 bytes from 1.1.1.1: seq=5 ttl=56 time=8.780 ms jitter=1.897 ms avg=1.399 ms rfc_jitter=0.947 ms
64 bytes from 1.1.1.1: seq=6 ttl=56 time=11.190 ms jitter=2.410 ms avg=1.567 ms rfc_jitter=1.038 ms
64 bytes from 1.1.1.1: seq=7 ttl=56 time=9.386 ms jitter=1.804 ms avg=1.601 ms rfc_jitter=1.086 ms
64 bytes from 1.1.1.1: seq=8 ttl=56 time=10.586 ms jitter=1.200 ms avg=1.551 ms rfc_jitter=1.093 ms
64 bytes from 1.1.1.1: seq=9 ttl=56 time=8.892 ms jitter=1.694 ms avg=1.567 ms rfc_jitter=1.131 ms

--- 1.1.1.1 ping statistics ---
9 jitters count
jitter min/avg/max = 0.736/1.567/2.410 ms, RFC1889 jitter 1.131 ms
rtt-1 min/avg/max = 8.780/10.145/11.488 ms
10 packets transmitted, 10 packets received, 0% packet loss
round-trip min/avg/max = 8.780/10.367/12.369 ms
```

5G NR, FR 2 for private

FR2	Band [GHz]	Name	Uplink / Downlink [GHz]			Channel bandwidths [MHz]	Duplex Mode
n257	**28**	**LMDS**	26,50	–	29,50	50, 100, 200, 400	TDD
n258	**26**	**K-band**	24,25	–	27,50	50, 100, 200, 400	TDD
n259	**41**	**V-band**	39,50	–	43,50	50, 100, 200, 400	TDD
n260	**39**	**Ka-band**	37,00	–	40,00	50, 100, 200, 400	TDD
n261	**28**	**Ka-band**	27,50	–	28,35	50, 100, 200, 400	TDD
n262	**47**	**V-band**	47,20	–	48,20	50, 100, 200, 400	TDD
n263	**60**	**V-band**	57,00	–	71,00	100, 400, 800, 1600, 2000	TDD

n263 - 5G NR Unlicensed

5G NR, FR 1 for Private

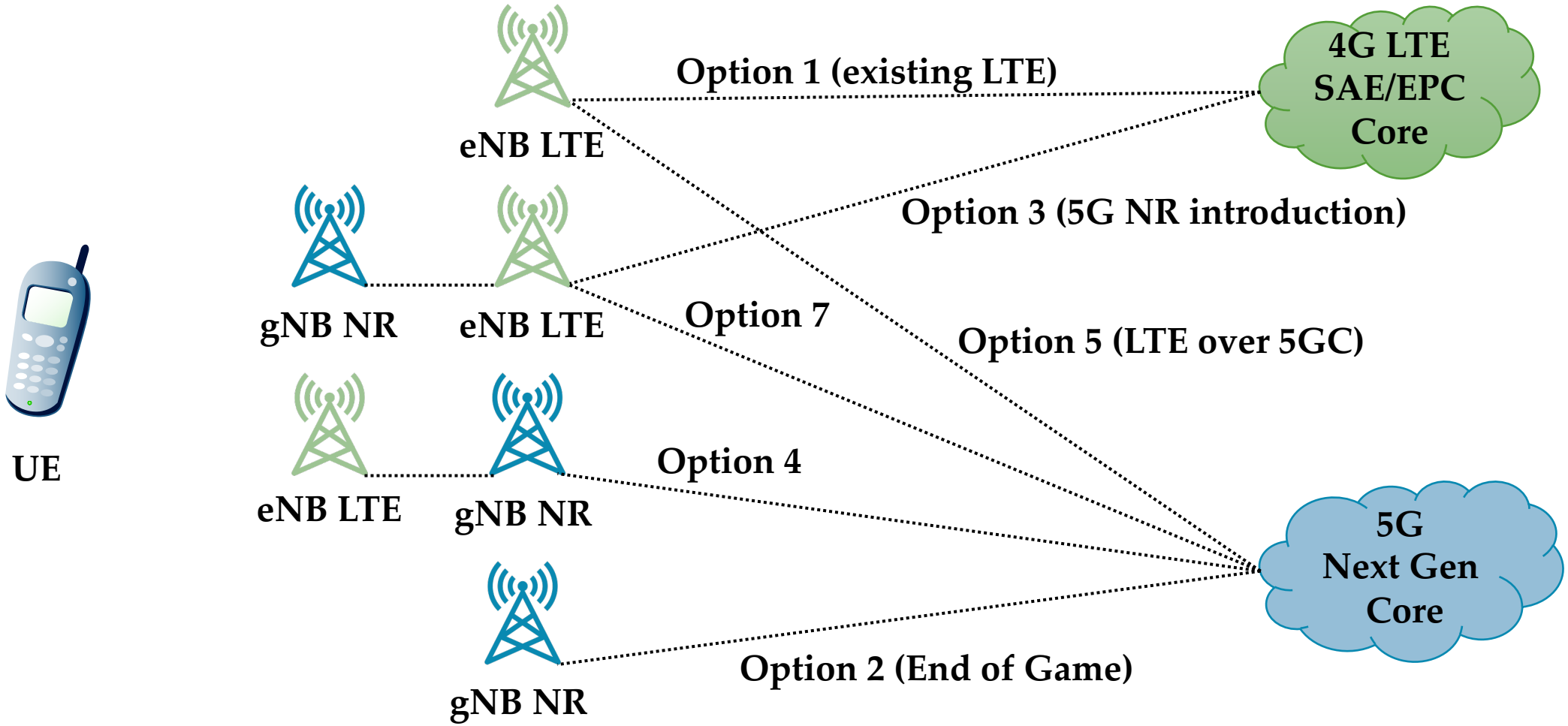
FR1	Uplink [GHz]	Downlink [GHz]	Duplex
n28	0.703 – 0.748	0.758 – 0.803	FDD
n77	3.3 – 4.2	3.3 – 4.2	TDD
n78	3.3 – 3.8	3.3 – 3.8	TDD
n79	4.4 – 5.0	4.4 – 5.0	TDD
n96	5.925 – 7.125	5.925 – 7.125	TDD
n102	5.925 – 6.425	5.925 – 6.425	TDD
n104	6.425 – 7.125	6.425 – 7125	TDD

n96, n102, n104 - 5G NR Unlicensed

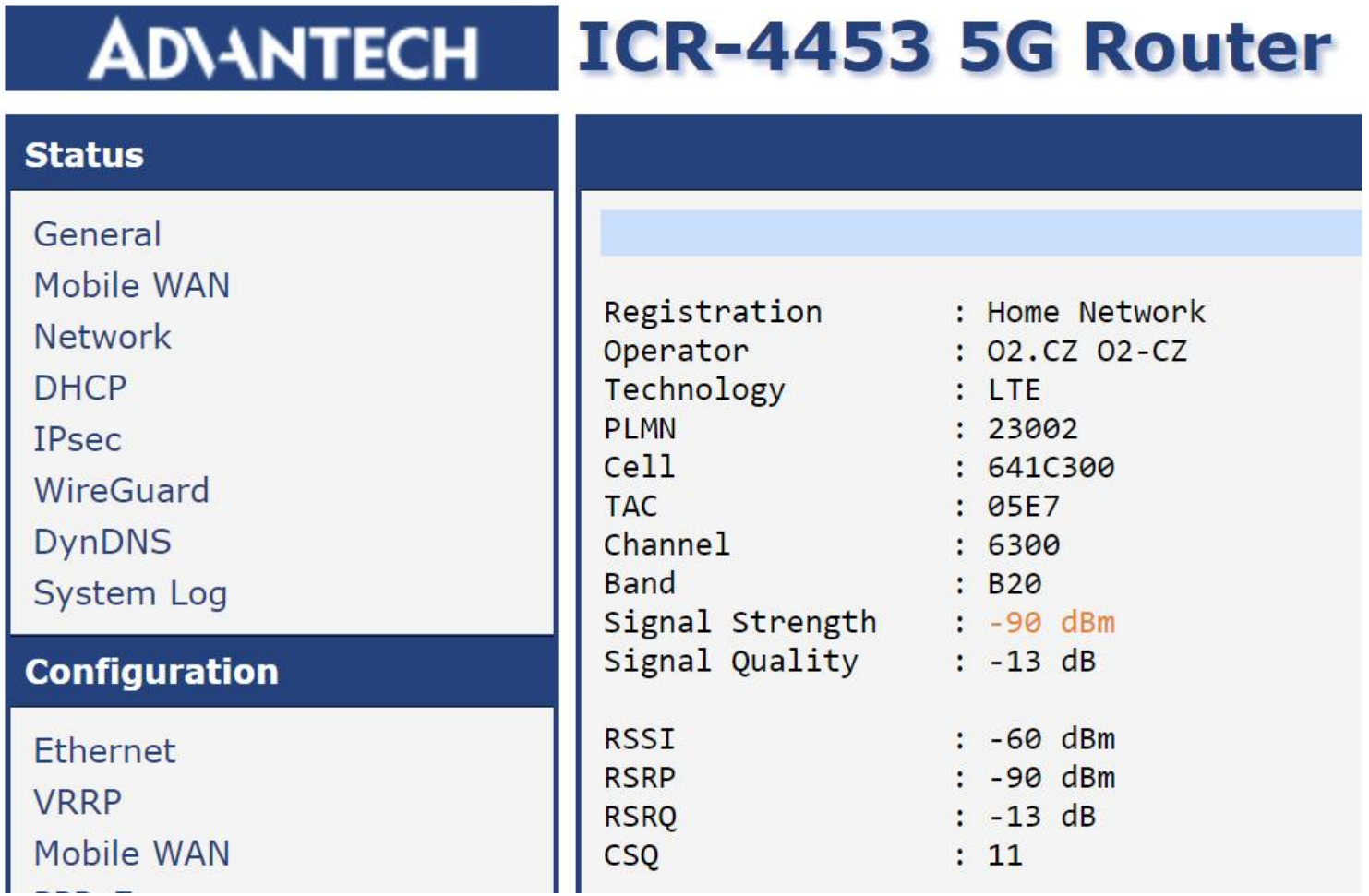
Unlicensed bands – EU

Band	FRQ [GHz]	Bandwidth	Indoor / Outdoor
2,4	2.4 – 2.4835	83.5 MHz	Indoor, Outdoor
5	5.150 – 5.350	200 MHz	Indoor
	5.470 – 5.725	255 MHz	Indoor / outdoor
6	5.945 – 6.425	480 MHz	Indoor, outdoor
17	17.1 – 17.3	200 MHz	Indoor, outdoor
60	57 – 66	9 GHz	Indoor, outdoor

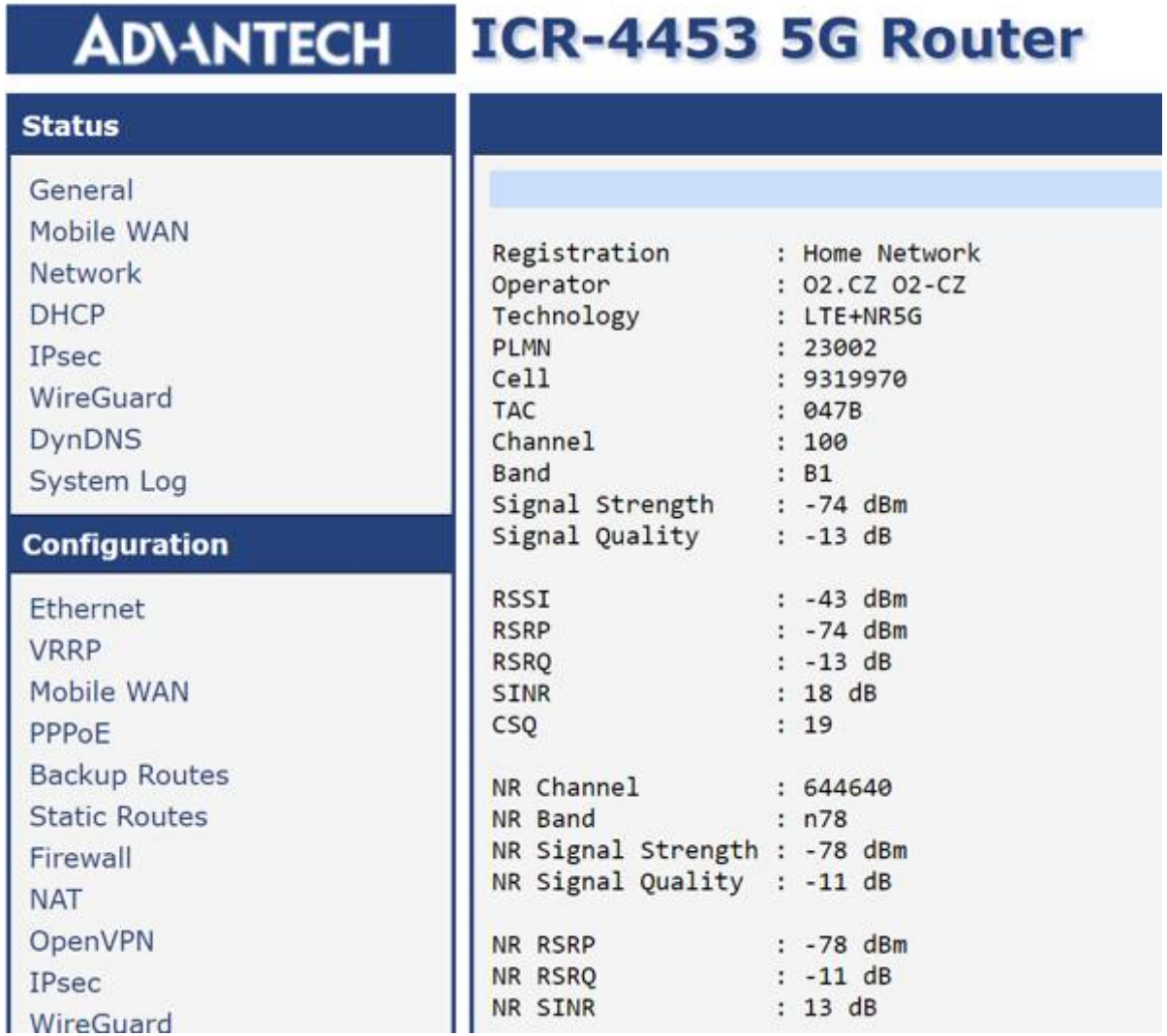
5G Architecture Options



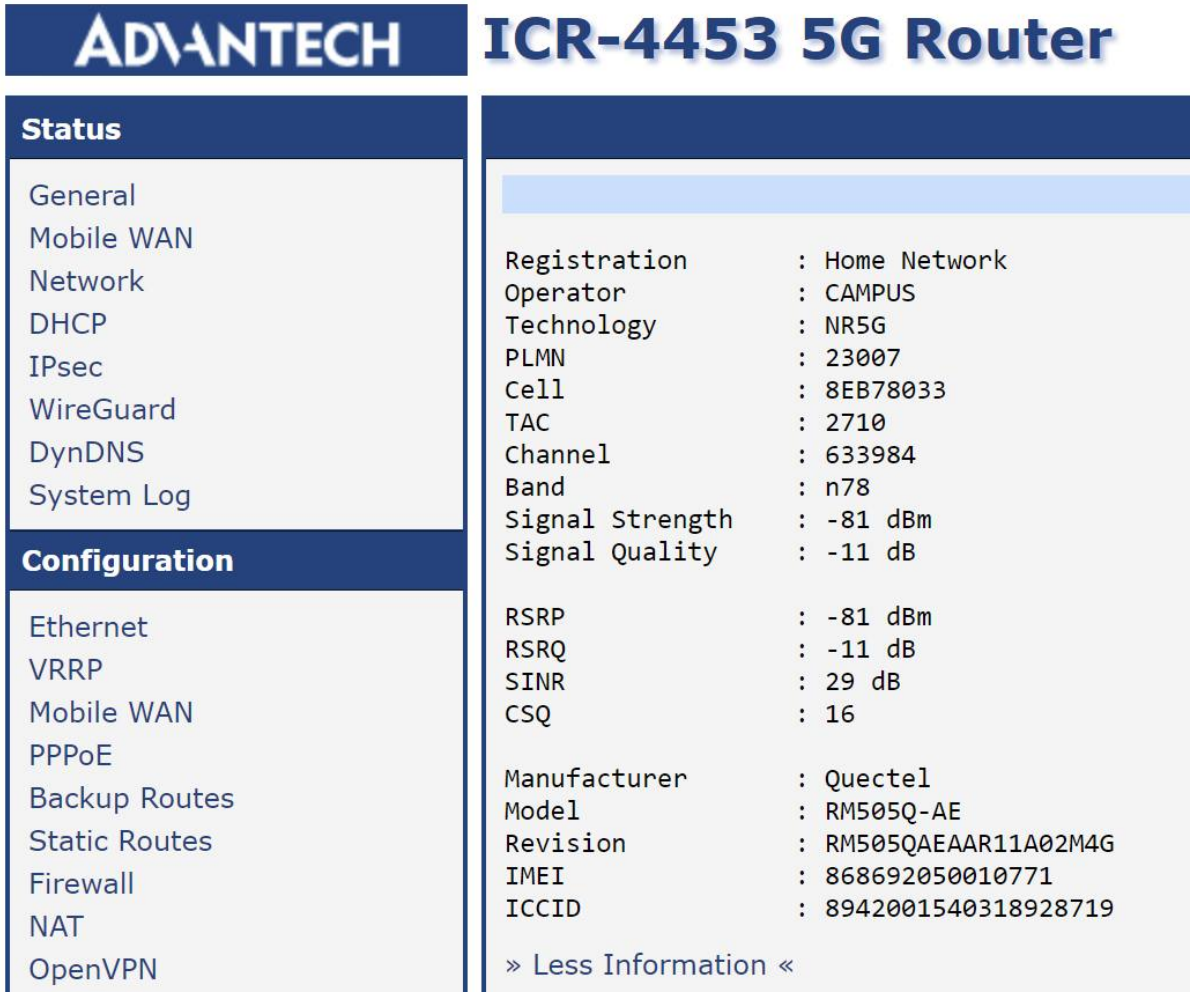
Long-Term Evolution (LTE)



LTE+5G NR Non-Standalone Mode (NSA)



5G NR Standalone Mode (SA)



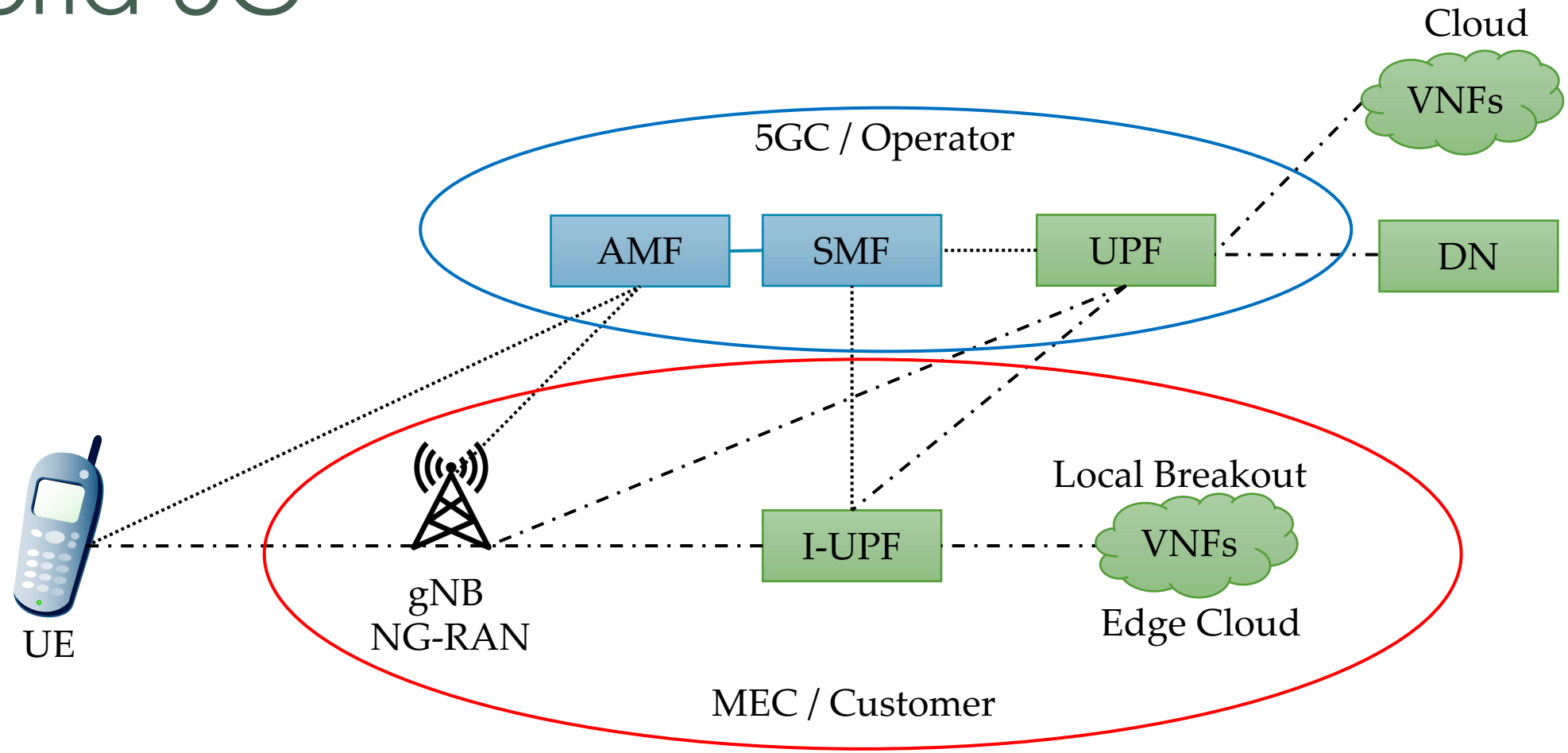
Standardized SST values

Standardized SST values provide a way for establishing global interoperability for slicing so that PLMNs can support the roaming use case more efficiently for the most commonly used Slice/Service Types.

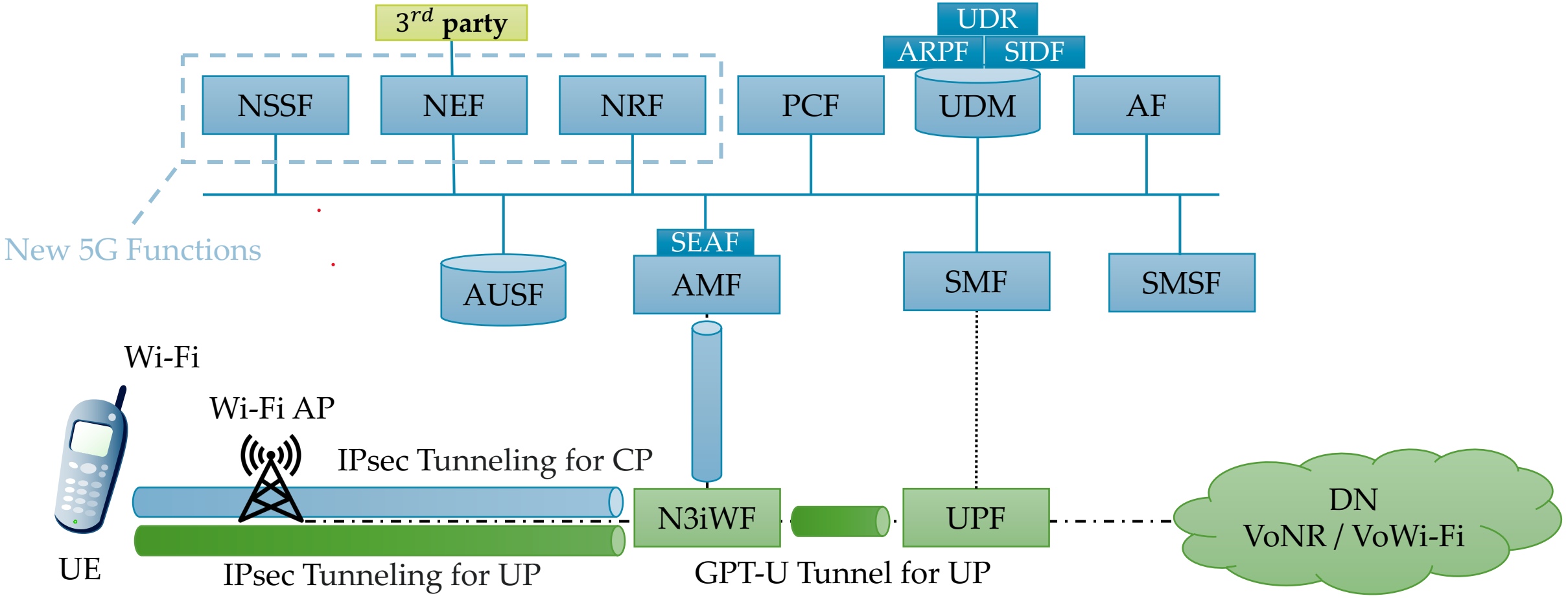
Slice/ Service type	SST value	Characteristics	Rel
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband.	15
uRLLC	2	Slice suitable for the handling of ultra- reliable low latency communications.	15
MIoT	3	Slice suitable for the handling of massive IoT.	15
V2X	4	Slice suitable for the handling of V2X services.	16
HMTC	5	Slice suitable for the handling of High-Performance Machine-Type Communications.	17

SST Slice/Service Type (SST)

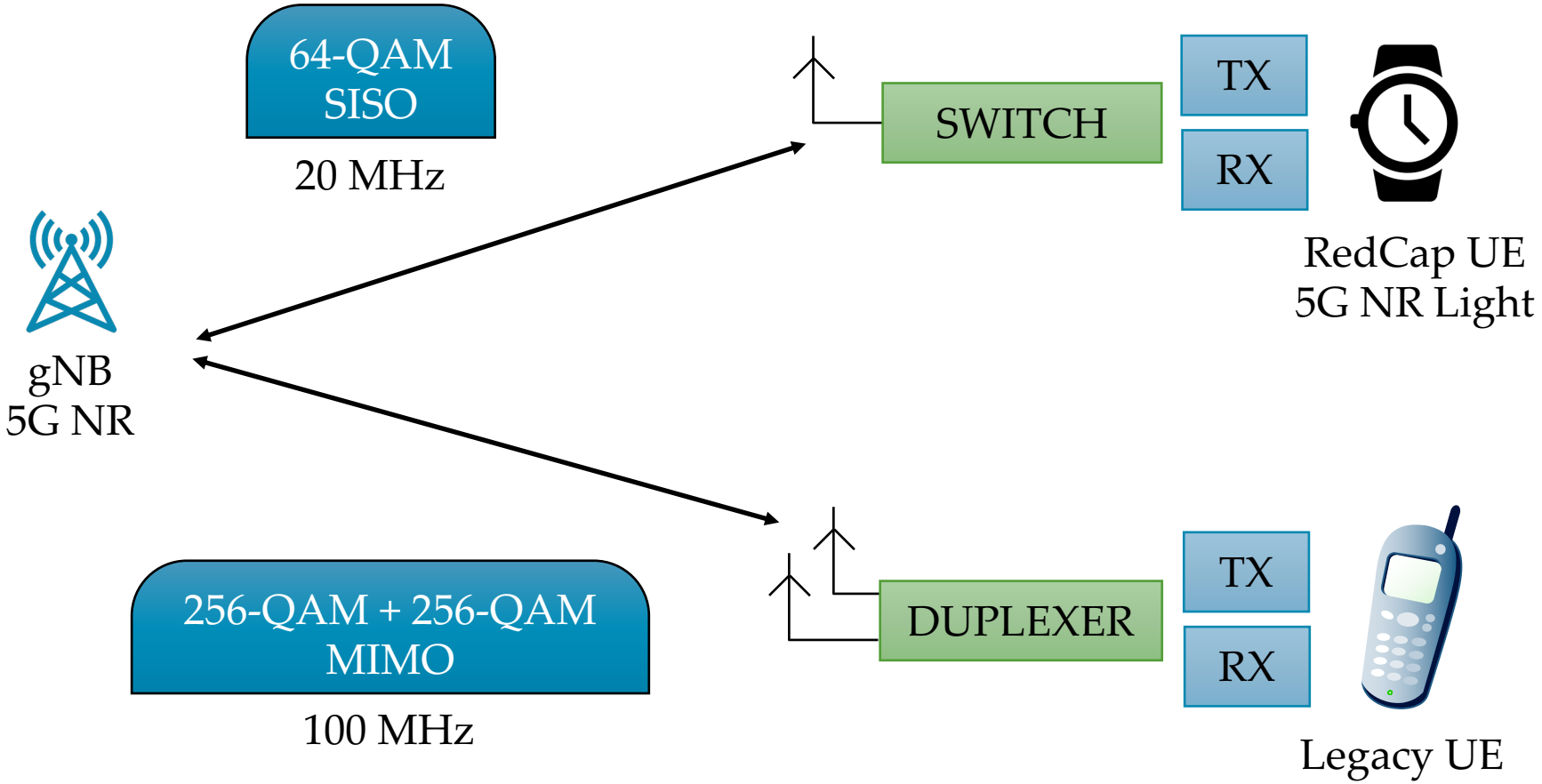
Multi-access Edge Computing (MEC) Hybrid 5G



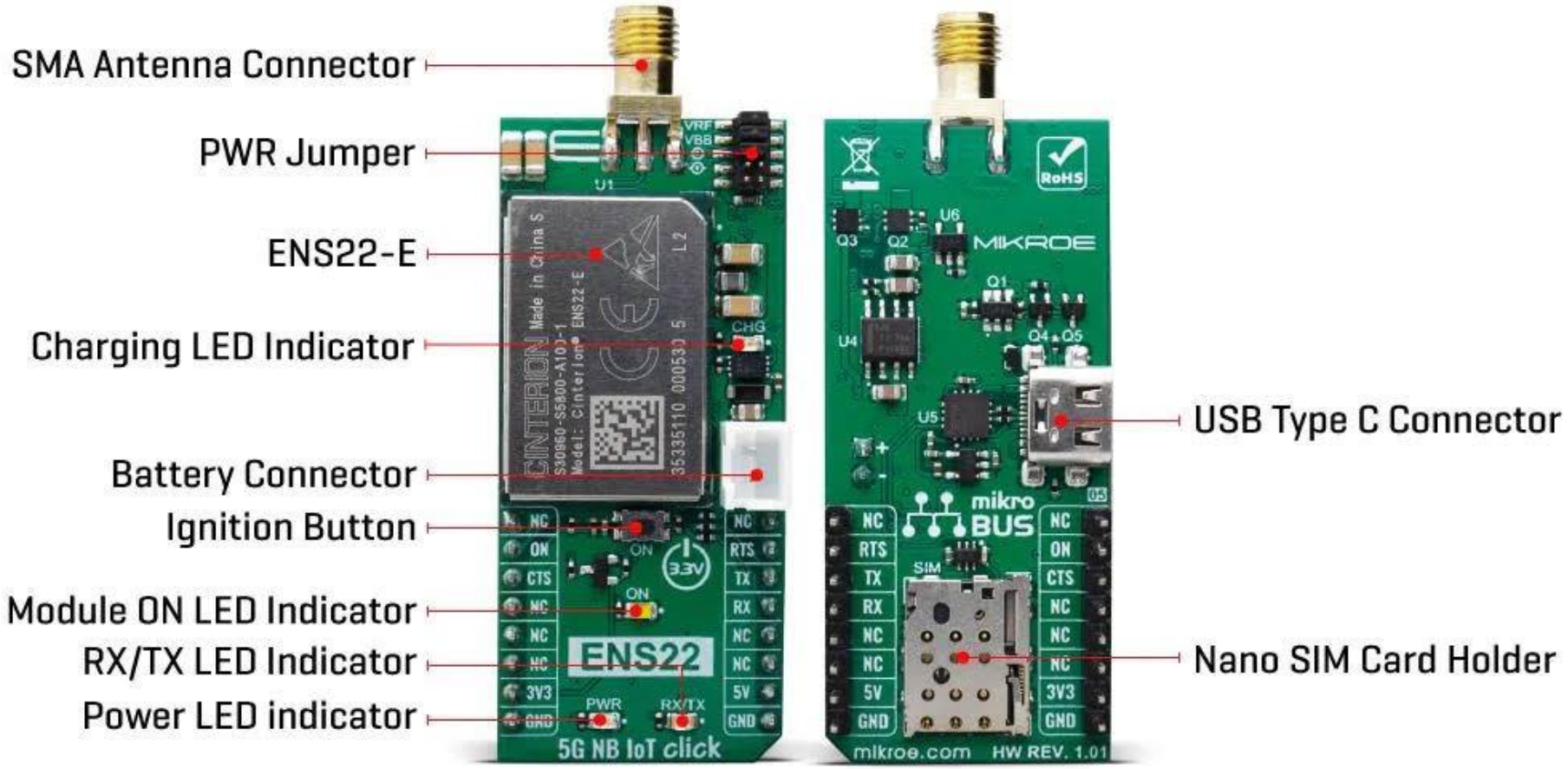
5G and Wi-Fi integration



RedCap vs Legacy 5G NR

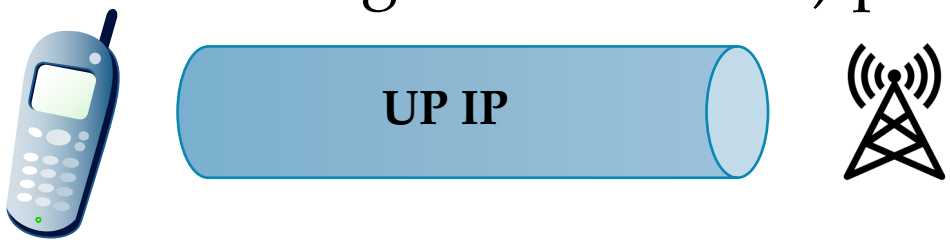


5G RedCap / NB IoT



5G Security enhancements

- Improved key hierarchy, algorithm flexibility (5G AKA, EAP-AKA)
- Subscriber policy – SUCI/SUPI (Subscription Concealed Identifier / Subscription Permanent Identifier), Subscriber paging by SUCI
- Interconnect security SEEP (Security Edge Protection Proxy) CP signaling and UP GTP attack
- Service Based Interface Security
- User plane Integrity Protection UP IP (serious 4G/LTE problem)
- 5G introduce PDCP (Packet Data Convergence Protocol) protection (in 4G LTE CP only)



Fundamental security features of 2G, 3G, 4G & 5G

Security features/Mobile Technology	2G	3G	4G	5G
Subscriber/device authentication to network	Y	Y	Y	Y
Network authentication to Device/Subscriber	N	Y	Y	Y
Interconnect Authentication	N	N	N	Y
IPSec	N	Optional	Optional	Y
Data Origin End to End – Integrity	N	N	N	Y
Data Encryption End to End – Confidentiality	N	N	N	Y
The Subscriber Identity De-concealing Function	N	N	N	Y

5G Audio Codecs – EVS

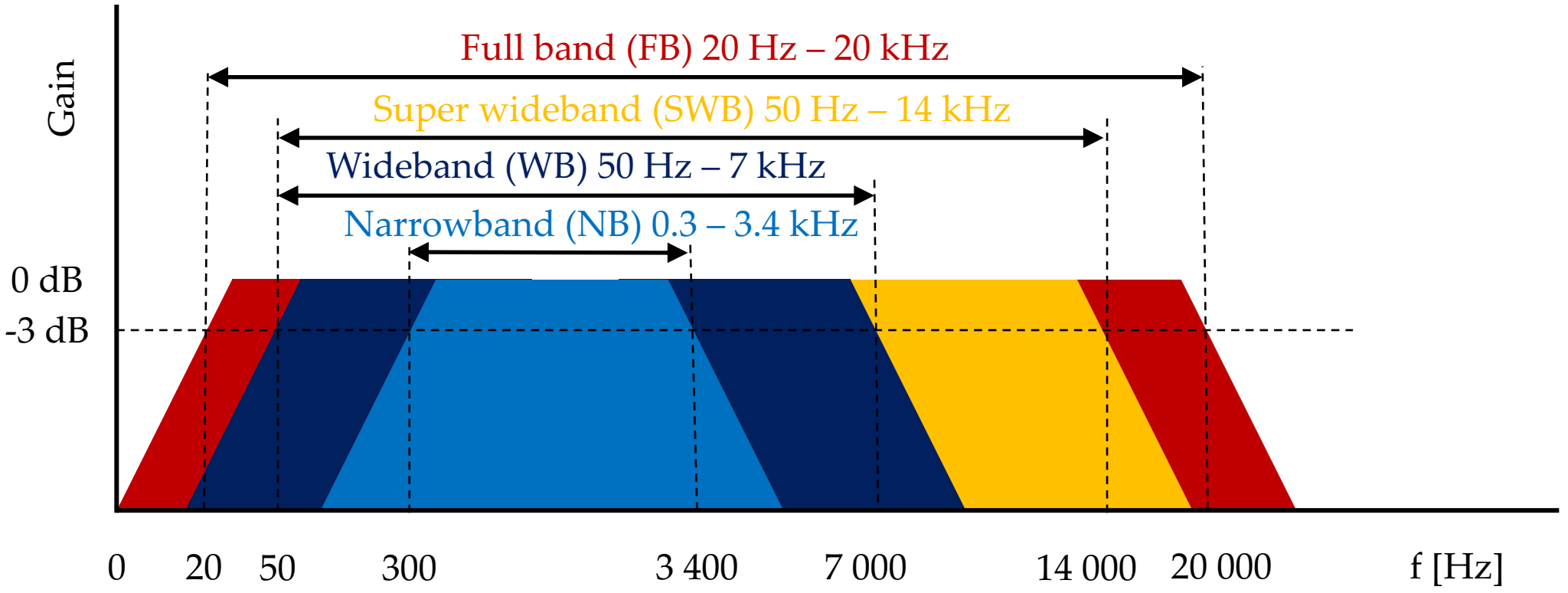
Enhanced Voice Services (EVS)

- **Full-band** (FB) 20 Hz – 20 kHz
- **Super-wide-band** (SWB) 50 Hz – 14 kHz
- **Wide-band** (WB) 50 Hz – 7 kHz
- **Narrow-band** (NB) 300 Hz – 3.4 kHz

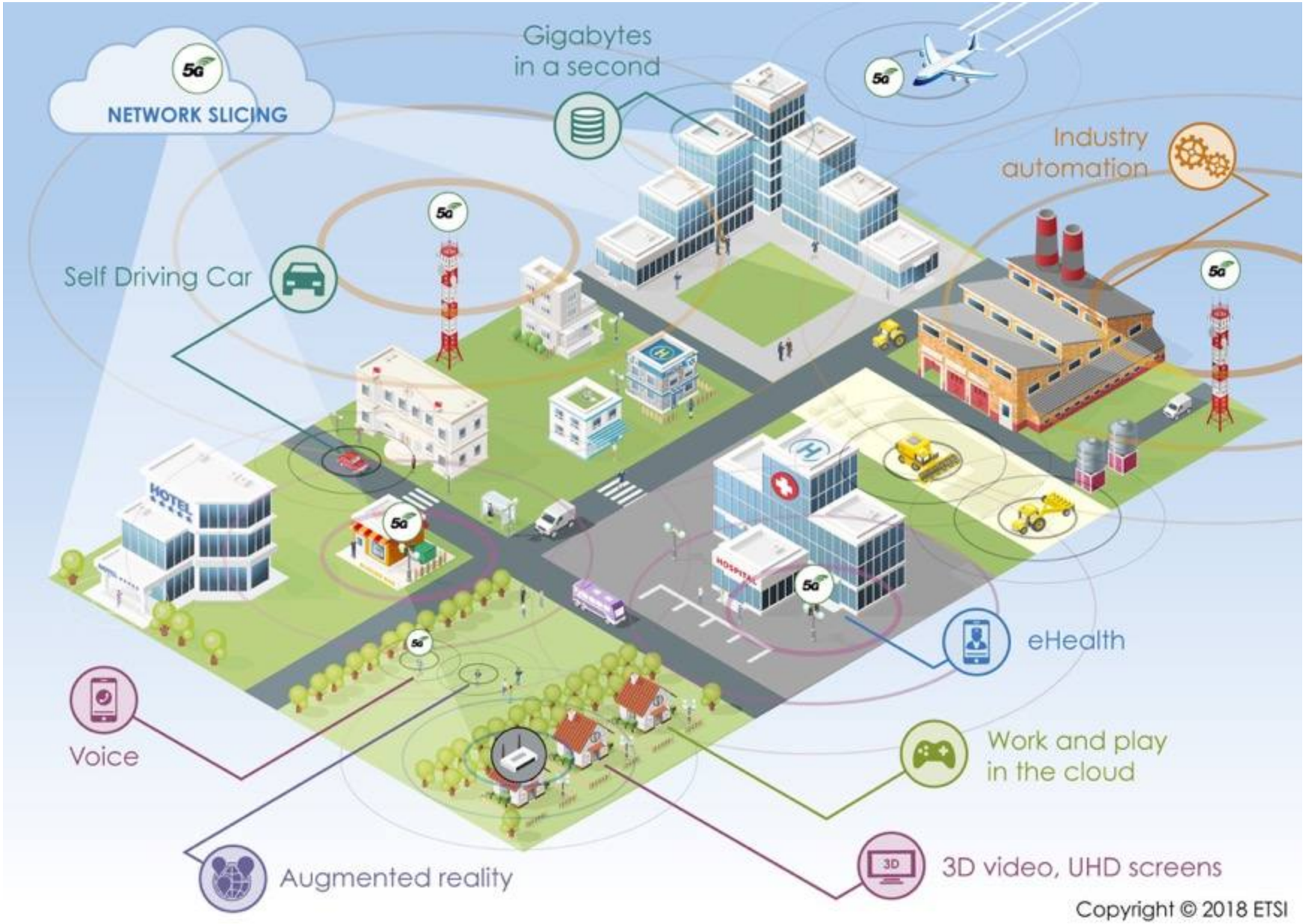
Sampling frequency: 48, 32, 16 or 8 kHz

Similarly, the decoder output: 48, 32, 16 or 8 kHz, FB, SWB, WB or NB

Evolution of audio bandwidth



5G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Gigabytes
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eHealth
Voice
Work and play
in the cloud
Augmented reality
3D video, UHD screens
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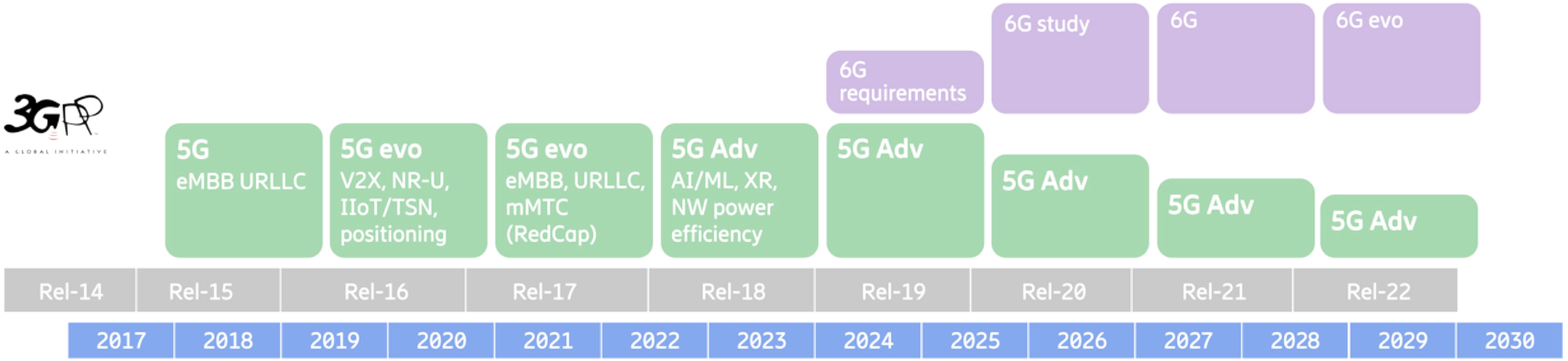
From 5G Rel 15 to Rel 22



End

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