5G FWA

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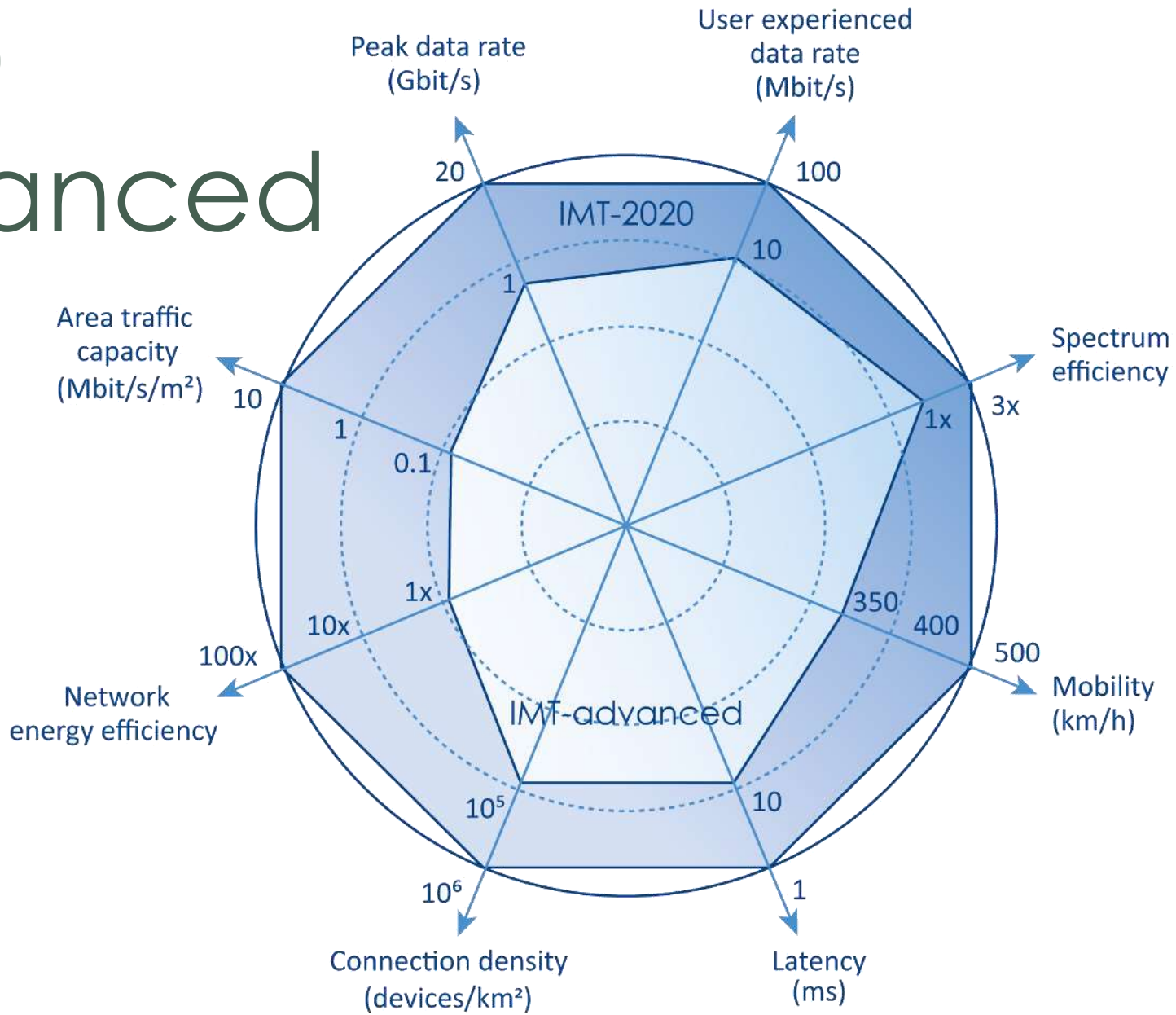
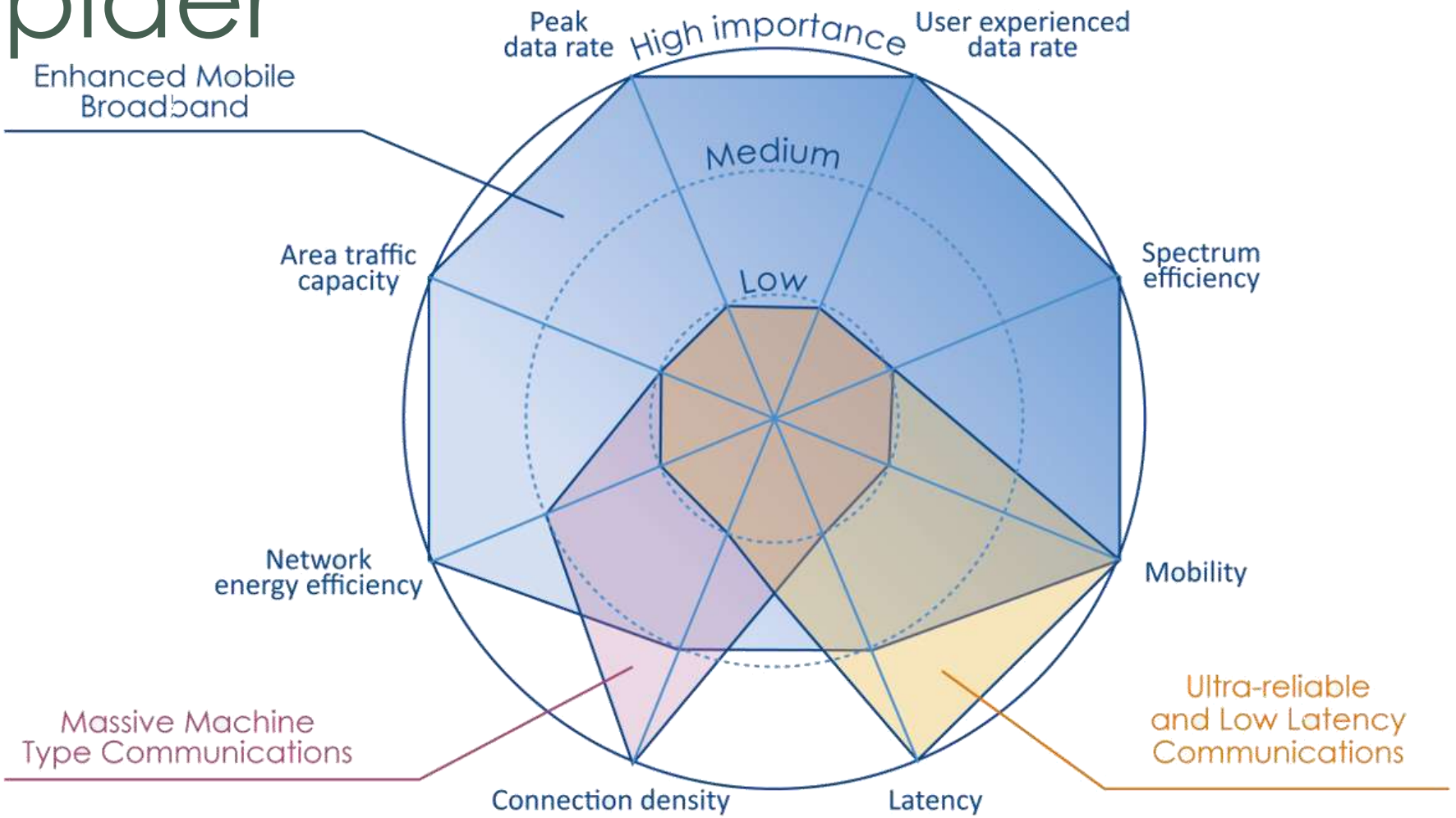
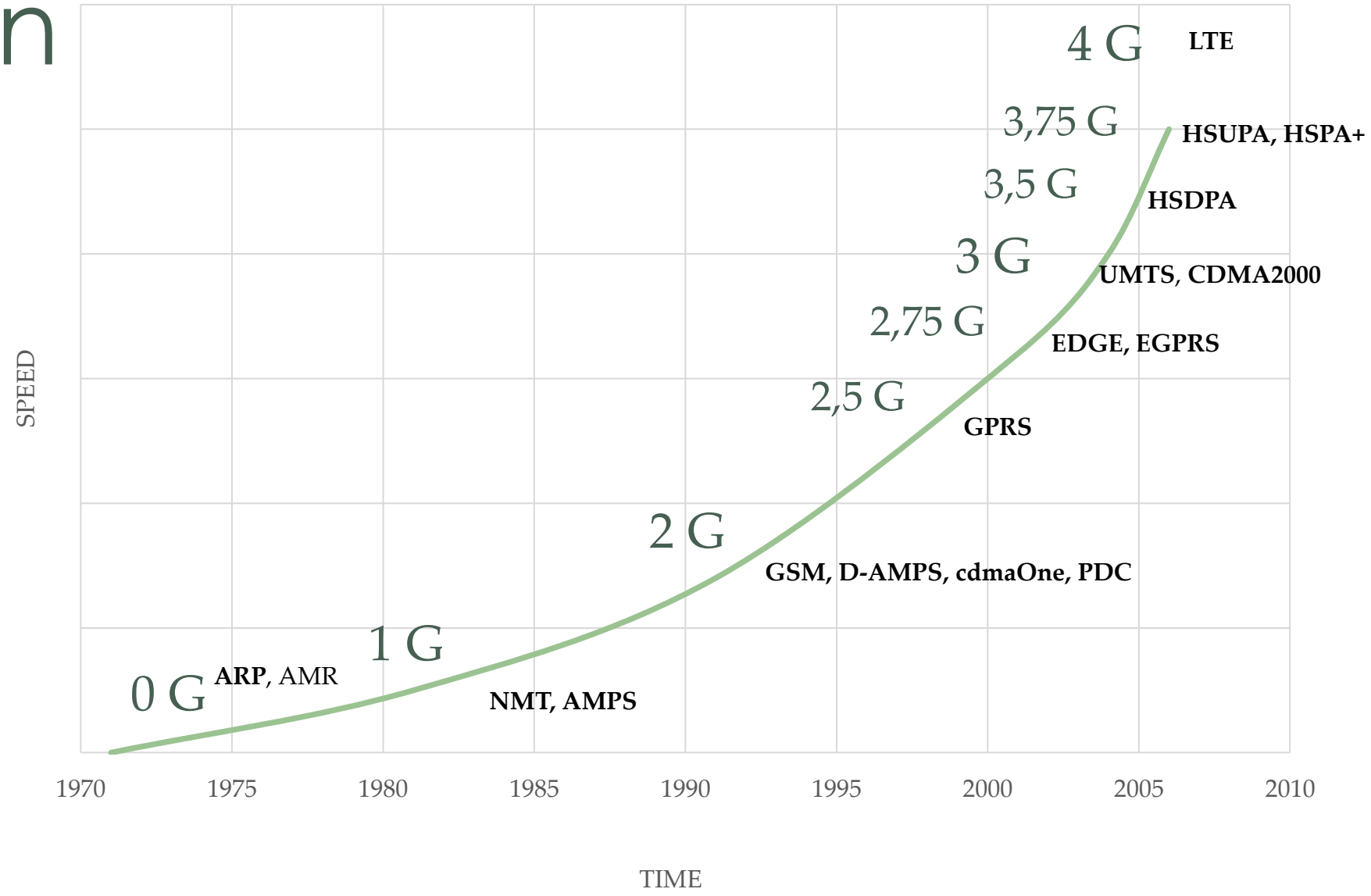
IMT-2020
IMT-advanced



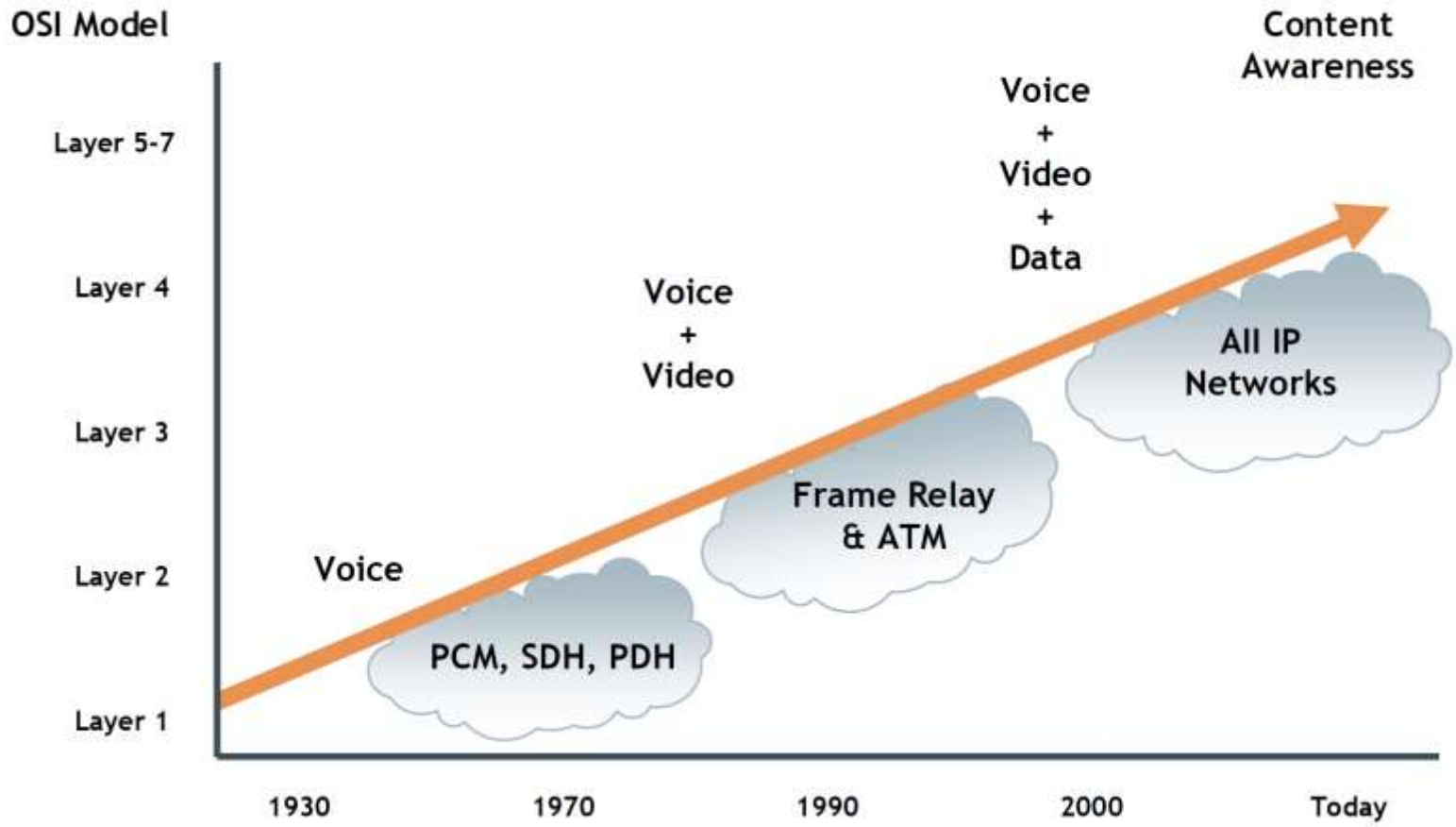
5G – Spider


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

Evolution


4 G
LTE
3,75 G
HSUPA, HSPA+
3,5 G
HSDPA
3 G
UMTS, CDMA2000
2,75 G
EDGE, EGPRS
2,5 G
GPRS
2 G
GSM, D-AMPS, cdmaOne, PDC
1 G
NMT, AMPS
0 G
ARP, AMR
SPEED
1970
1975
1980
1985
1990
1995
2000
2005
2010
TIME

The Evolution of Infrastructure & Shifting service



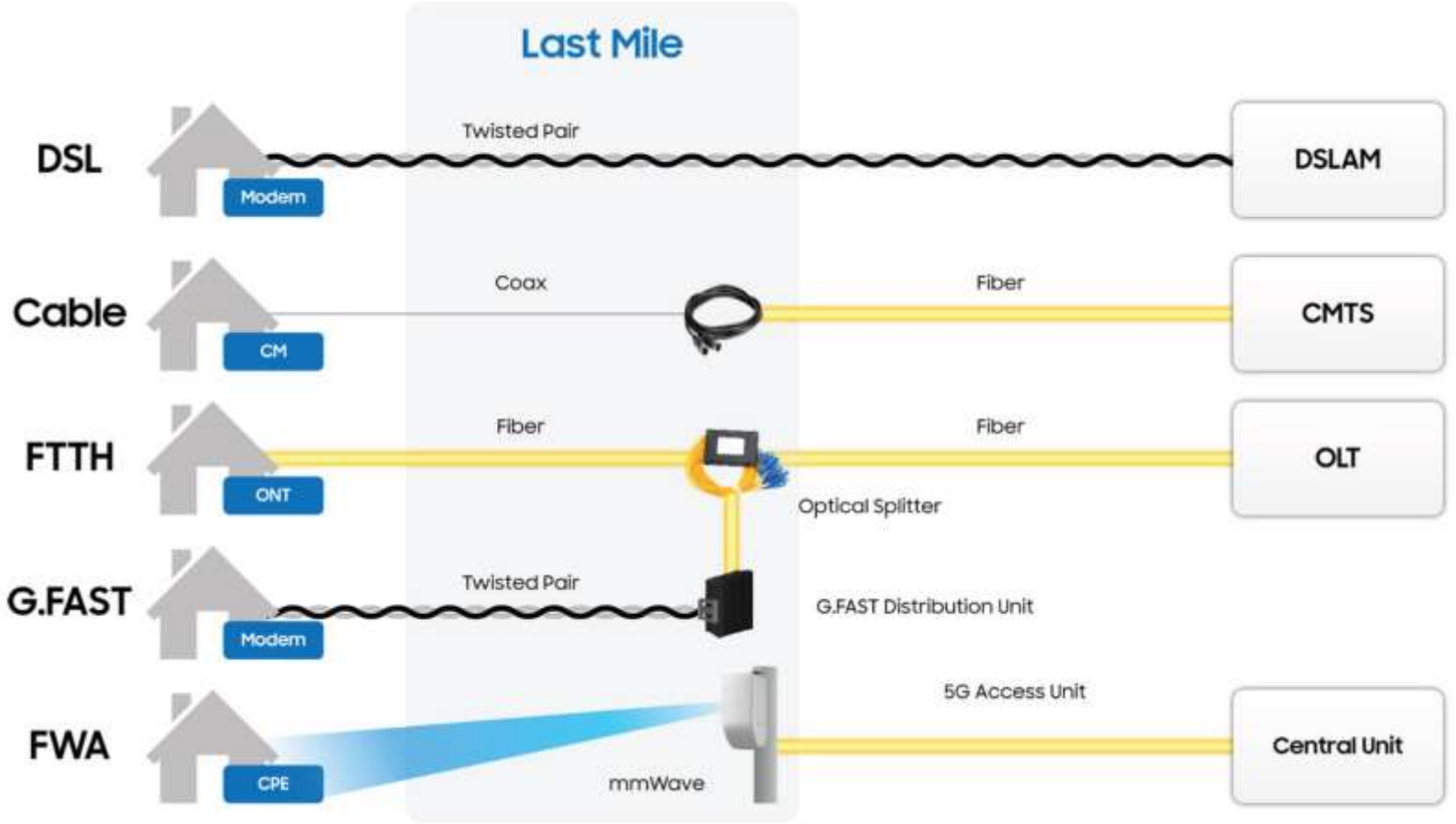
5G FWA

- Díky novému rádiu (NR) v milimetrové vlnové délce (mmWave) může 5G FWA poskytnout konkurenceschopnou alternativu k DSL, kabelové TV a vláknům.
- 5G FWA nabízí potřebnou šířku pásma pro příměstské a venkovské lokality k podpoře streamovacích služeb s vysokým rozlišením a vysokorychlostního přístupu k internetu.
- Standard dle 3GPP, ETSI

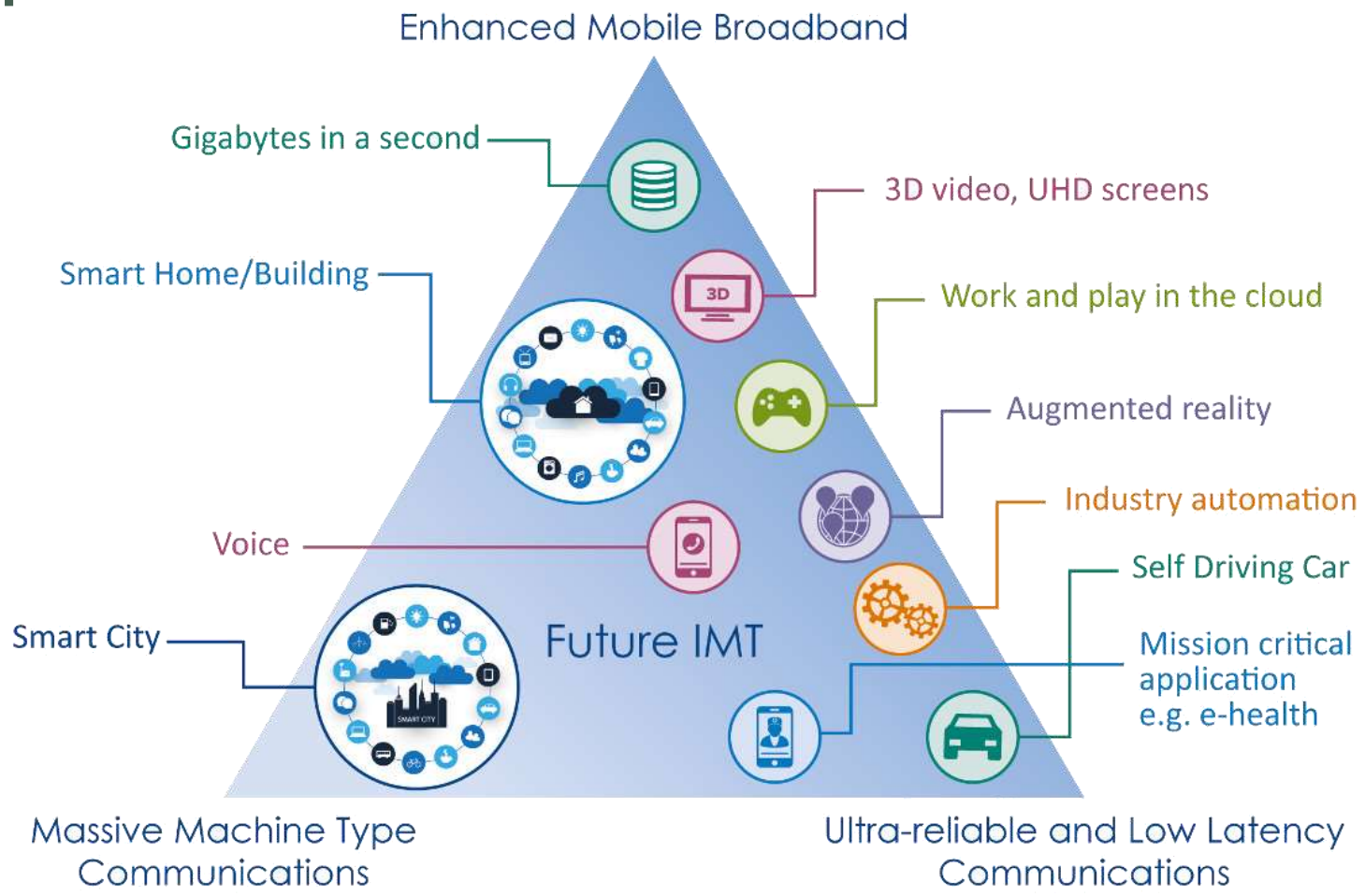
WiMAX

- Technologie WiMAX do značné míry zklamla jelikož potřebovala zcela novou překryvnou infrastrukturu a drahé proprietární vybavení.
- WiMAX také nabízel poměrně malé rychlosti.
- Naproti tomu 5G Fixed Wireless Access (FWA) využívá standardizované architektury 3GPP a běžné mobilní komponenty k poskytování ultrarychlých širokopásmových služeb domácím předplatitelům a podnikovým zákazníkům.

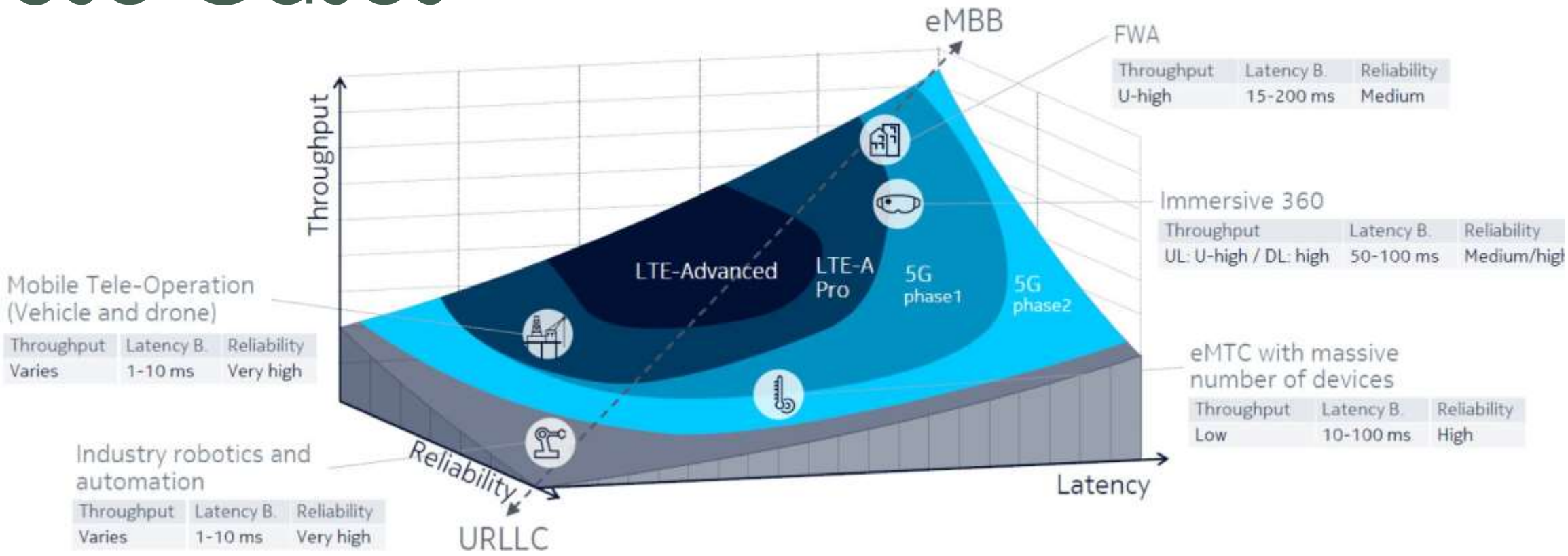
Last Mile


Last Mile
DSL
Modem
Twisted Pair
DSLAM
Cable
CM
Coax
Fiber
CMTS
FTTH
ONT
Fiber
Fiber
OLT
Optical Splitter
G.FAST
Modem
Twisted Pair
G.FAST Distribution Unit
FWA
CPE
mmWave
5G Access Unit
Central Unit

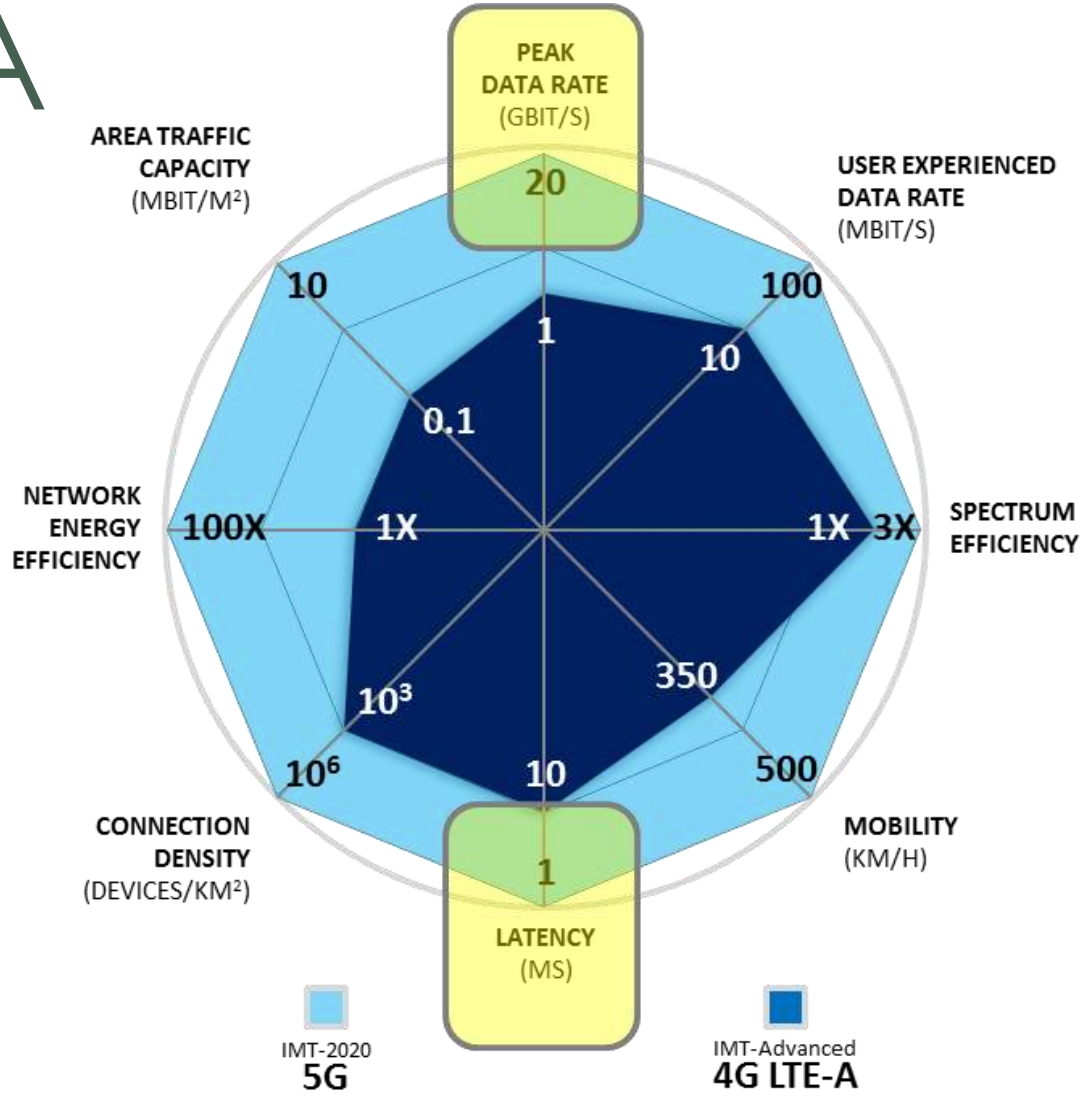
5G – type of communication



Requirements for Different 5G Use Cases



5G – 4G LTE-A


PEAK
DATA RATE
(GBIT/S)
20
1
USER EXPERIENCED
DATA RATE
(MBIT/S)
100
10
SPECTRUM
EFFICIENCY
3X
1X
MOBILITY
(KM/H)
500
350
LATENCY
(MS)
1
10
CONNECTION
DENSITY
(DEVICES/KM²)
10⁶
10³
NETWORK
ENERGY
EFFICIENCY
100X
1X
AREA TRAFFIC
CAPACITY
(MBIT/M²)
10
0.1
IMT-2020
5G
IMT-Advanced
4G LTE-A

LTE vs 5G / services

	LTE	5G
Mobile Broadband	1 Gbit/s capacity	10-20 Gbit/s capacity, peak 100x
IoT	NB-IoT Rel 16	Longer Battery Life
Mission Critical	Limited Support	Ground-Up design

5G Use Cases and type of communication

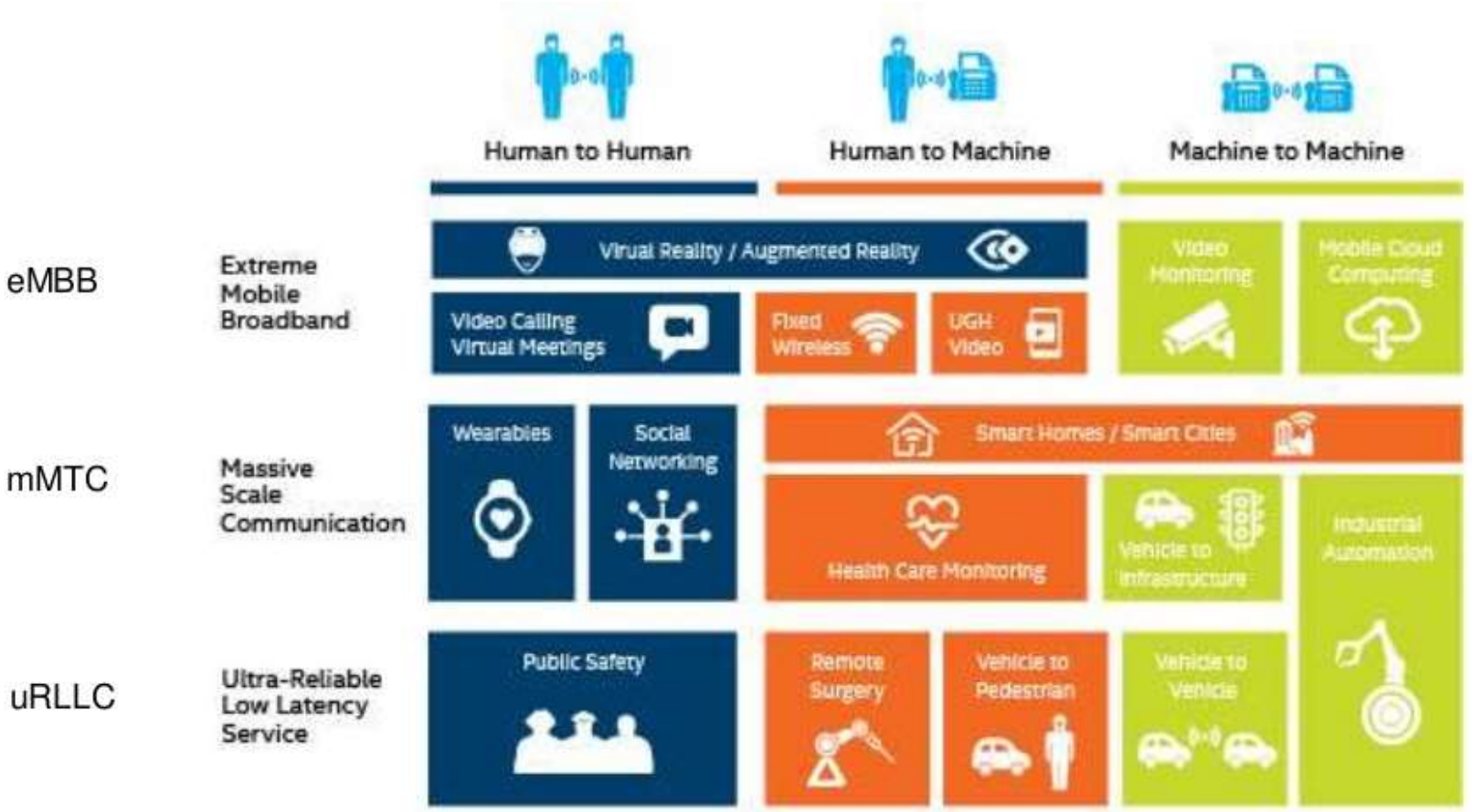
Services:

- eMBB – Extreme Mobile Broadband
- mMTC- Massive Scale Communication
- uRLLC – Ultra-Reliable Low Latency Service

Type of communication:

- Human to Human
- Human to Machine
- Machine to Machine

5G – type of communication



From Silos to a Common Core for All

Heterogeneous Access:

- 4G UE
- 5G UE
- Wi-Fi UE
- CPE - 5G FWA

Voice:

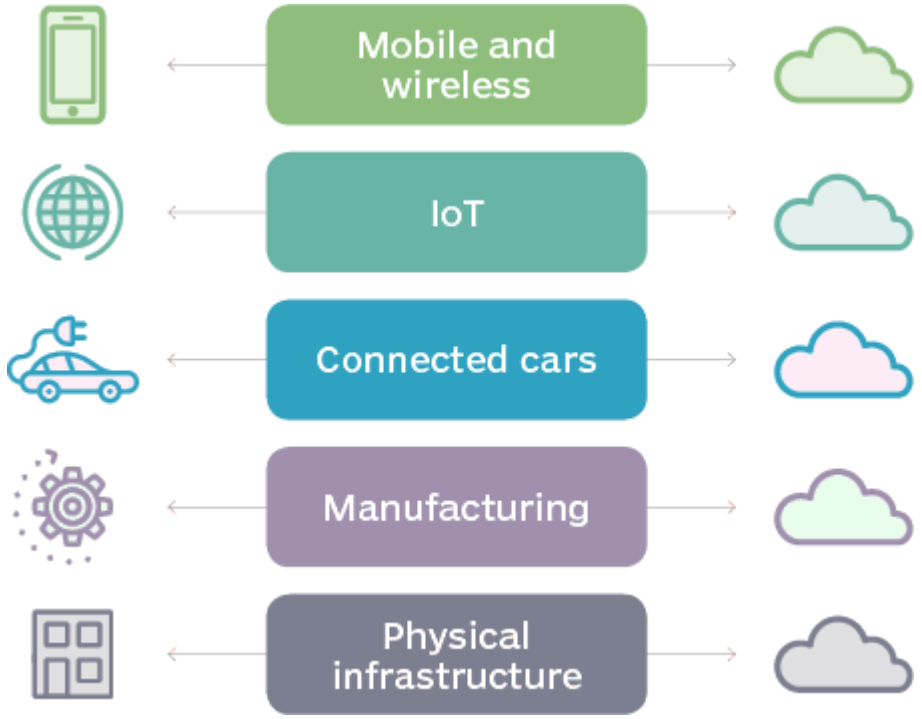
- Common Core – IP Multimedia Subsystem (IMS)

5G Cases according ITU

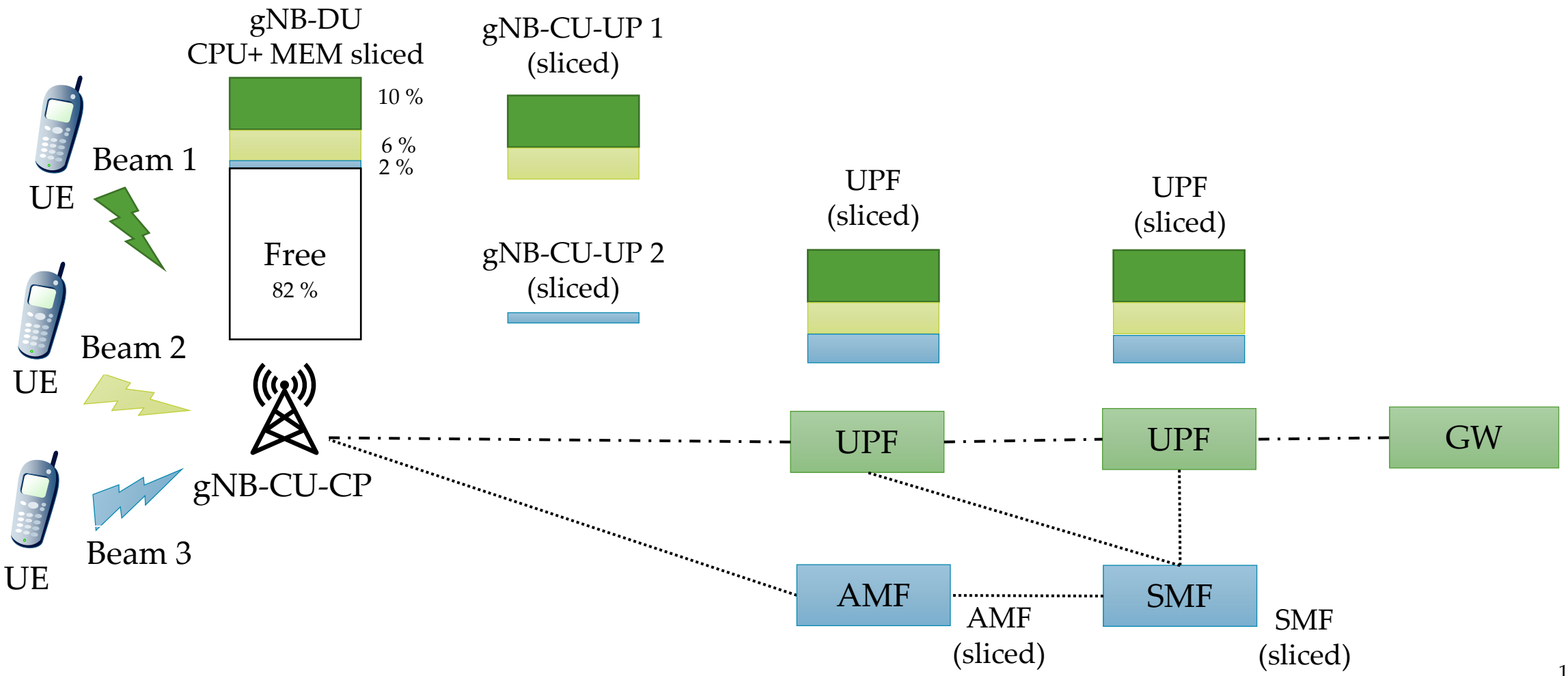
- **Enhanced Mobile Broadband (eMBB).** eMBB is the most obvious extension of LTE capability, providing higher speeds for applications such as streaming, Web access, video conferencing, and virtual reality. Highest speeds will occur in small cells with limited movement speed of end users, such as with pedestrians.
- **Massive Machine-Type Communications (mMTC).** Massive machine-type communications extends LTE Internet of Things capabilities—for example, NB-IoT—to support huge numbers of devices with lower costs, enhanced coverage, and long battery life. As shown in the ITU objectives, below, 5G will support ten times as many devices in an area as LTE.
- **Ultra-Reliable and Low-Latency Communications (uRLLC).** Of the three categories, uRLLC enables wireless applications never before possible. Driven by high dependability and extremely short network traversal time, uRLLC, also referred to as "mission-critical" communications, will enable industrial automation, drone control, new medical applications, and autonomous vehicles. This category is also referred to as **critical machine-type communications (cMTC)**.

NGMN – 5G Network Slicing

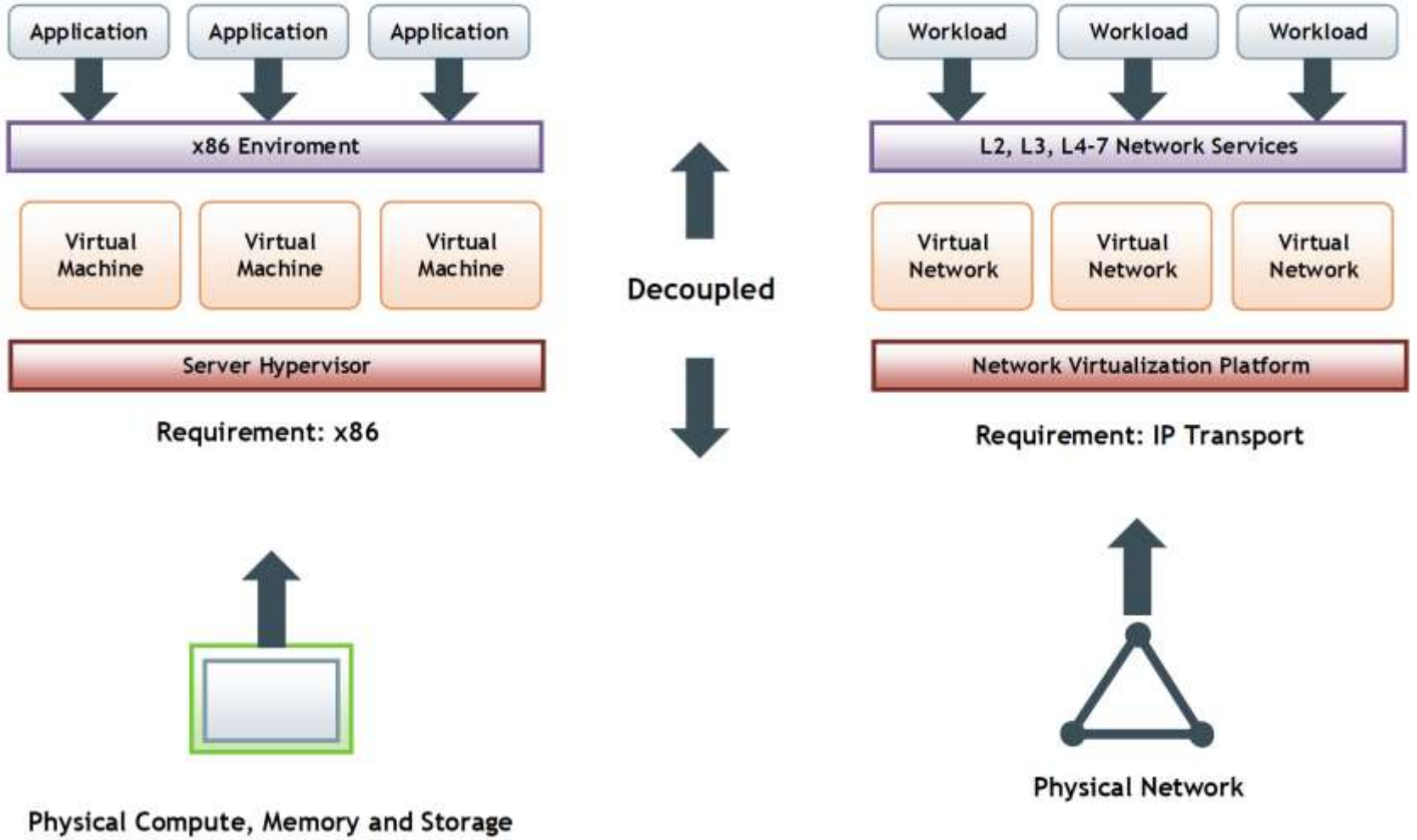
- Next Generation Mobile Networks (NGMN)
- Software Defined Networking (SDN)
- Network Functions Virtualization (NFV)
- Control and User Plane Separation (CUPS)



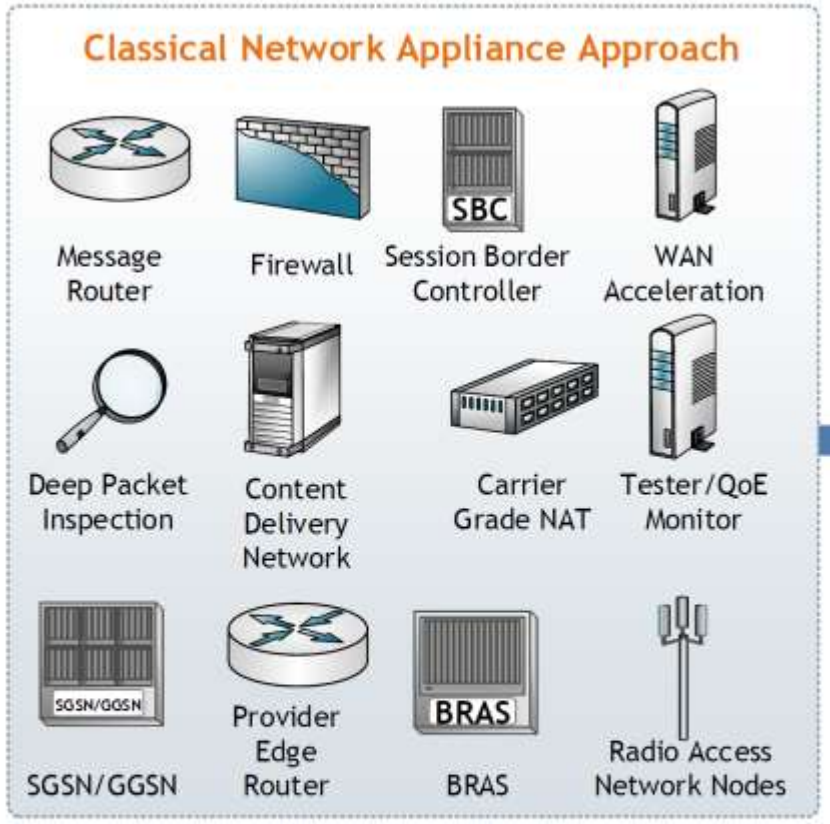
NGMN – 5G Network Slicing

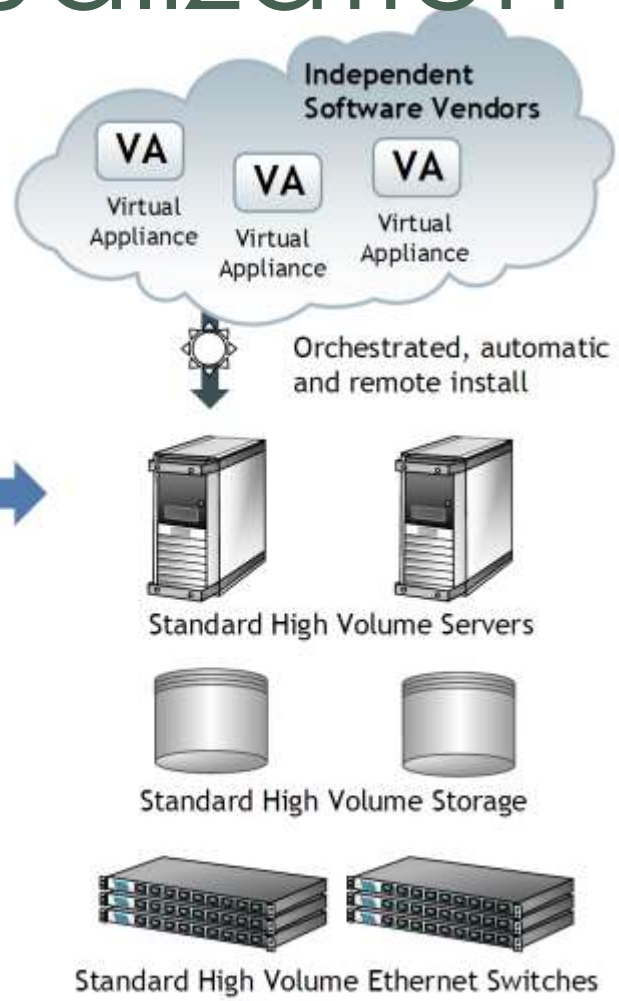


Server & Net Virtualization Analogy



Classical & Net Virtualization





- Fragmented non-commodity hardware.
- Physical install per appliance per site.
- Hardware development large barrier to entry for new vendors, constraining innovation and competition.

5G radio frequencies – New Radio

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)

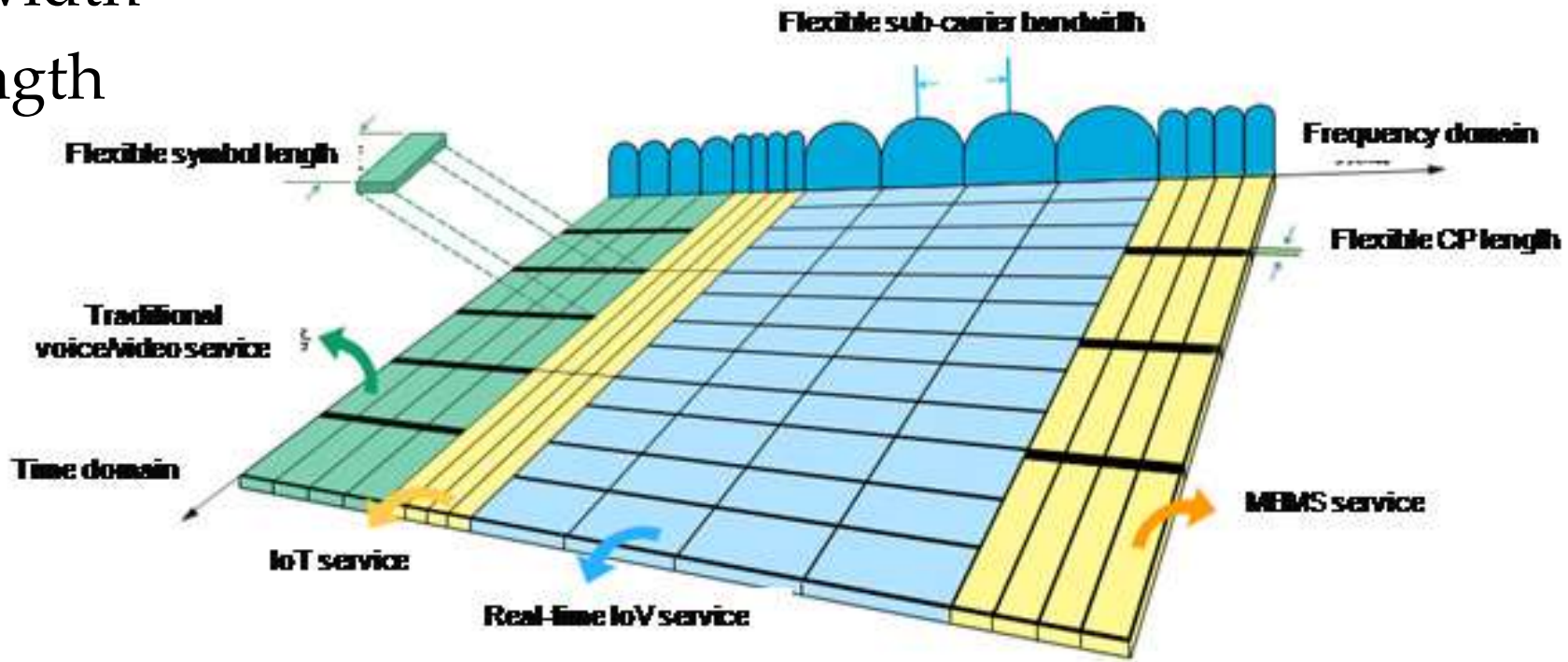
- The maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3–4.2 GHz.

Frequency range 2 (> 24 GHz)

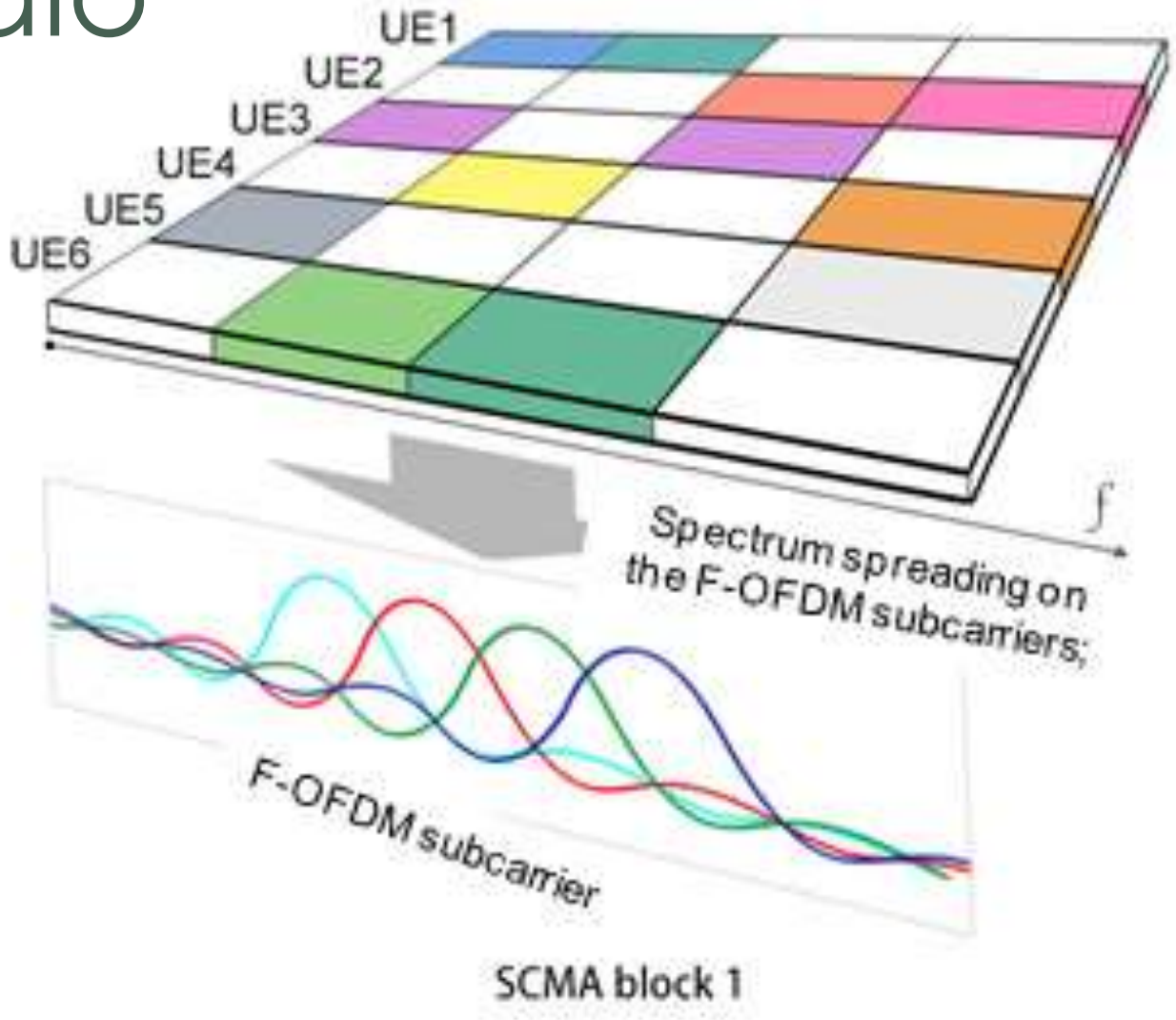
- The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. The higher the frequency, the greater the ability to support high data-transfer speeds.

Flexible Radio Scheduling

- Flexible symbol length
- Flexible bandwidth
- Flexible CP length

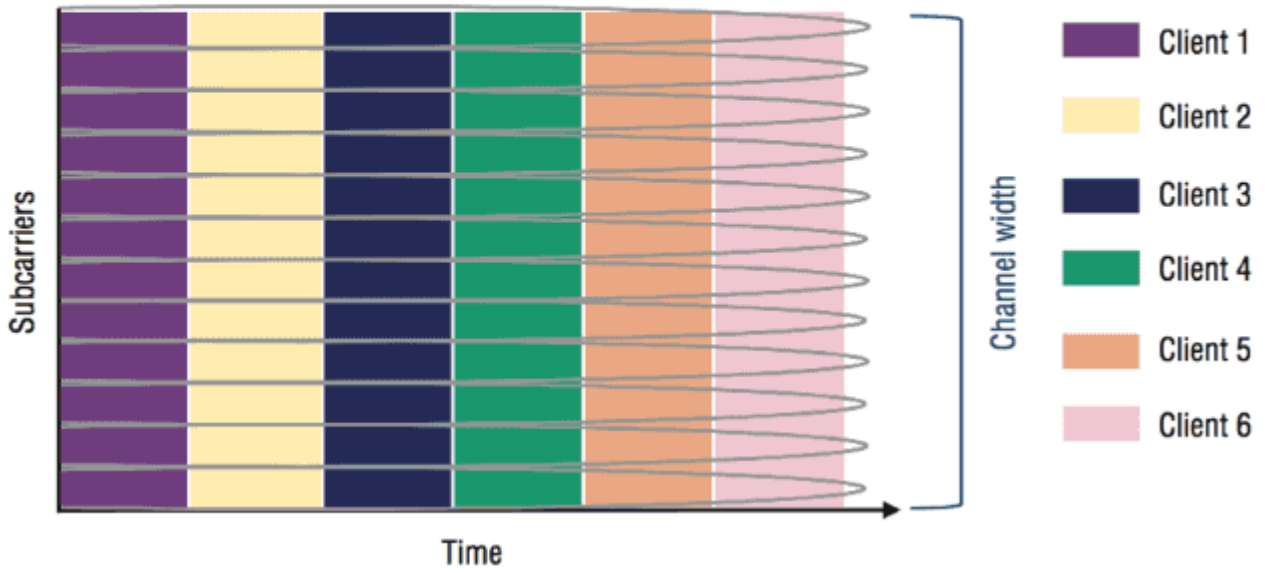


New Radio


UE1
UE2
UE3
UE4
UE5
UE6
Spectrum spreading on the F-OFDM subcarriers;
F-OFDM subcarrier
SCMA block 1

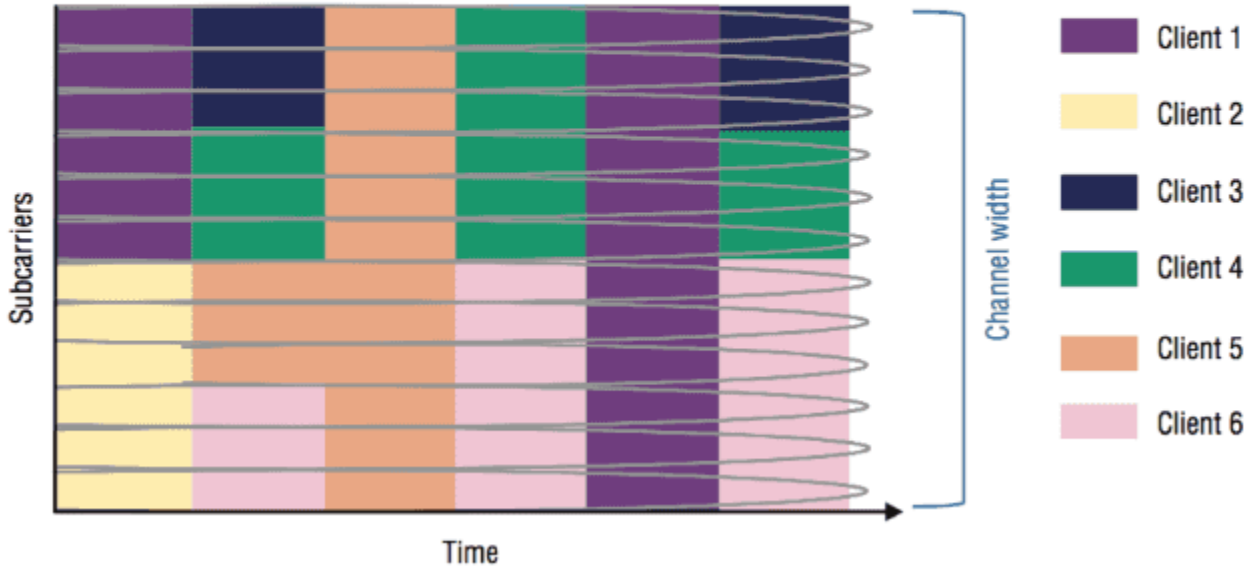
OFDM

Orthogonal Frequency-Division Multiplexing



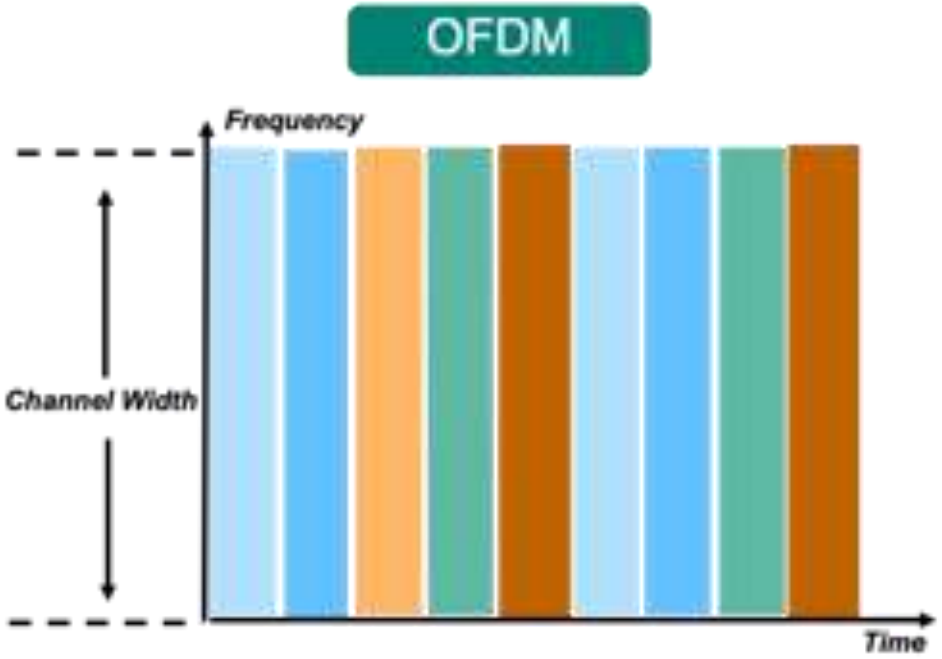
OFDMA

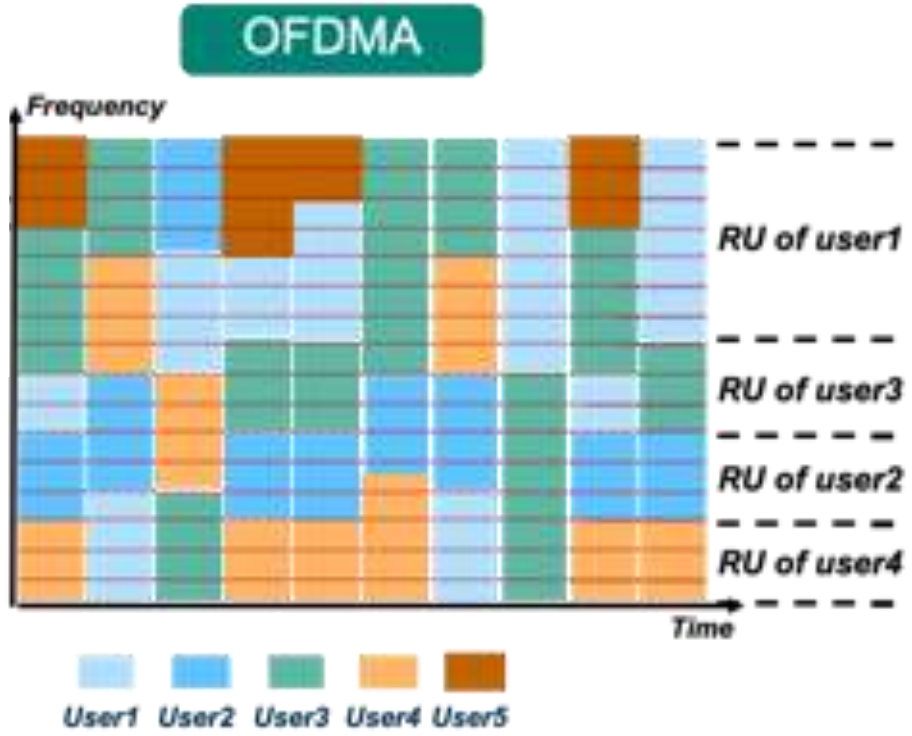
Orthogonal Frequency-Division Multiple Access



OFDM x OFDMA

Orthogonal Frequency-Division Multiple Access

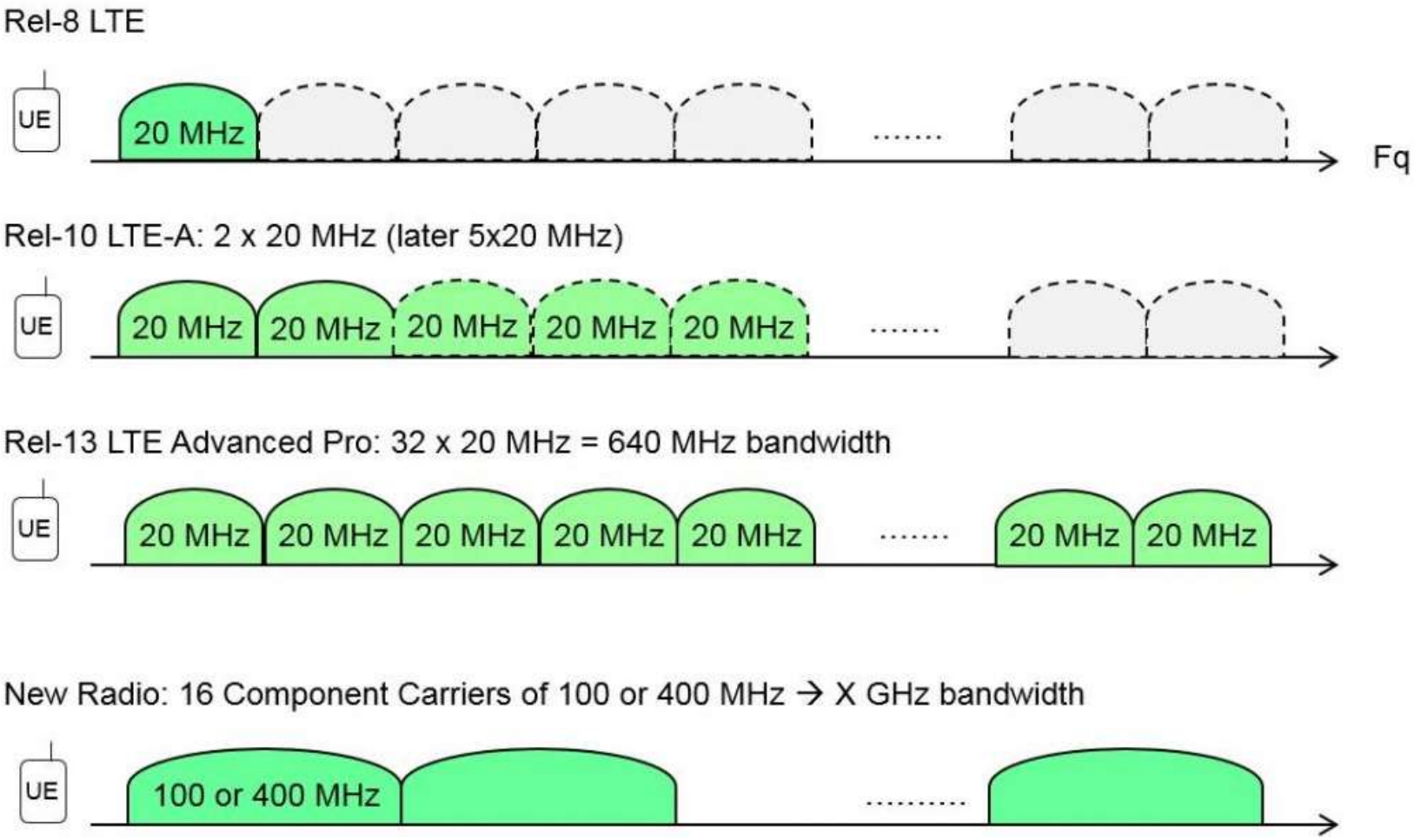




Carrier Aggregation

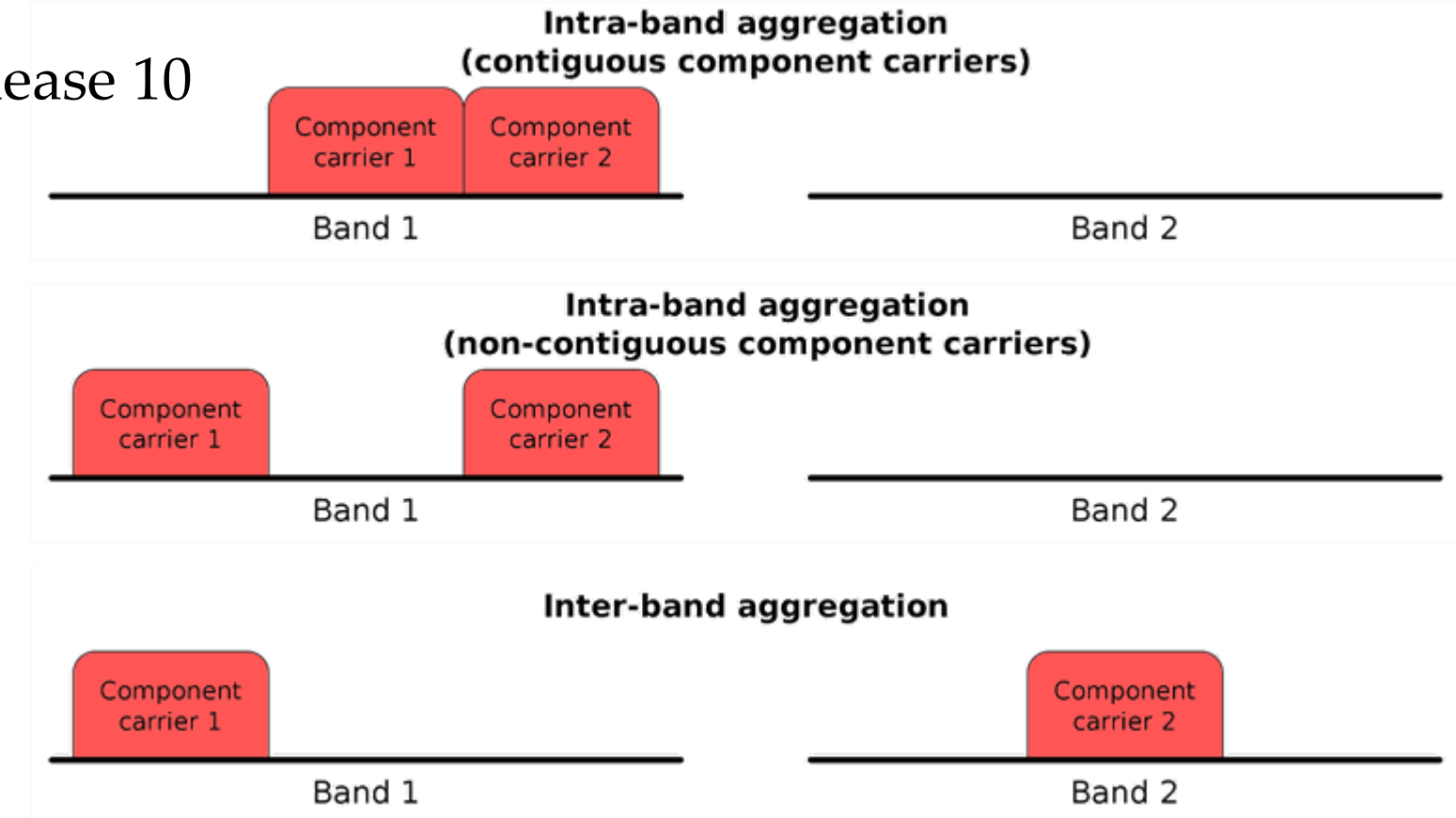
- UMTS/HSPA+ - 2 downlink carriers may be assigned to one user since Release 8. Release 10 supports four-carrier aggregation and eight-carrier-aggregation is supported since Release 11 standardized carrier aggregation for HSPA+ for the uplink for up to 2 component carriers since Release 9
- LTE/LTE-Advanced - channel bandwidths of 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz, 4x4 MIMO
- 5 G low-band with a 5 G mid-band can improve mid-band coverage by up to 7dB extending the cell coverage area by up to 2.5 times and increasing the population that can be supported by the mid-band by up to 25%. The higher available capacity means that more traffic can be offloaded on to mid-band 5G -which uses spectrum more efficiently than 4 G-, leading to an overall capacity increase of 27%.
- 5 G low-band with a 5 G high-band can improve high-band coverage by up to 10 dB extending the high-band cell coverage area by up to 3.7 times. The extended mid-band and high-band coverage also enables a greater offload of traffic from the lower bands to the mid and high-bands providing a higher throughput at the cell edge.

Carrier Aggregation

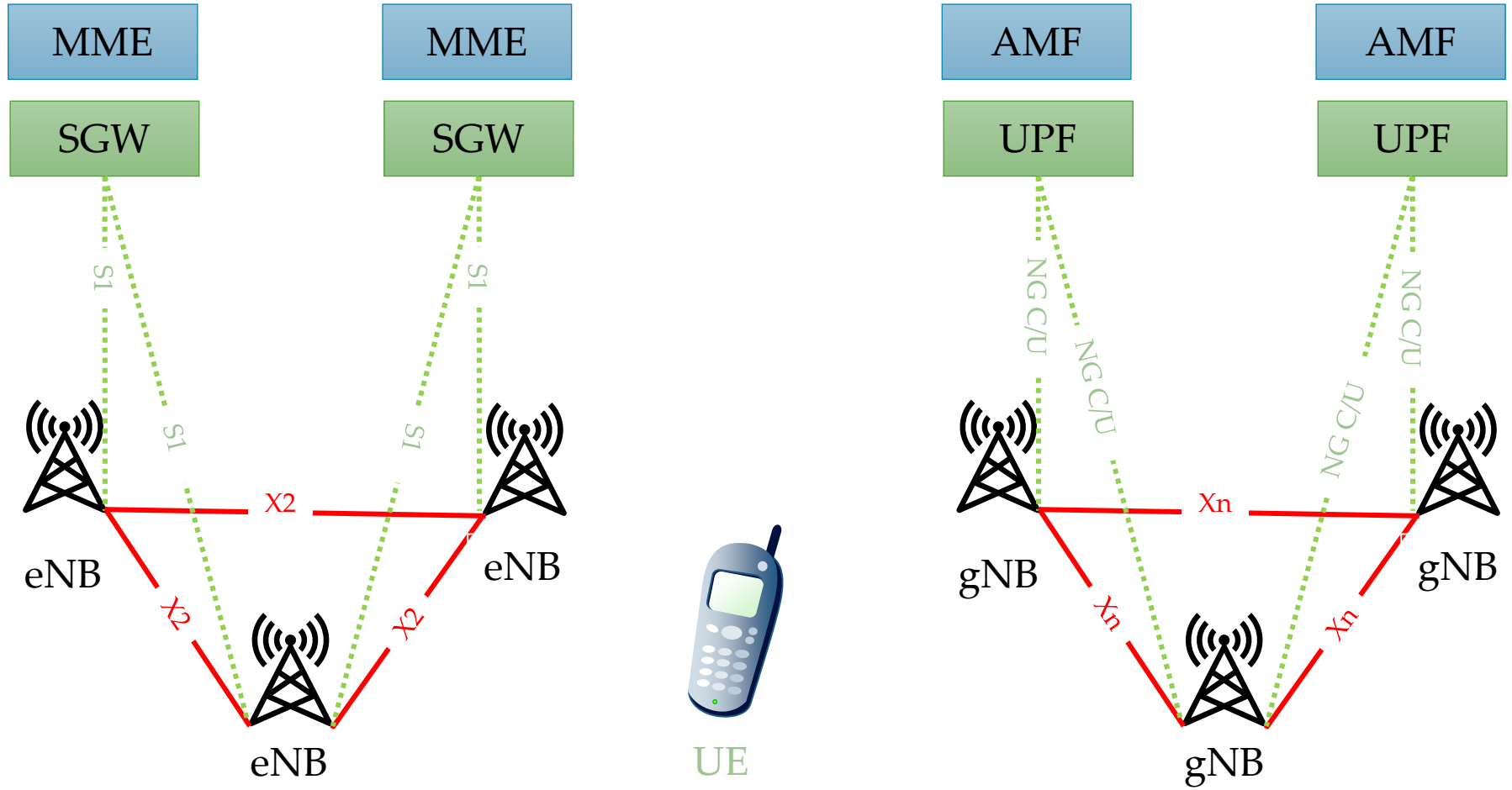


Carrier Aggregation

From Release 10



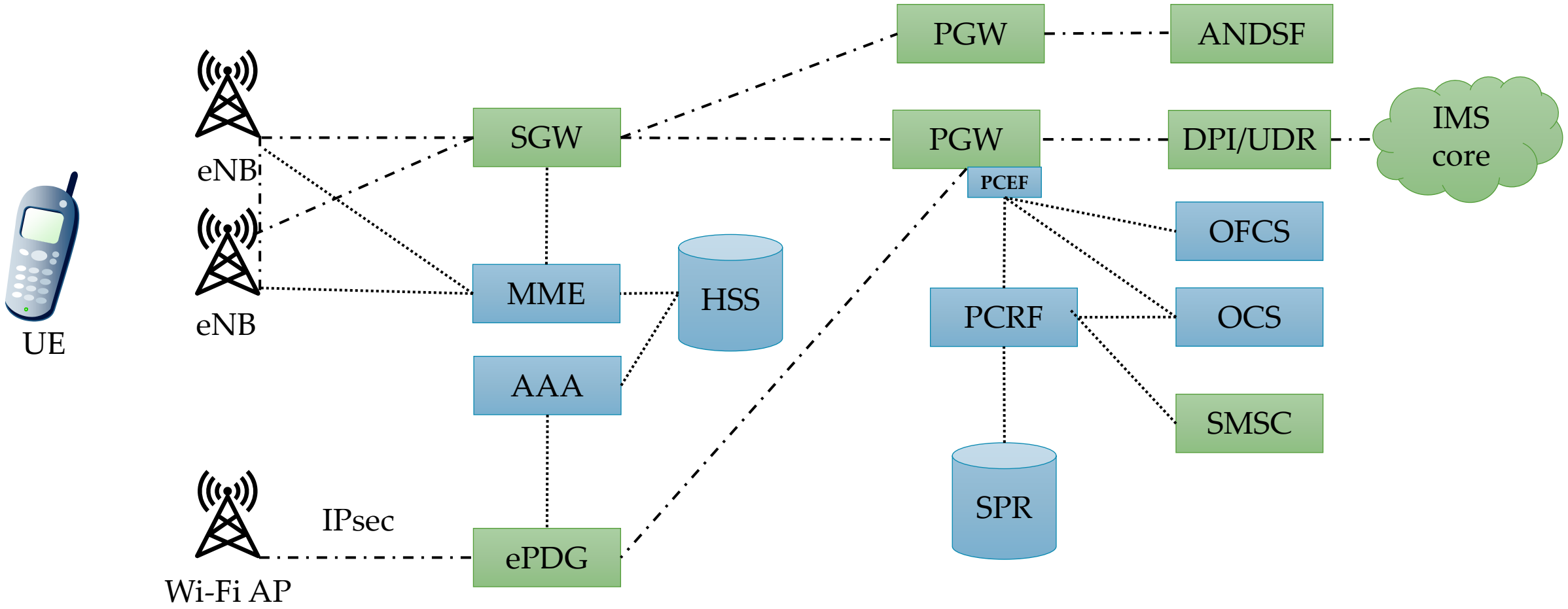
4G LTE vs 5G NR



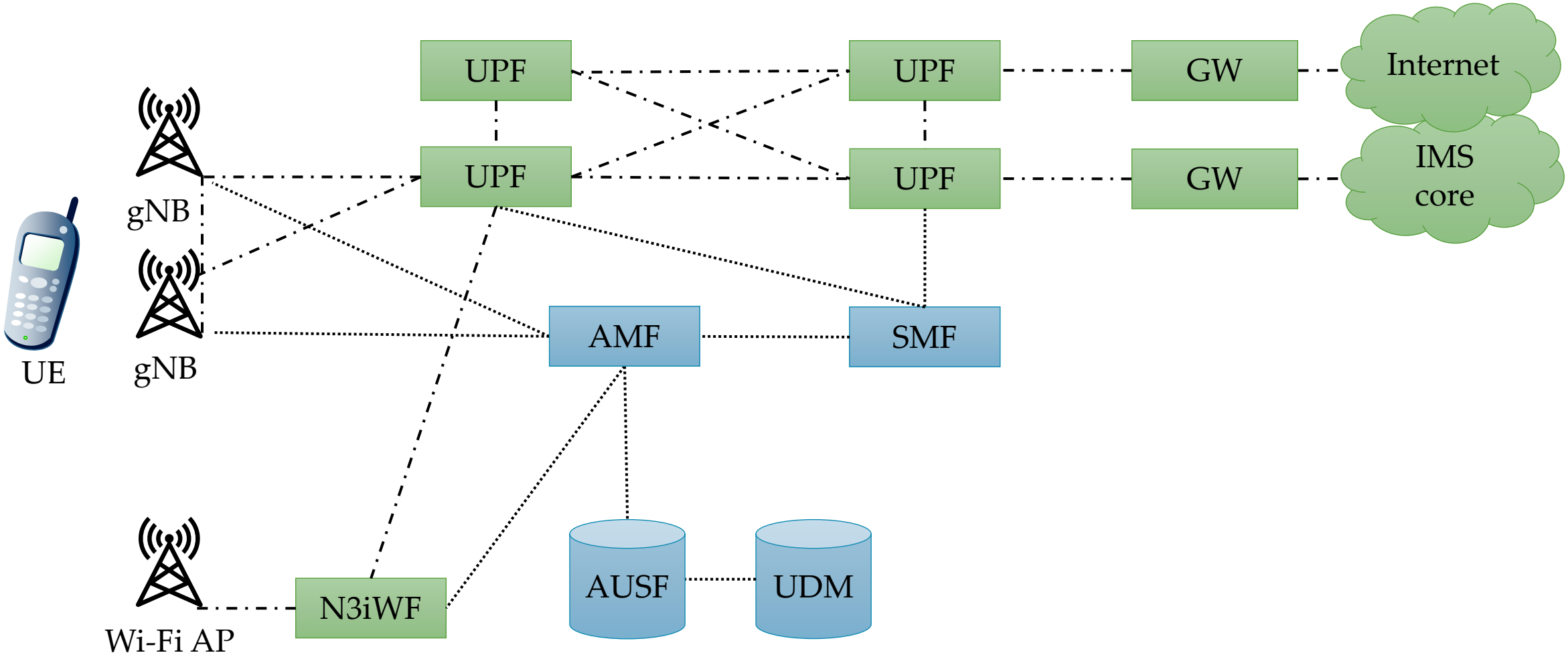
Core Network and Radio

Gen	2,5 G	3 G	4 G	5 G
Home Register	HLR	HLR	HSS	AUSF/UDM
Mobility management	MSC/VLR	MSC	MME	AMF
DN GW user plane	GGSN	GGSN	PGW-U	UPF
DN GW control plane	N/A	N/A	PGW-C	SMF
Gateway - user plane	SGSN	SGSN	SGW-U	I-UPF optional
Gateway - control plane	N/A	N/A	SGW-C	SMF
Radio controller	BSC+PCU	RNC	N/A	N/A
Base station / Radio	BTS	Node-B	eNB	gNB (NR)
Police & Charing	PCRF	PCRF	PCRF	PCF
AAA	N/A	N/A	AAA	AMF
Wi-Fi access	N/A	N/A	ePDG	N3IWF
Network Slicing	N/A	N/A	N/A	NSSF

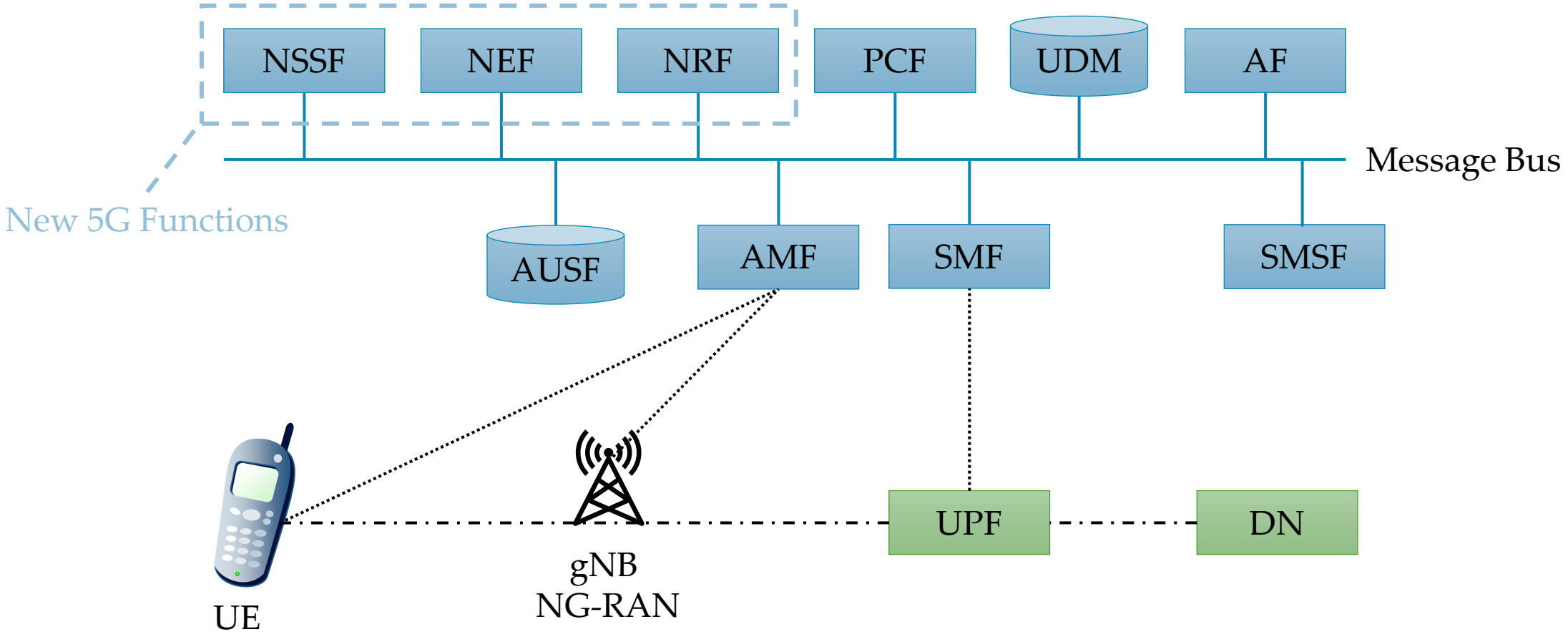
4G EPC R8 with PCC



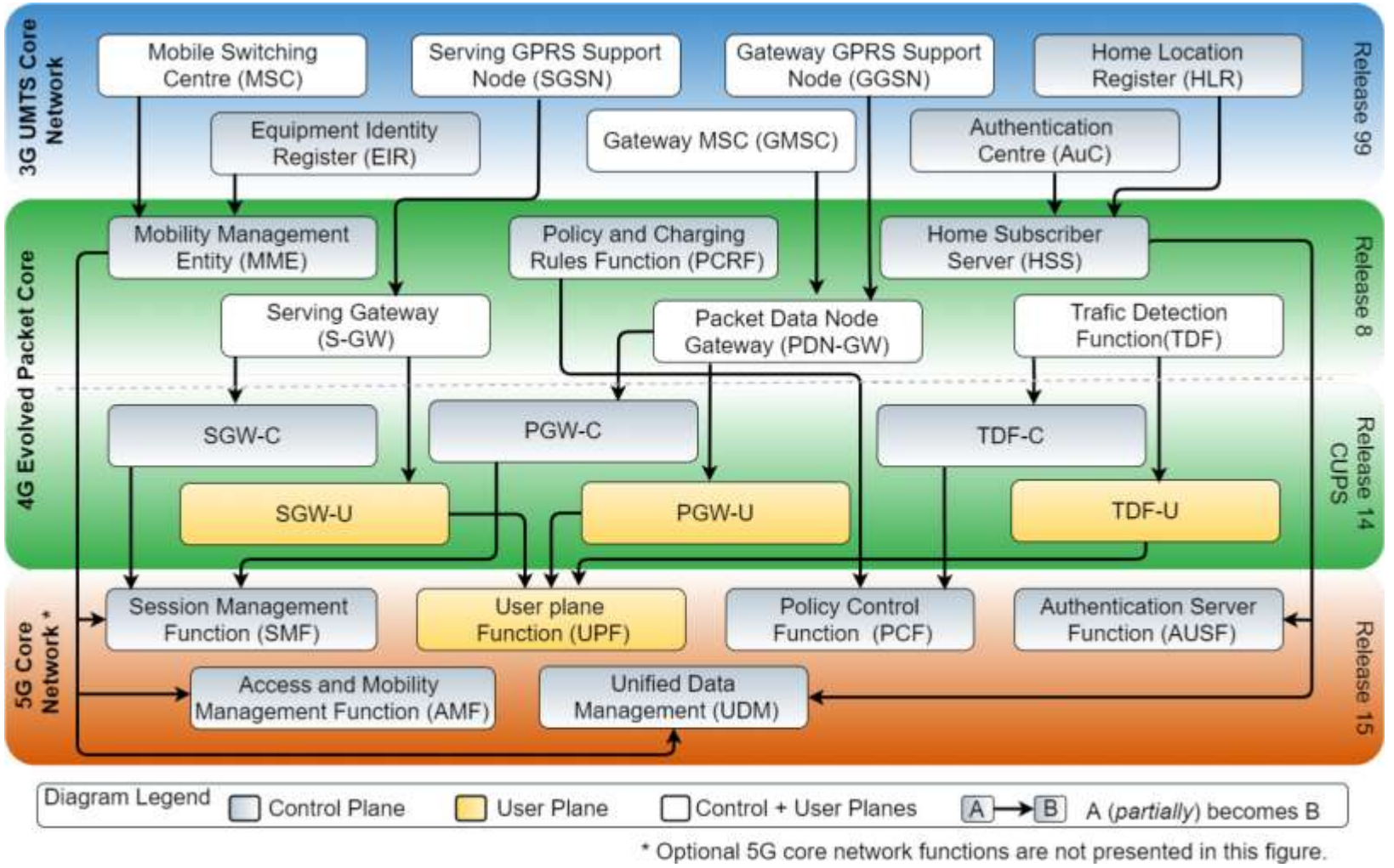
5G Architecture



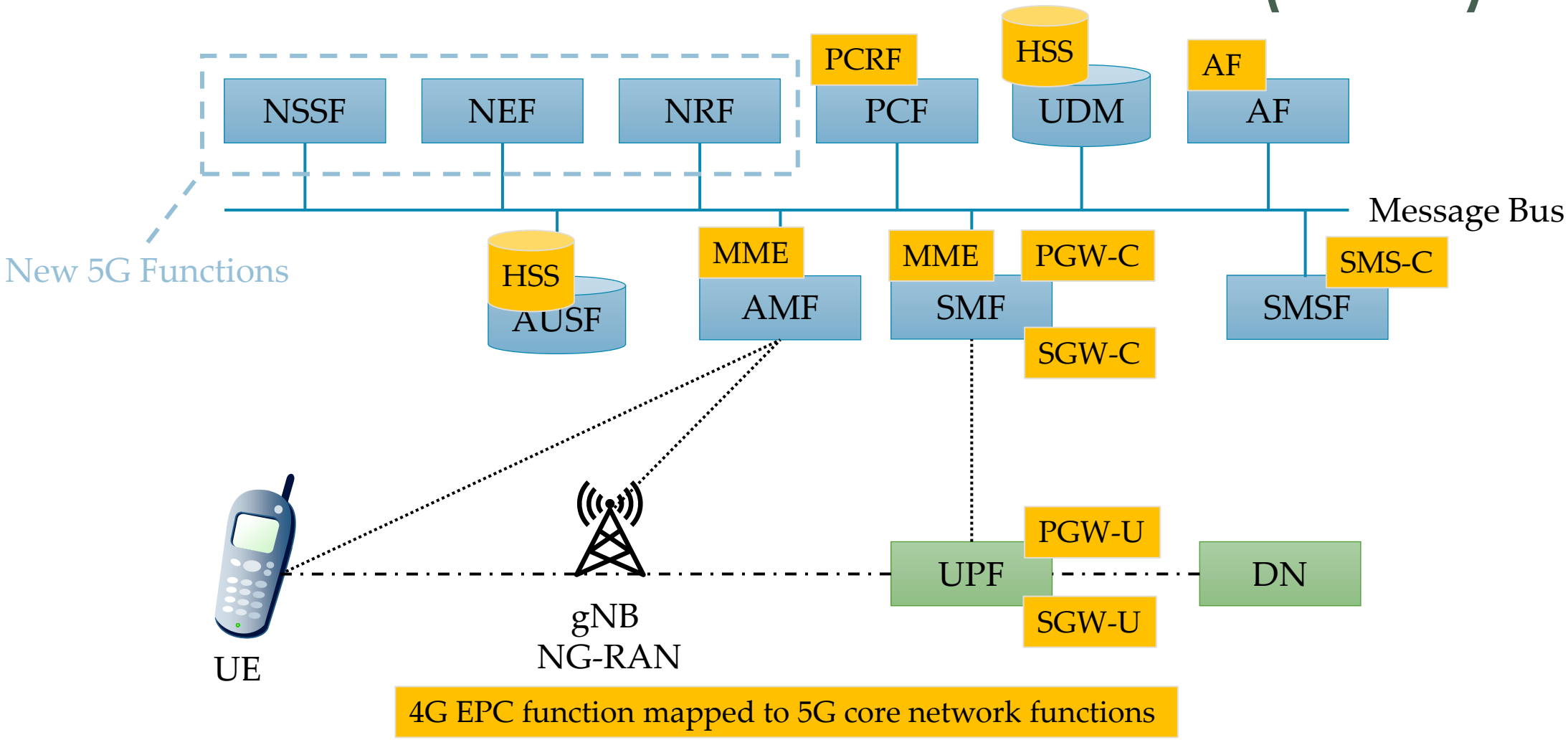
Service Based Architecture (SBA)



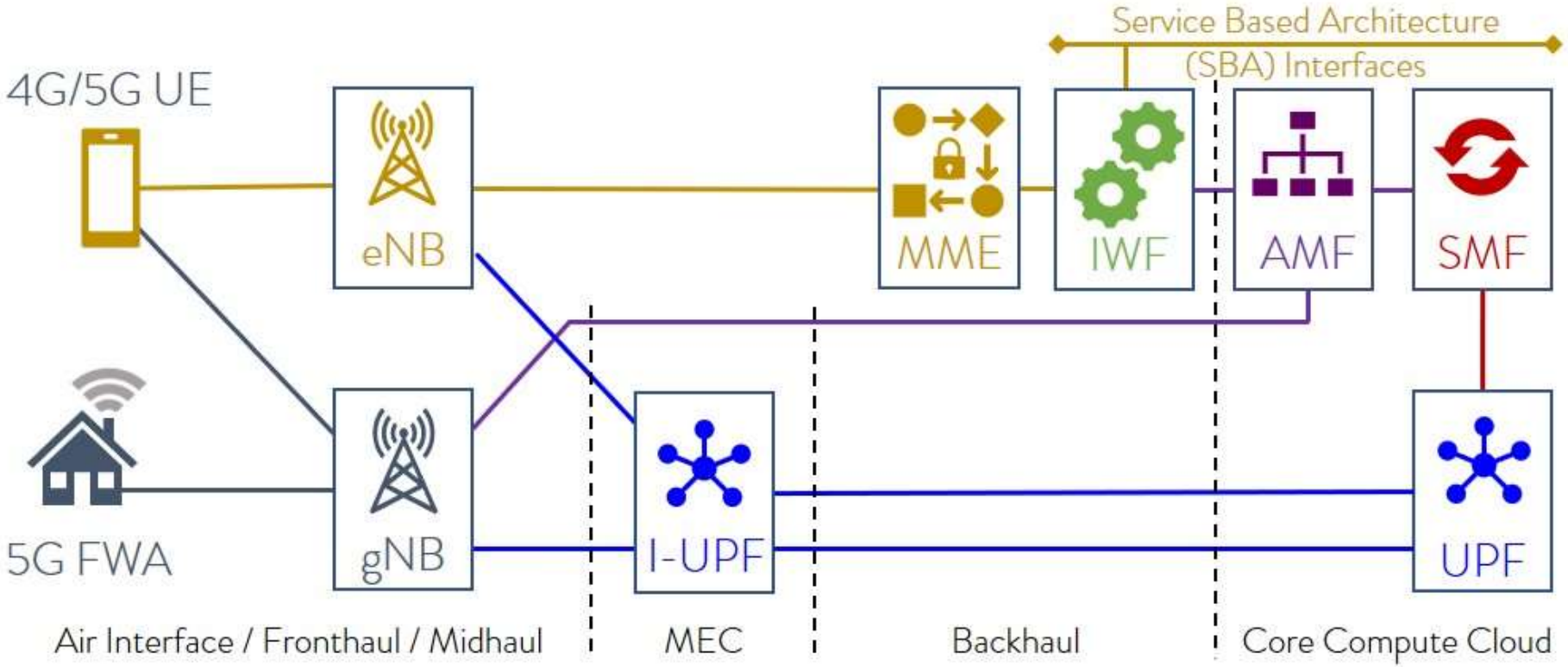
R99, R8, R14 - CUPS, R15



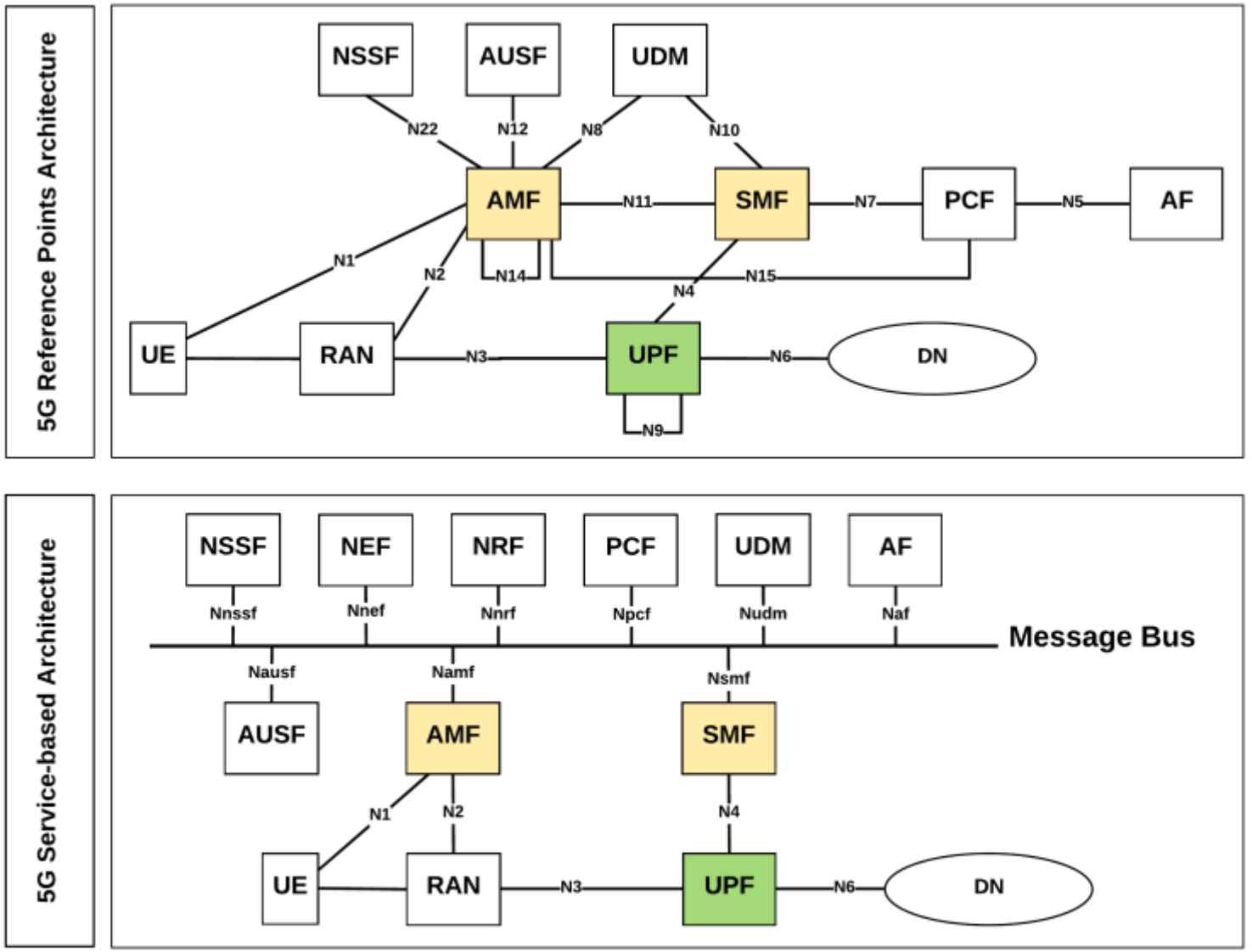
Service Based Architecture (SBA)



5G FWA a 5G

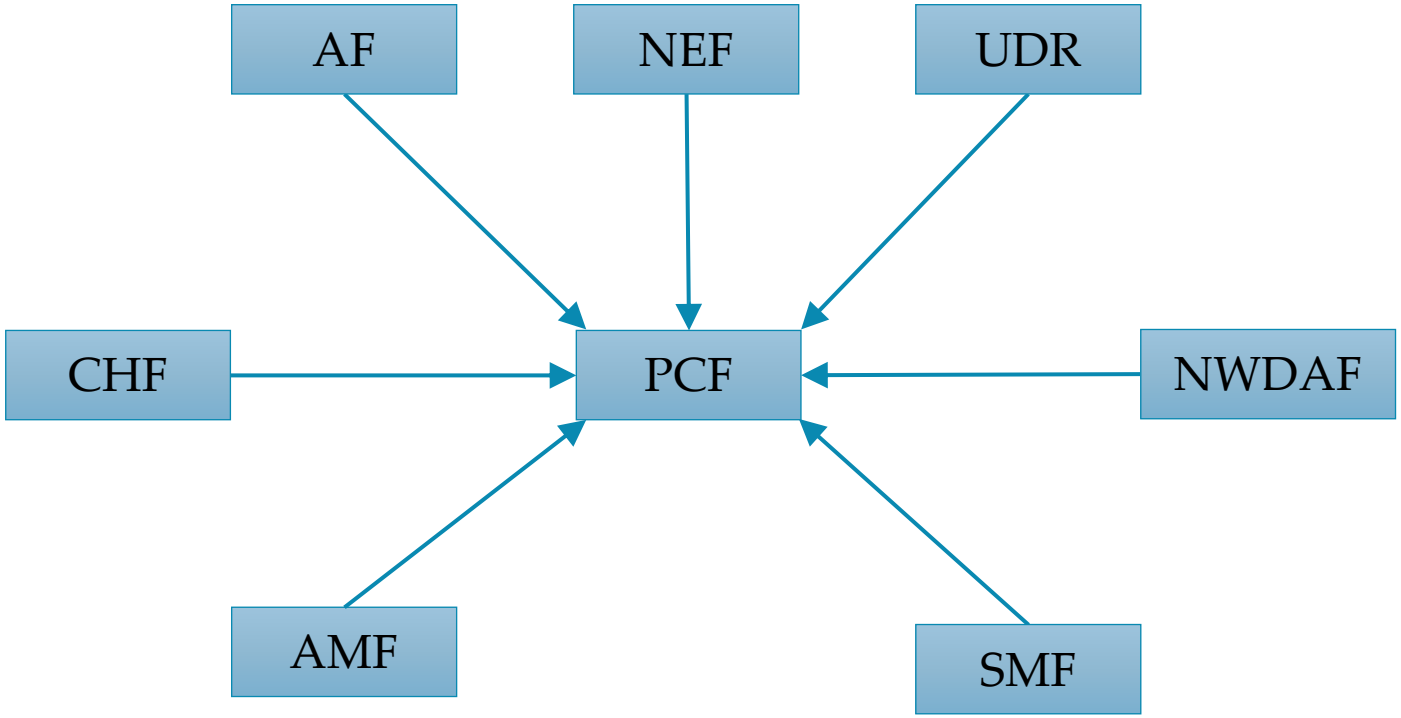

Service Based Architecture
(SBA) Interfaces
4G/5G UE
eNB
MME
IWF
AMF
SMF
5G FWA
gNB
I-UPF
UPF
Air Interface / Fronthaul / Midhaul
MEC
Backhaul
Core Compute Cloud

5G Core



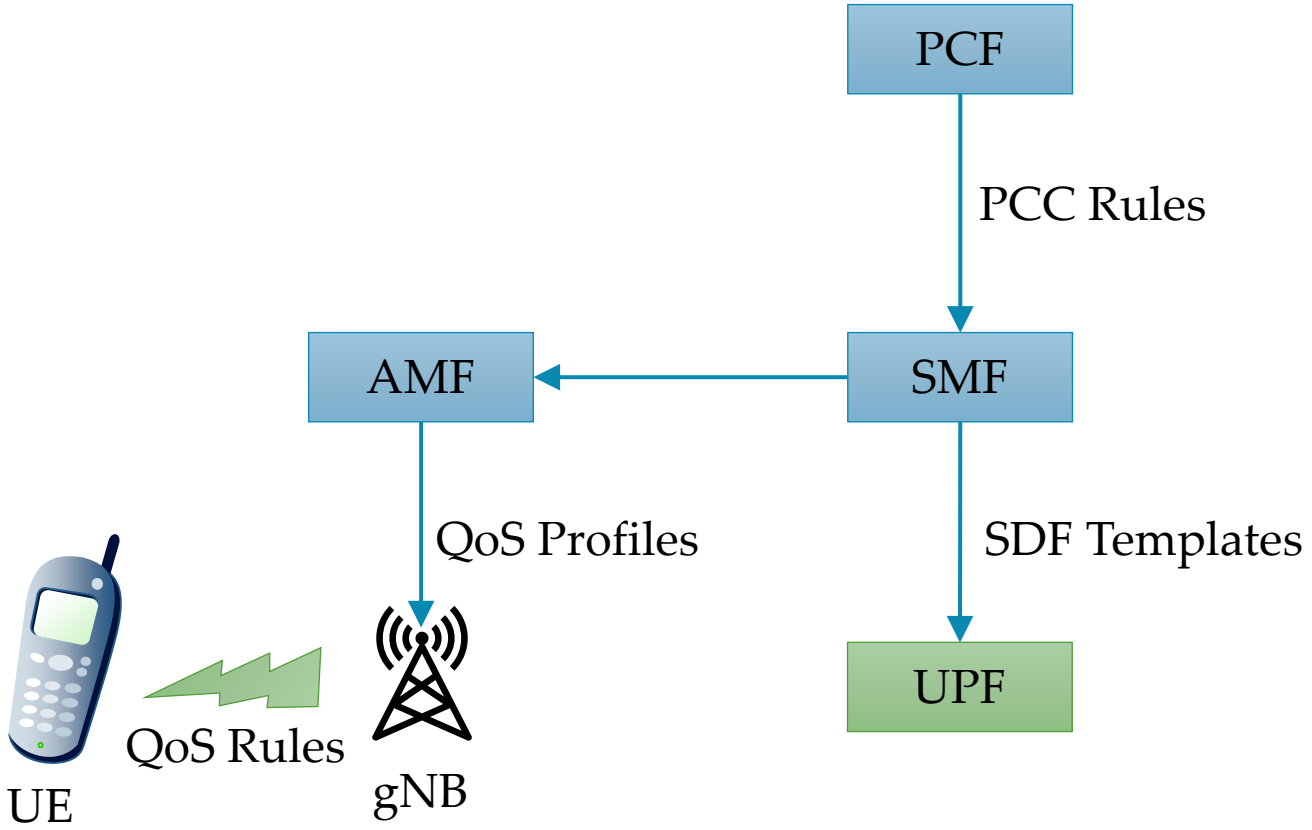
AMF: Access & Mobility Management Function
SMF: Session Management Function
UPF: User Plane Function
NEF: Network Exposure Function
NRF: NF Repository Function
NSSF: Network Slice Selection Function
UDM: Unified Data Function
AUSF: Authentication Server Function
PCF: Policy Control Function

Policy and Charging Control

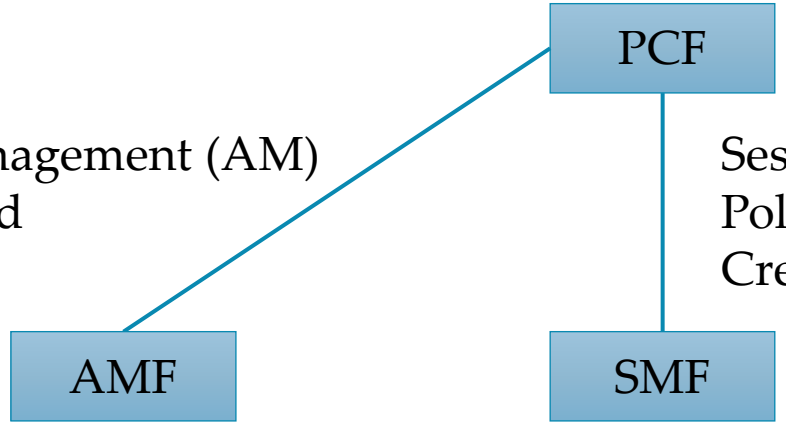


Input sources for PCC decision

Distribution of Session Policies 5G



Access and Mobility Policies Control

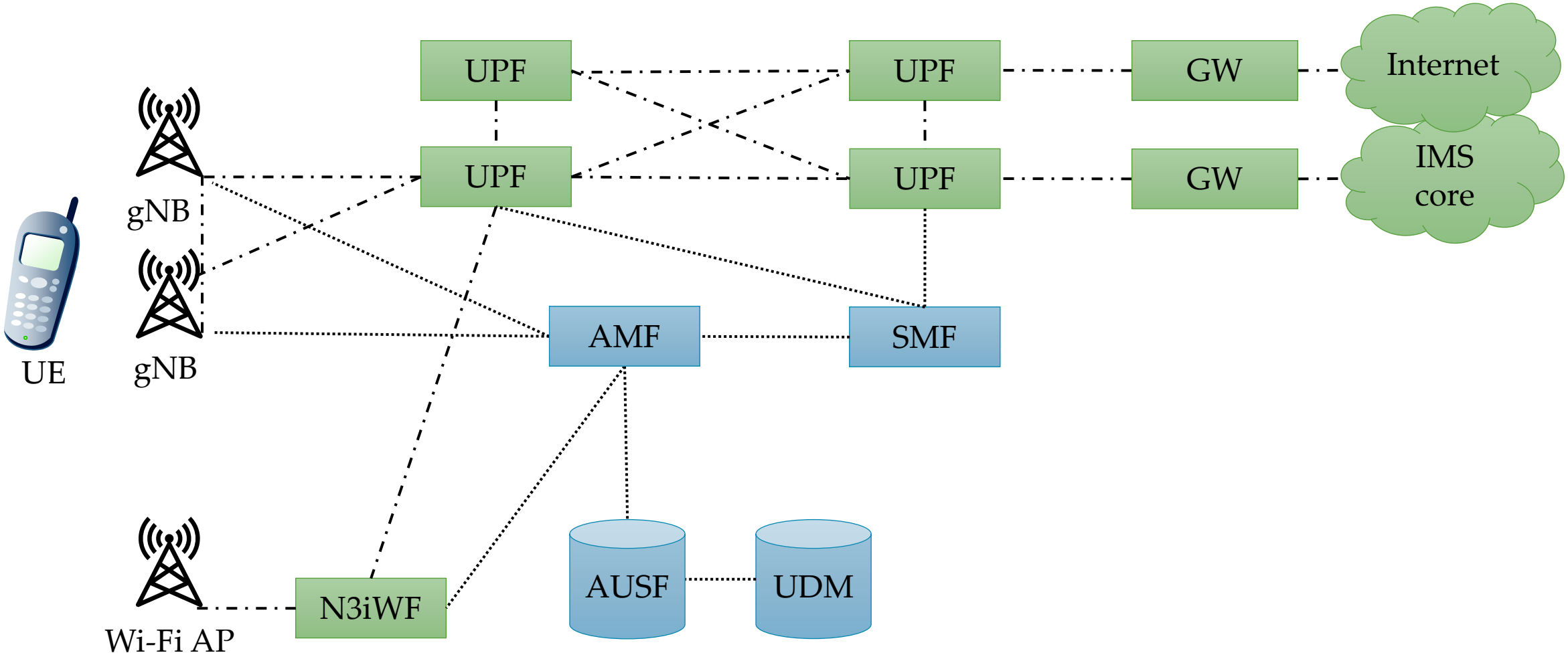


Access and Mobility Management (AM)
Policy Association created
at 5G Registration

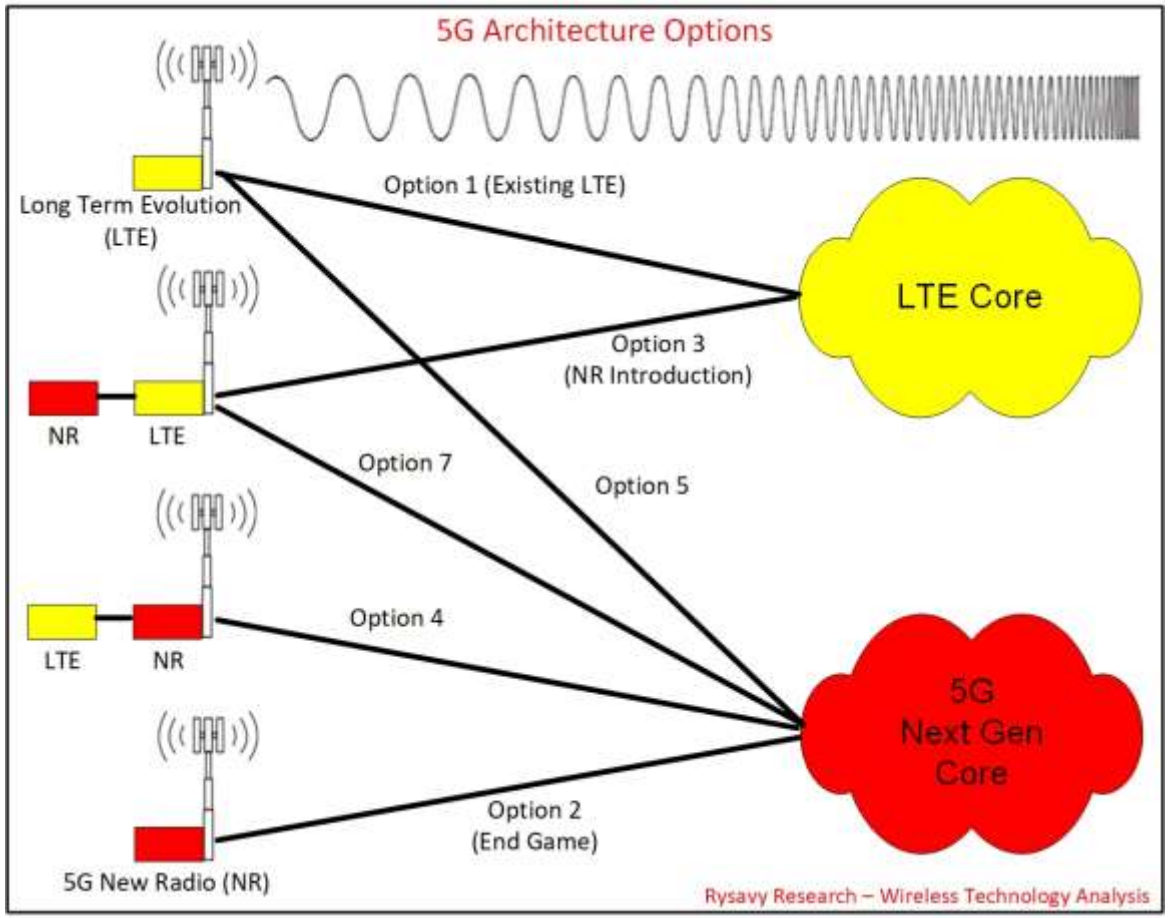
Session Management (SM)
Policy Association,
Created at PDU Session Establishment

5G Policy Associations

5G Architecture



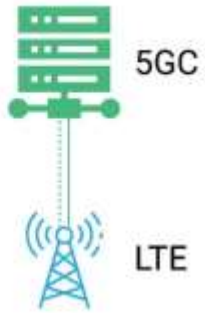
From 4G to 5G


5G Architecture Options
Long Term Evolution (LTE)
Option 1 (Existing LTE)
LTE Core
Option 3 (NR Introduction)
NR
LTE
Option 7
Option 5
LTE
NR
Option 4
5G Next Gen Core
Option 2 (End Game)
5G New Radio (NR)
Rysavy Research – Wireless Technology Analysis

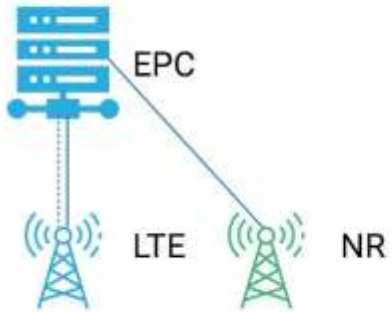
From 4G to 5G

Standalone LTE under EPC (option 1)

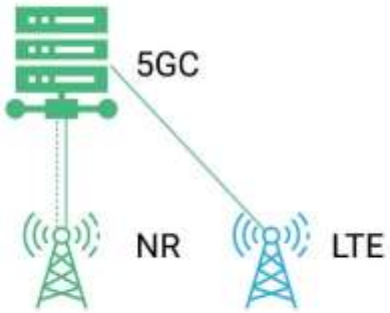
Standalone NR under 5GC (option 2)



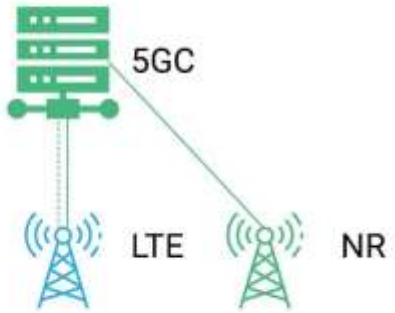
Standalone LTE under 5GC (option 5)



Non-standalone LTE and NR under EPC (option 3)

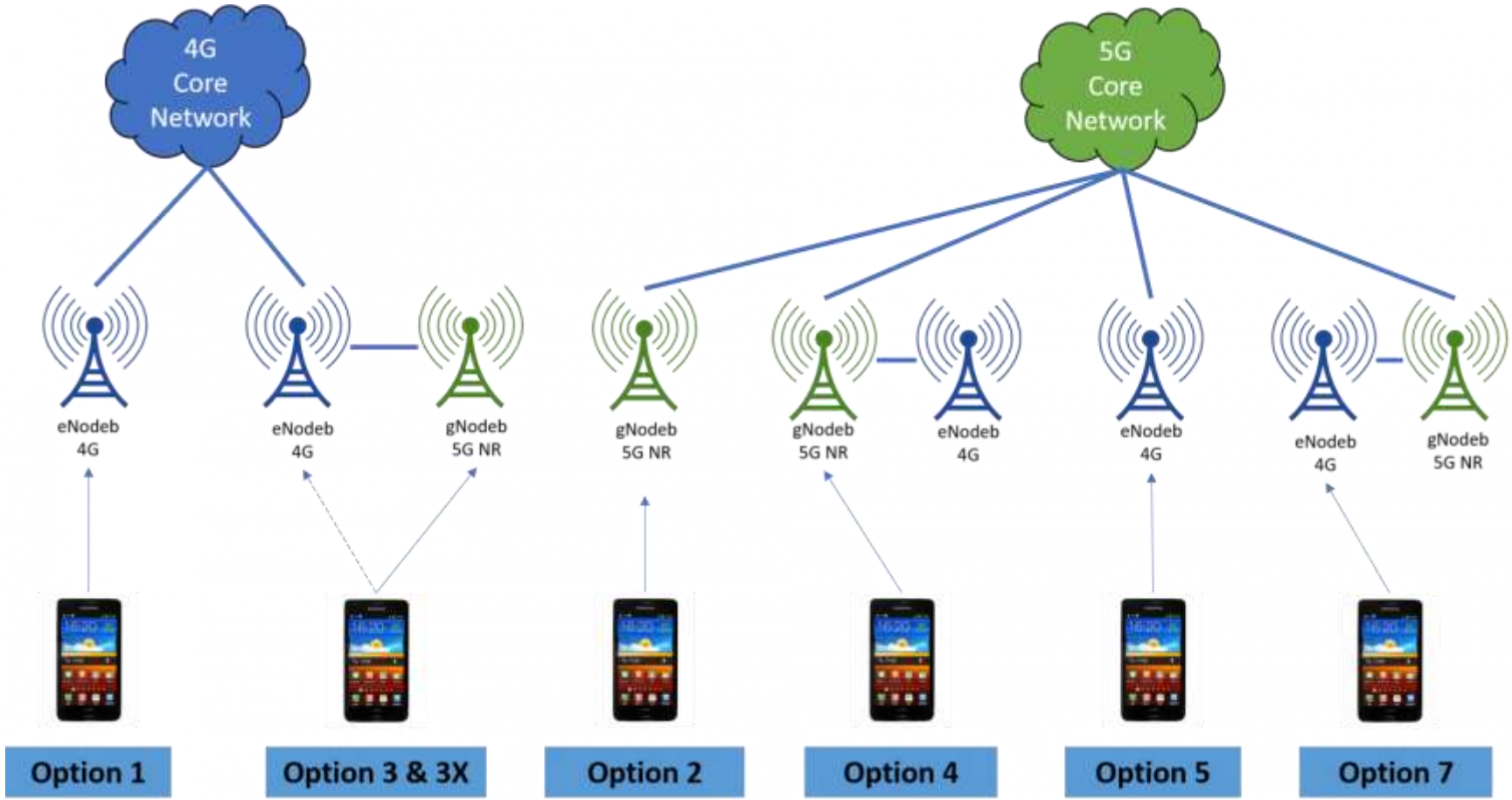


Non-standalone NR and LTE under 5GC (option 4)



Non-standalone LTE and NR under 5GC (option 7)

From 4G to 5G


4G
Core
Network
5G
Core
Network
eNodeb
4G
eNodeb
4G
gNodeb
5G NR
gNodeb
5G NR
gNodeb
5G NR
eNodeb
4G
eNodeb
4G
eNodeb
4G
gNodeb
5G NR
Option 1
Option 3 & 3X
Option 2
Option 4
Option 5
Option 7

Mobile transformations

Intensifying Role of Wireless Communications

- Access to vast amounts of new spectrum (including unlicensed)
- Small cells ready for mass deployment
- New network architecture – NVF, SDN, network slicing, Mobile edge computing
- Artificial intelligence and machine learning

Propustnost rádiové sítě

- Pokrytí se rozděluje do buněk
- Propustnost rádiové sítě – měří se v [bit/s/km^2]
- Hustota buněk [Cell/km^2]
- Dostupné spektrum [Hz]
- Spektrální účinnost [bit/s/Hz/Cell]

$$\frac{Throughput}{[bit/s/km^2]} = \frac{CellDensity}{[Cell/km^2]} * \frac{AvailableSpectrum}{[Hz]} * \frac{SpectralEfficiency}{[bit/s/Hz/Cell]}$$

Jak zvýšit spektrální účinnost?

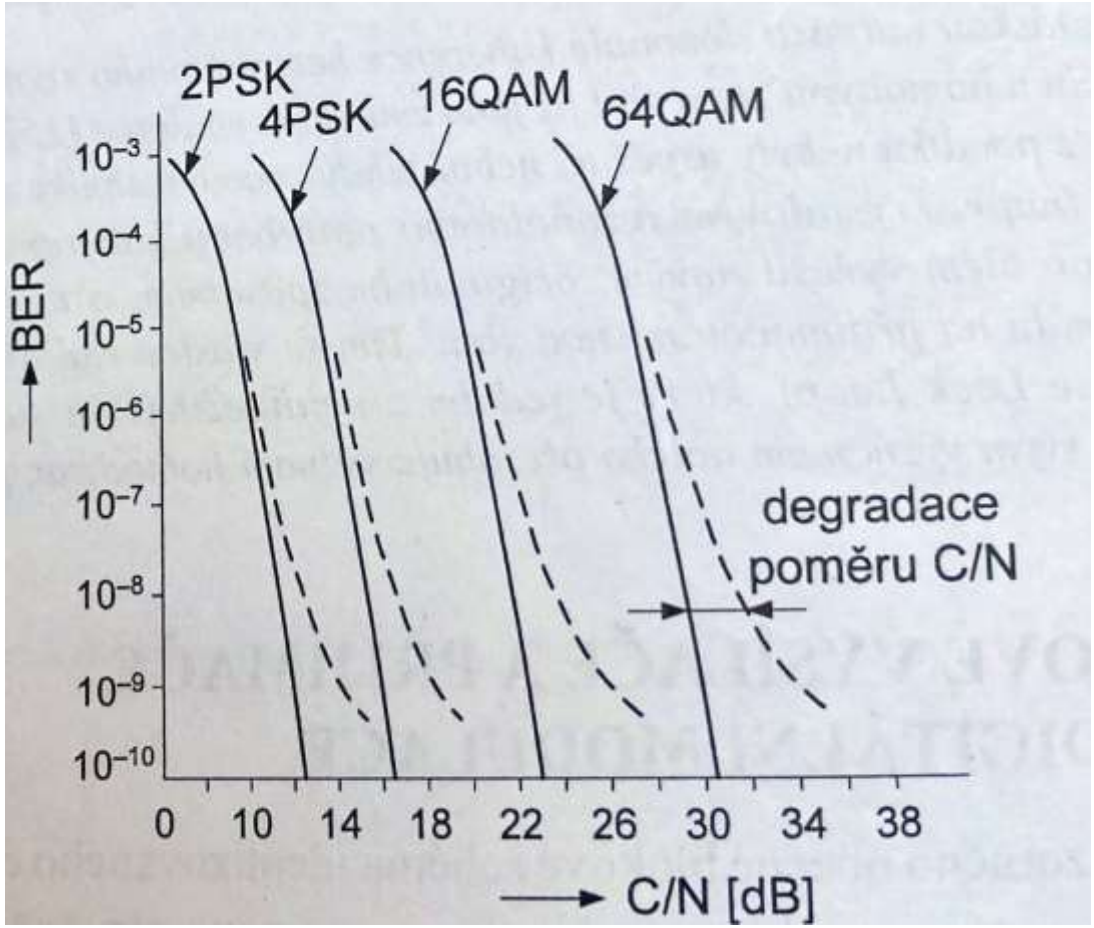
- Shannon–Hartley theorem
- C – kapacita kanálu
- B – šířka pásma
- S/N – poměr signál šum

$$C = B \log_2 \left(1 + \frac{S}{N}\right)$$

$$\log_2(1 + \frac{ReceivedSignalPower}{InterferencePower + NoisePower})[bit/s/Hz/user]$$

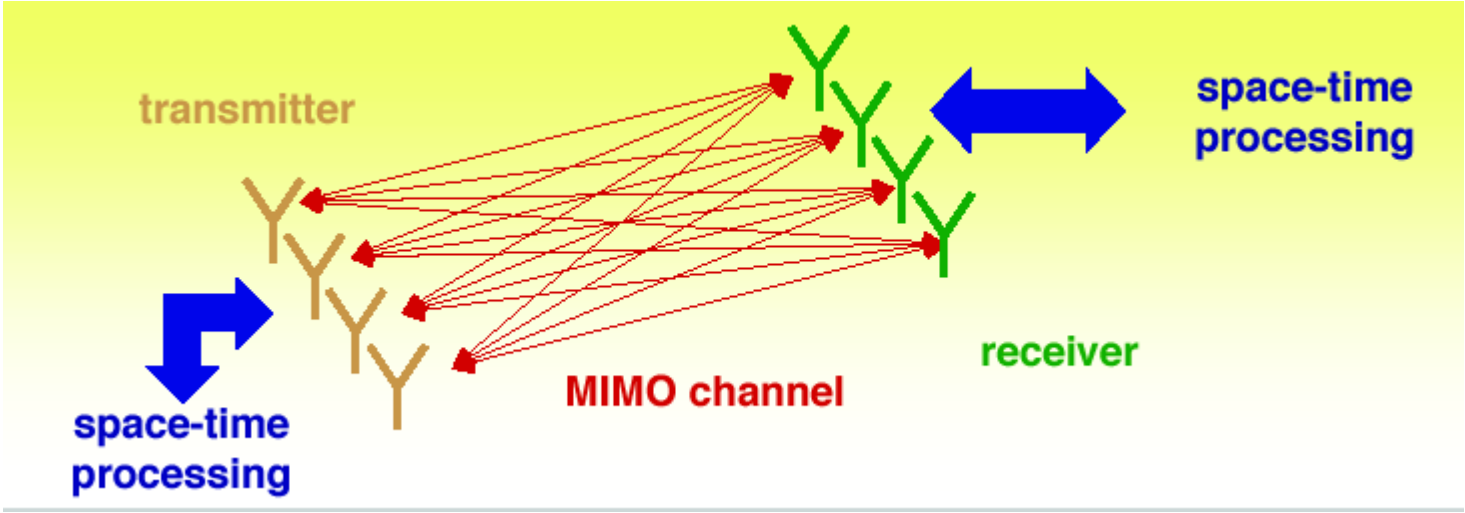
4 bit/s/Hz –> 8 bit/s/Hz znamená 17 vyšší výkon

Modulace – porovnání C/N a BER

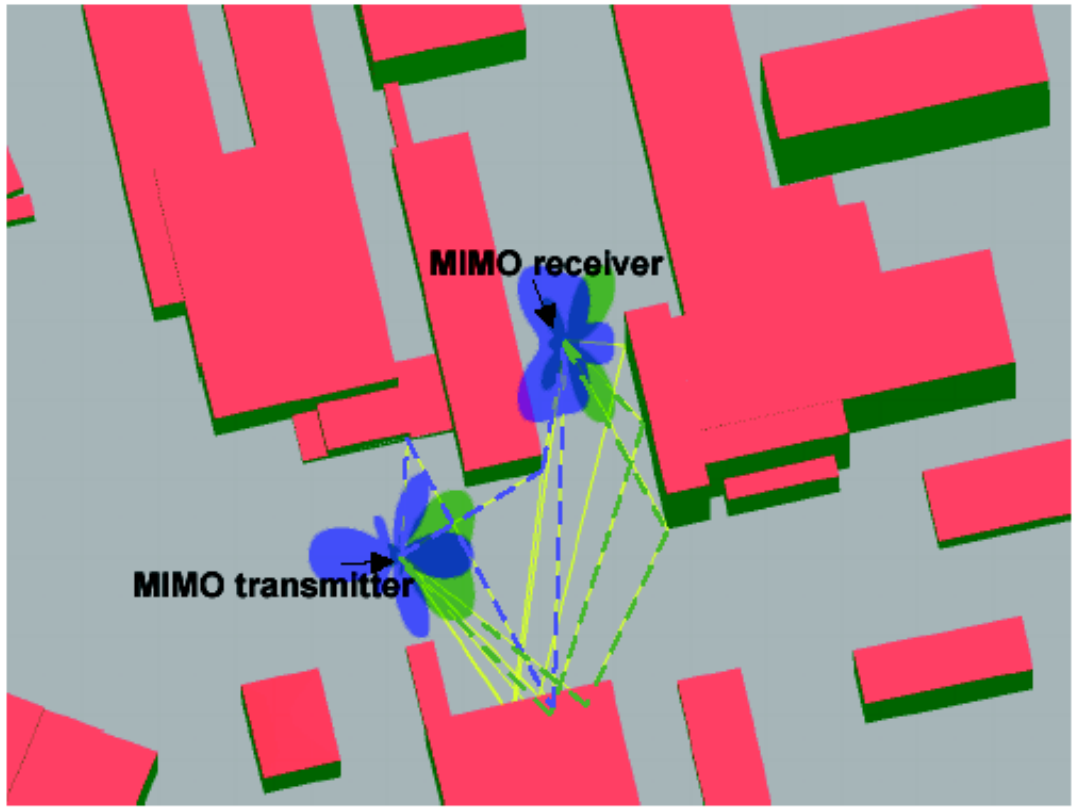


Jak zvýšit spektrální účinnost?

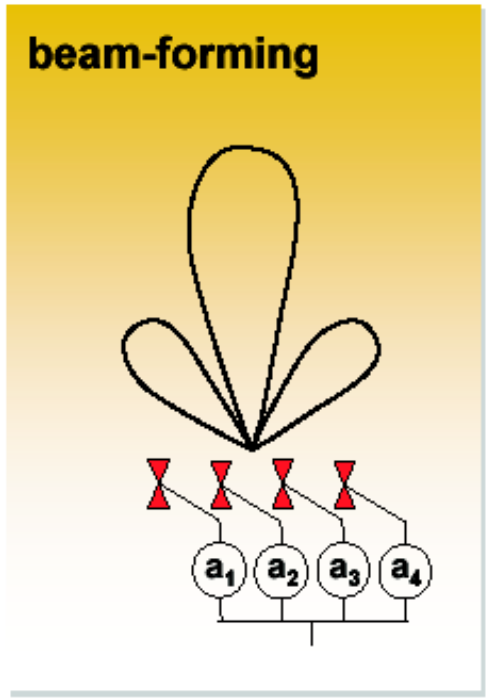
- Zvýšit výkon je v případě tarminálů napájených z akumulátoru problém.
- Jak z toho ven?
- Více paralelních přenosů – MIMO – Multiple-Input and Multiple-Output
- Více antén více směrovosti



MIMO and Beam-Forming

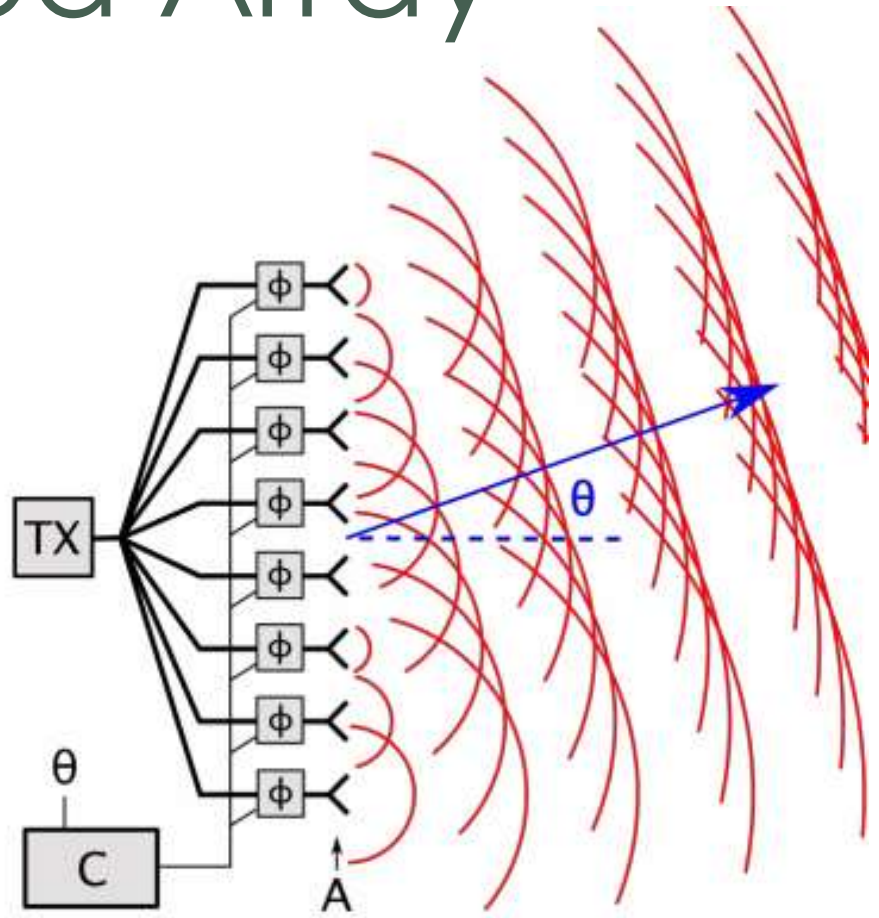


building
propagation path
1. sub channel
2. sub channel



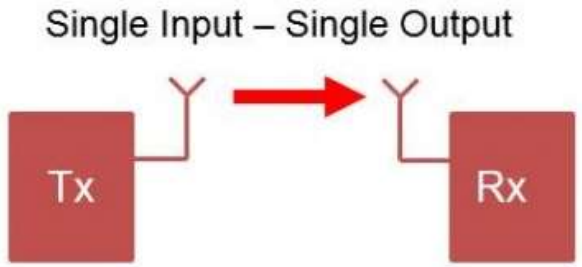
array with 4 dipoles
with λ/2 spacing

MIMO – Phased Array



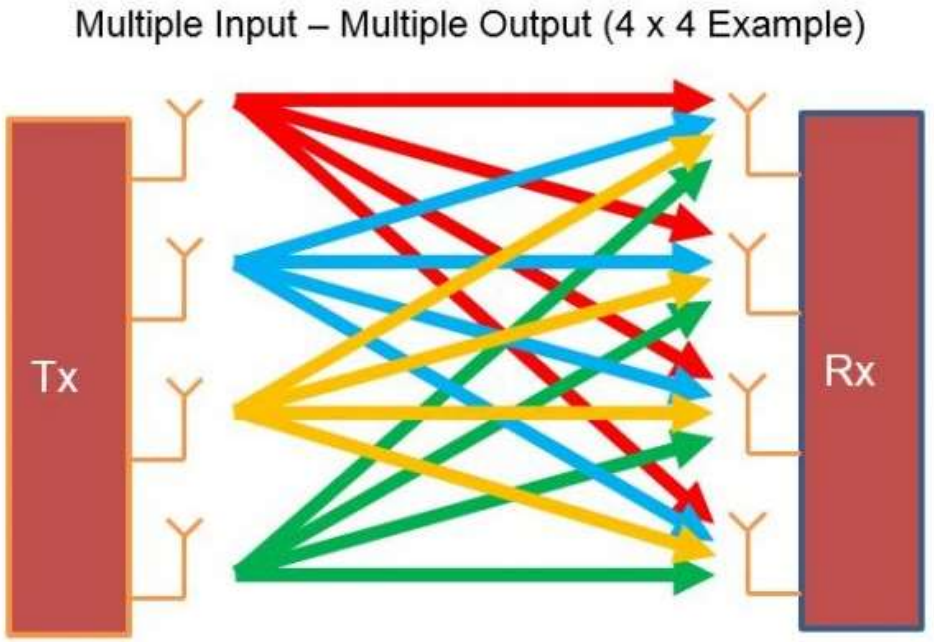
SISO a MIMO

Single-input and Single-output (SISO)



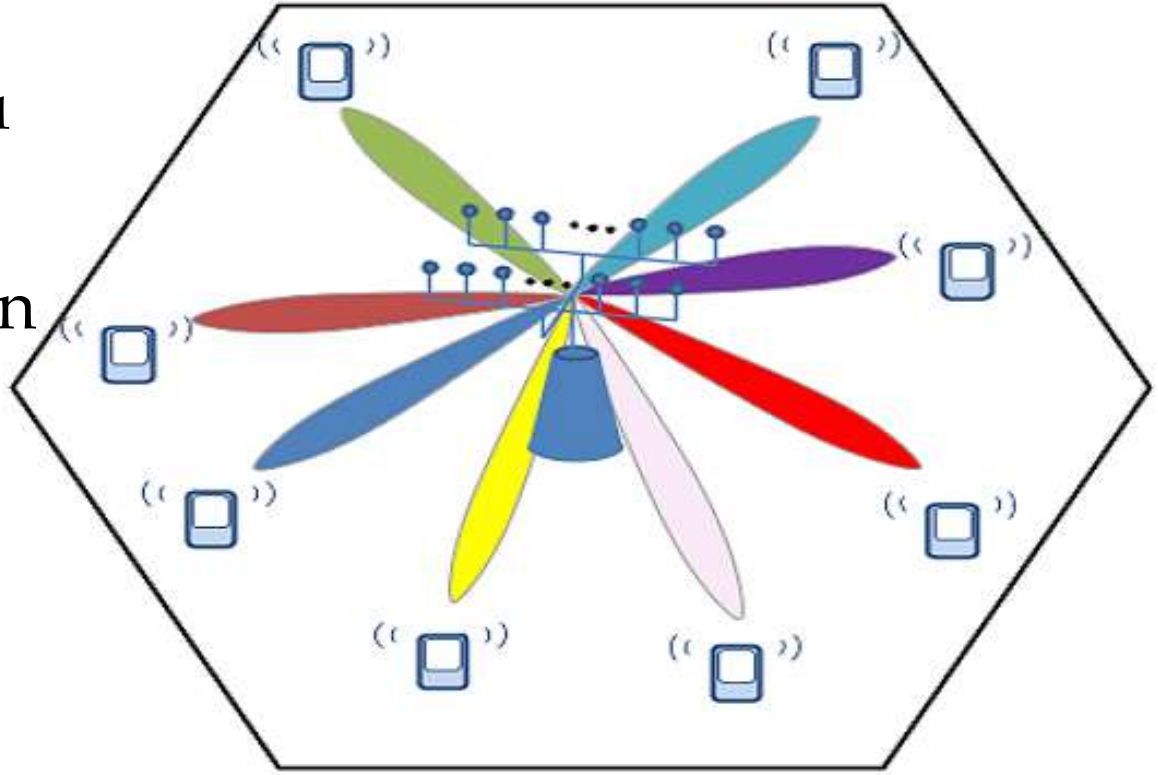
MIMO

- Singe-user MIMO (SU-MIMO)
- Multi-user MIMO (MU-MIMO)
- Cooperative MIMO (CO-MIMO)
- Massive MIMO

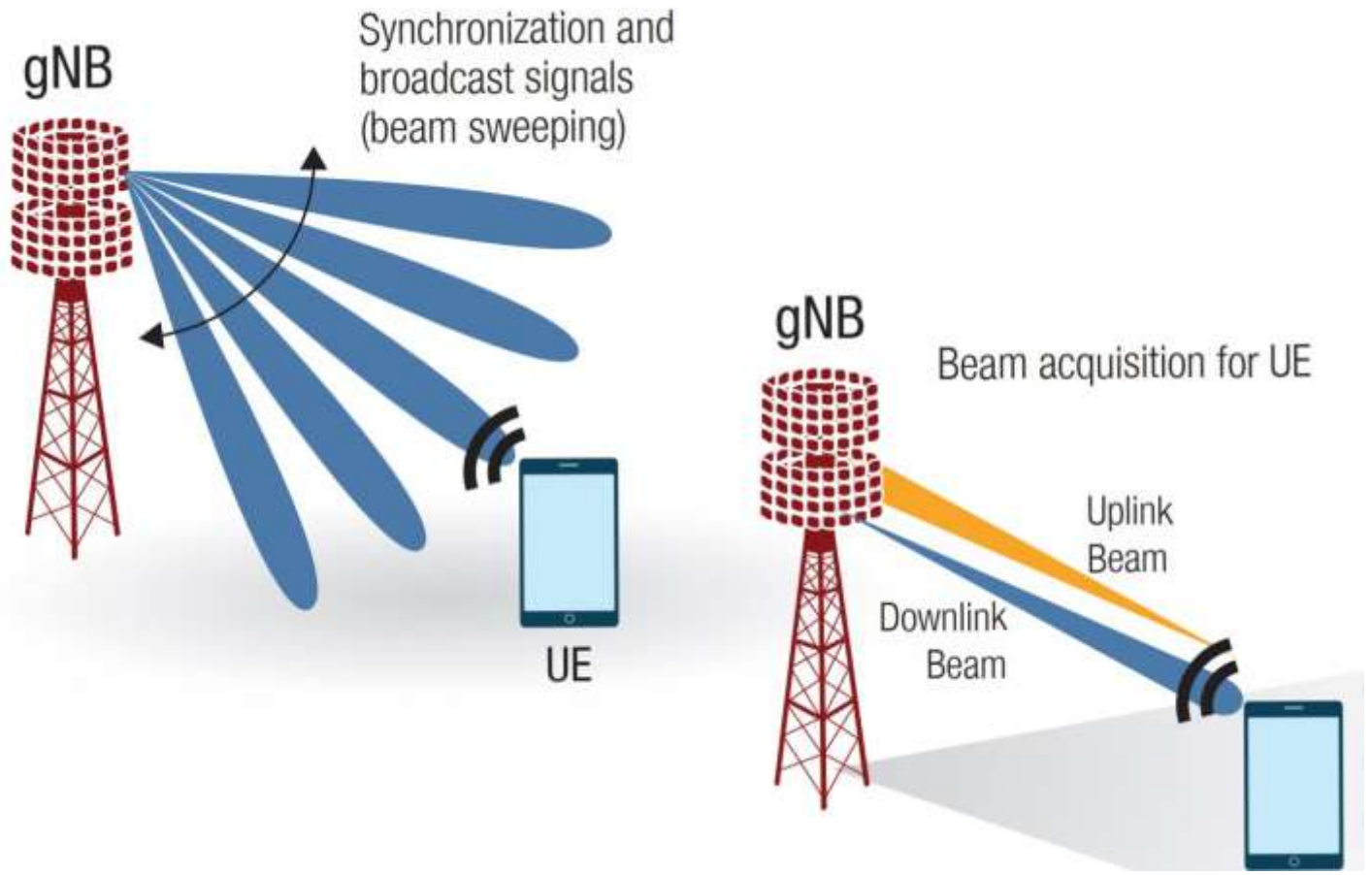


Massive MIMO

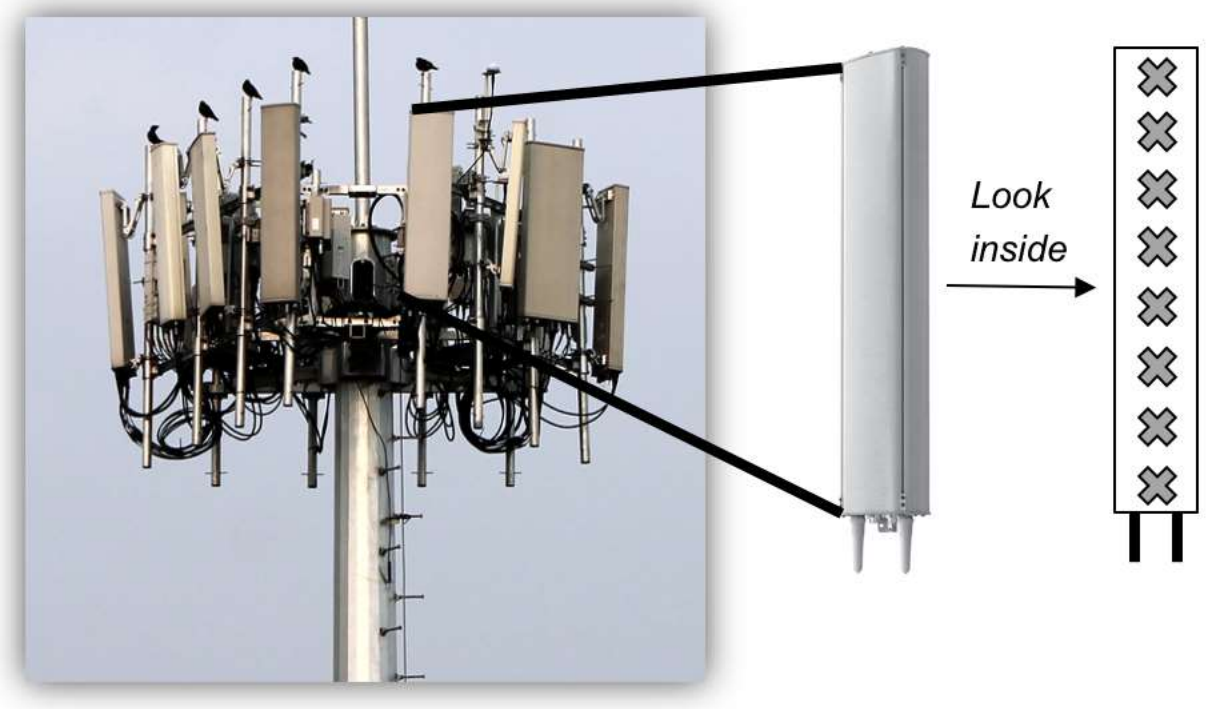
- Počet antén >> počet uživatelů
- Například 200 antén pro 40 uživatelů
- Jak moc masivní?
- 3 sektory 8 x 8 antén 64 * 3 = 192 antén



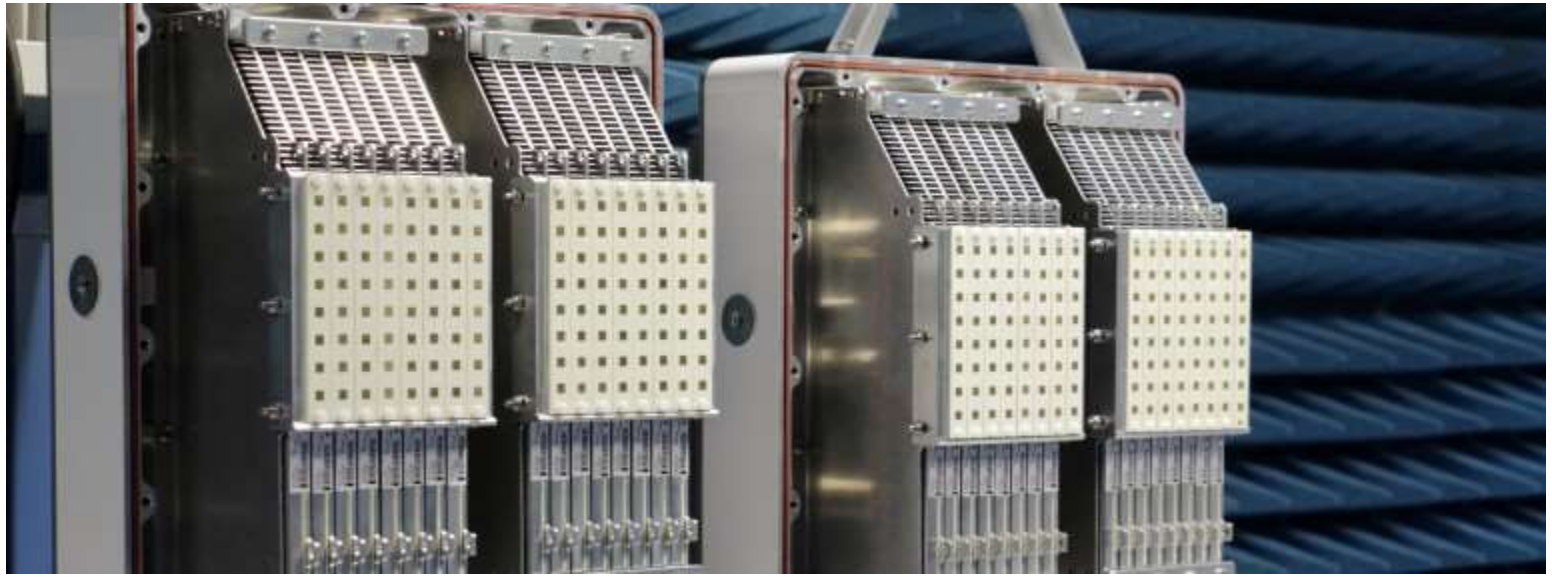
Massive MIMO



Massive MIMO



64 TX + 64 RX 5G MU-MIMO ant suitable for Massive MIMO



MIMO and Smart antennas

Smart antennas:

- Through higher-order MIMO and beamforming, smart antennas gain added sophistication in each 3GPP release and are the primary contributor to increased spectral efficiency (bit/s/Hz).
- Massive MIMO, beginning in Release 13, will support 16-antenna-element systems and in 5G, will expand to hundreds of antenna elements.

Cooperative MIMO

- Coordinated Multipoint
- Fixed Relays
- Mobile Relays

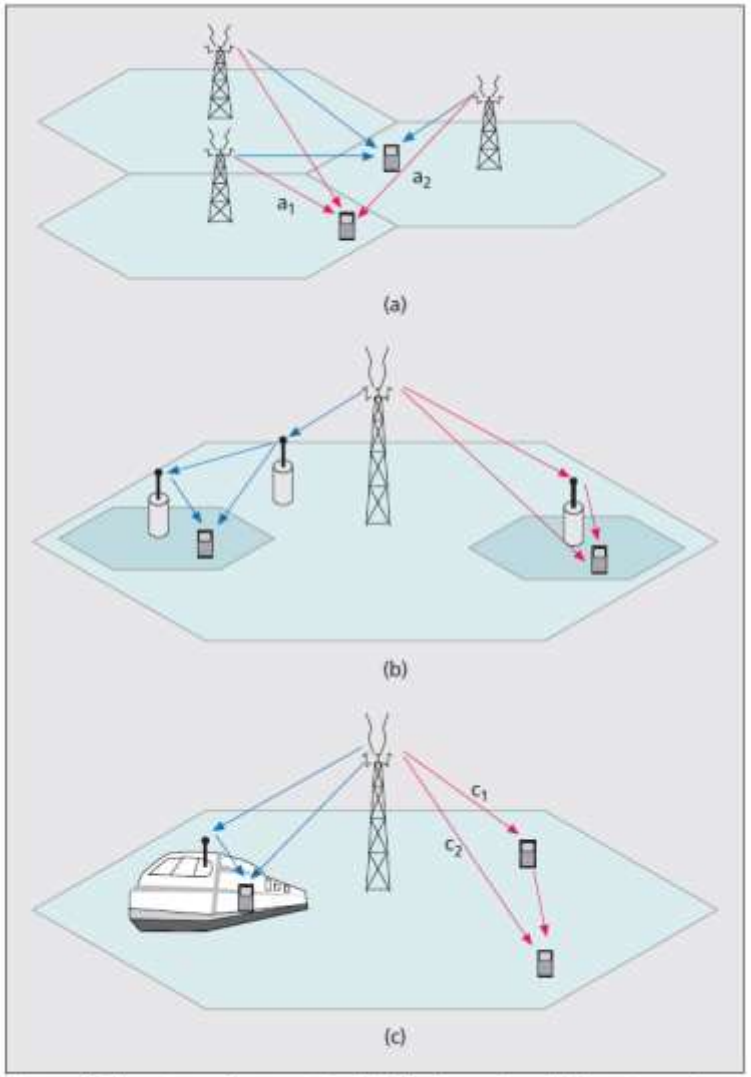
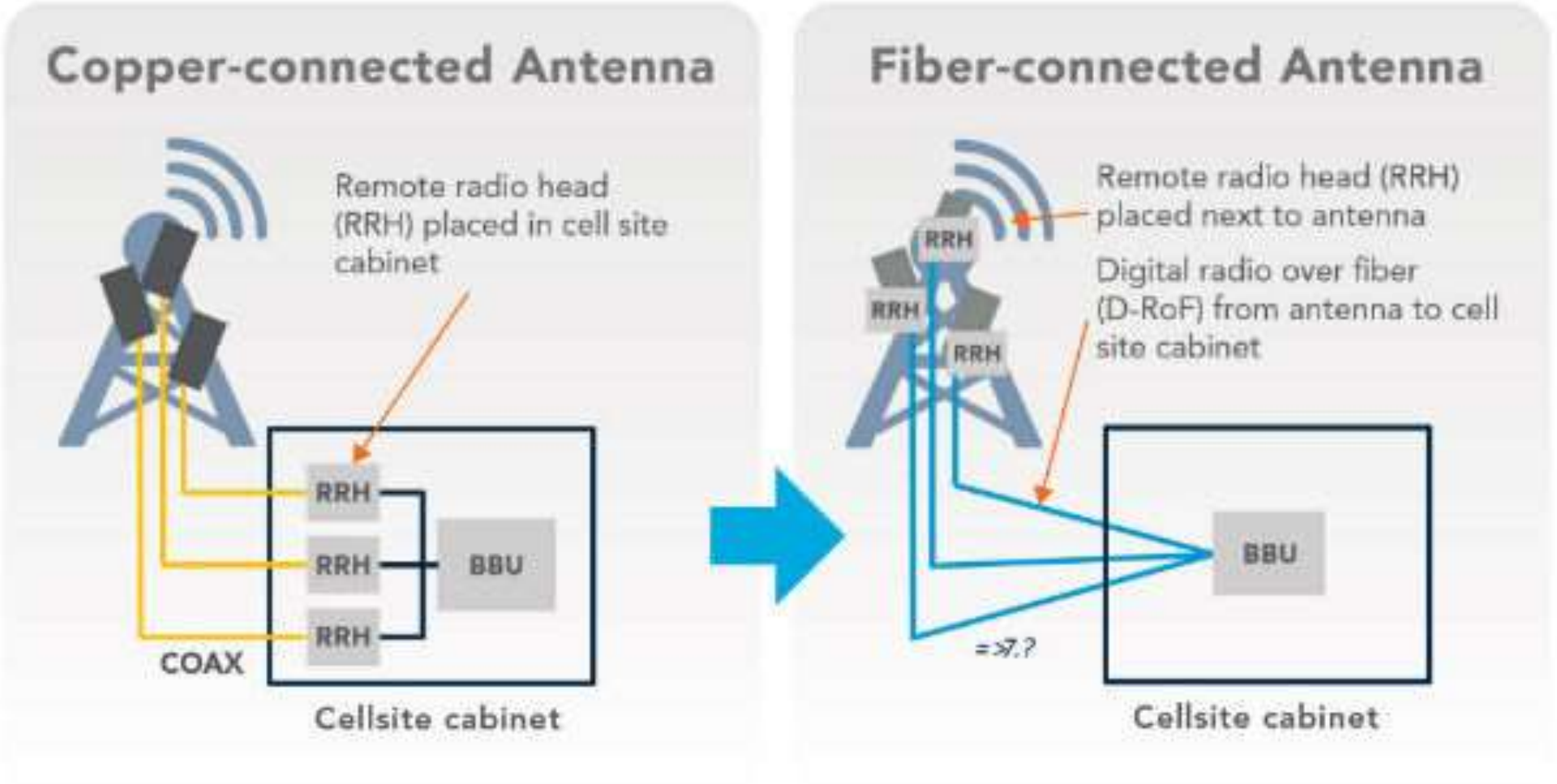
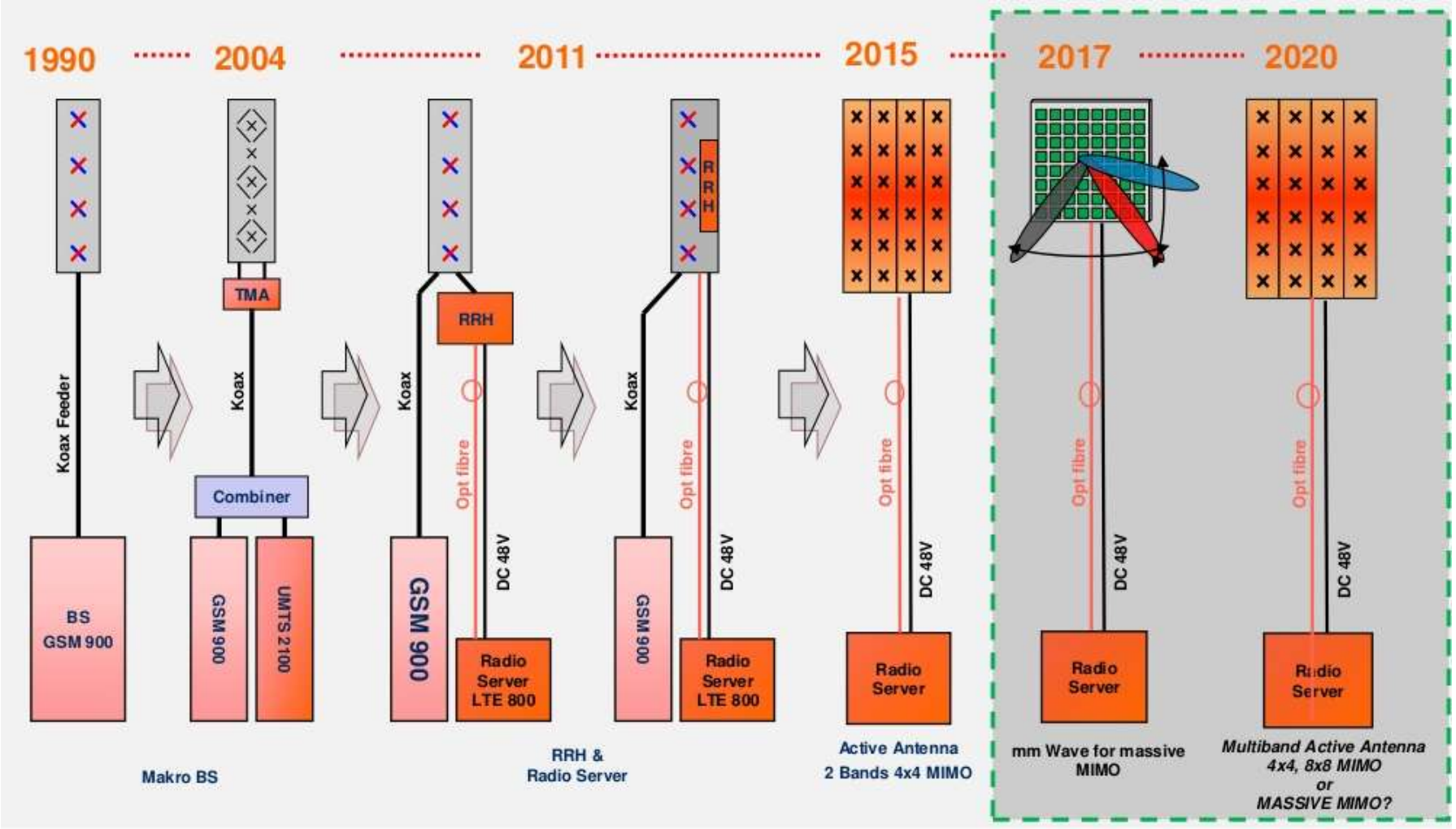


Figure 1. *Three types of cooperative MIMO schemes in cellular systems: a) CoMP; b) fixed relay; c) mobile relay.*

Coax vs Fiber-connected Antenna



From coax feeder to fiber



Antenna evolution – New Radio

Passive Antennas:

- Generation 1 – BTS – single omni antenna or sectors, coax from BTS to ant
- Generation 1,5 – BTS + NodeB, combiner, more sectors, cross Polarized
- Generation 2 – NodeB – fiber fronthaul one RRH, 2x2 MIMO, Cross Polarized
- Generation 2 – NodeB – fiber fronthaul more RRH, 4x4 MIMO, Cross Polarized

Active antenna:

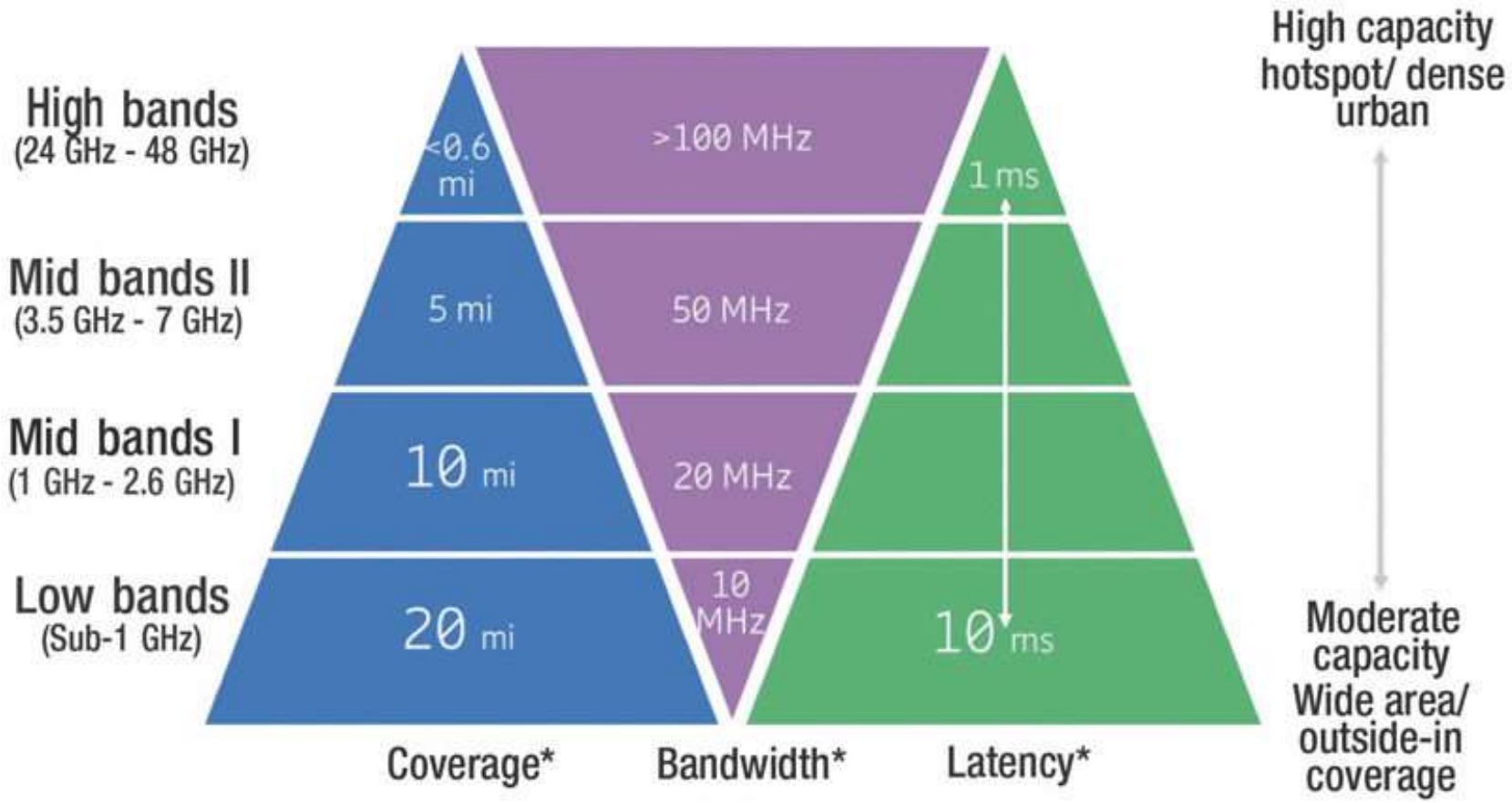
- Generation 3 – 64 Element FD-Mimo
- Generation 4 – Massive MIMO

FWA – Fixed Wireless Access

- Point to Multipoint
- Substitution of ADSL, VDSL, SDSL, … Optics
- FUP – Fair User Policy ?

- 5G user data rates: experienced 100 Mbit/s, peak 20 Gbit/s
- 6G user data rates: experienced 1 Gbit/s, peak 1 Tbit/s

Coverage, Bandwidth, Latency



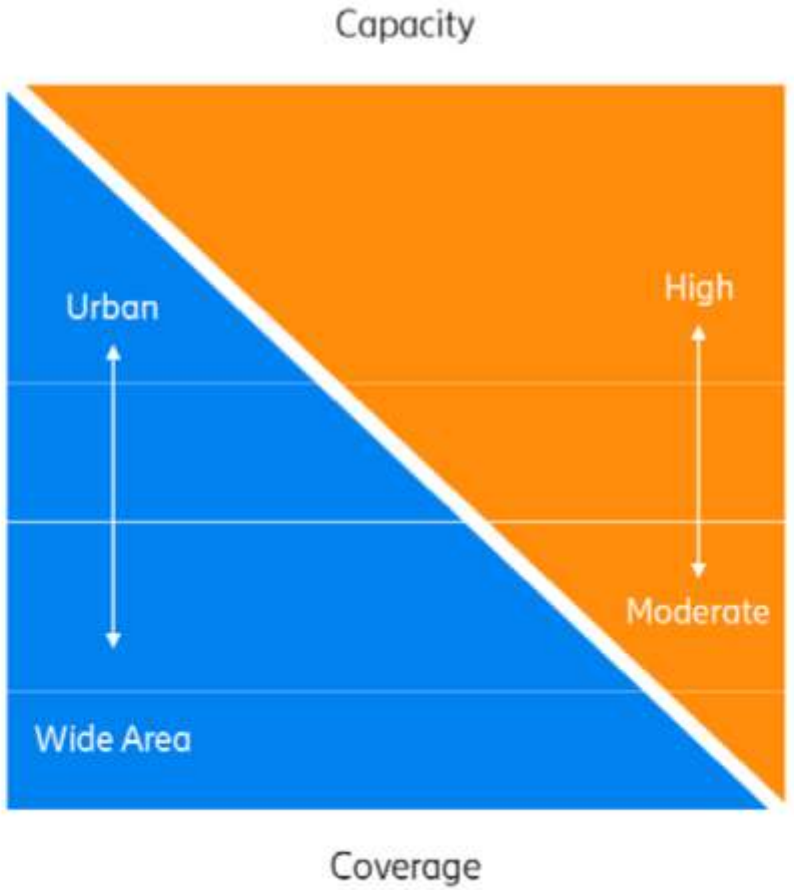
5G Capacity

High bands
- (24GHz – 48GHz)
- New

Mid bands TDD
- (2.3GHz - 6GHz)
- Legacy

Low bands FDD
- (1GHz - 2.6GHz)
- Legacy

Low bands
- (Sub - 1GHz)
- New/Legacy



High capacity dense urban/localised deployments

Moderate capacity wide area/ outside-in coverage

mmWave – FR2 více než 24 GHz

- U 5G se počítá mmWave.
- Spektrum mmWave nabízí ve srovnání s dnešními sítěmi 4G rychlosti řádově 10krát větší.
- V USA také 7 GHz, které se již v USA používají
- Nelicencované pásmo také 6 GHz
- Nelicencované 57 až 64 GHz USA
- FR2 v EU 26, 28, 39 a 41 GHz

5G FWA Coverage

Frequency	FWA?	Coverage	Throughput
700 MHz	N	Excellent	Poor
3,4 – 3.8 GHz	Y	Good	Good
24,25 – 27,5 GHz	Y	Poor	Excellent

5G NR – Frequency Range 2

FR2	Pásmo	Jméno	FRQ [GHz]	Šířka pásma [MHz]
n258	26	K-band	24,25 – 27,50	50, 100, 200, 400
n257	28	LMDS	26,50 – 29,50	50, 100, 200, 400
n261	28	Ka-band	27,50 – 28,35	50, 100, 200, 400
n260	39	Ka-band	37,00 – 40,00	50, 100, 200, 400
n259	41	V-band	39,50 – 43,50	50, 100, 200, 400
n262	47	V-band	47,20 – 48,20	50, 100, 200, 400

5G NR – Frequency Range 2

n257
26.5 - 29.5 GHz
(n261 is a subset)

n260
37.0 - 40.0 GHz

n258
24.25 - 27.5 GHz

n262
47.2 - 48.2 GHz

n259
39.5 - 43.5 GHz (planned in e.g. Europe)

5G FWA reálné parametry

- Latence 11 ms
- Vzdálenost CPE od AU do 1 km
- Download 900 Mbit/s / Upload 300 Mbit/s / výborné podmínky
- Download 900 Mbit/s / Upload 150 Mbit/s / dobré podmínky
- Download 500 Mbit/s / Upload 100 Mbit/s / špatné podmínky

6 GHz spectrum

Today, 6 GHz spectrum is used by cable operators for distribution of services, radars, and dedicated microwave communication links.

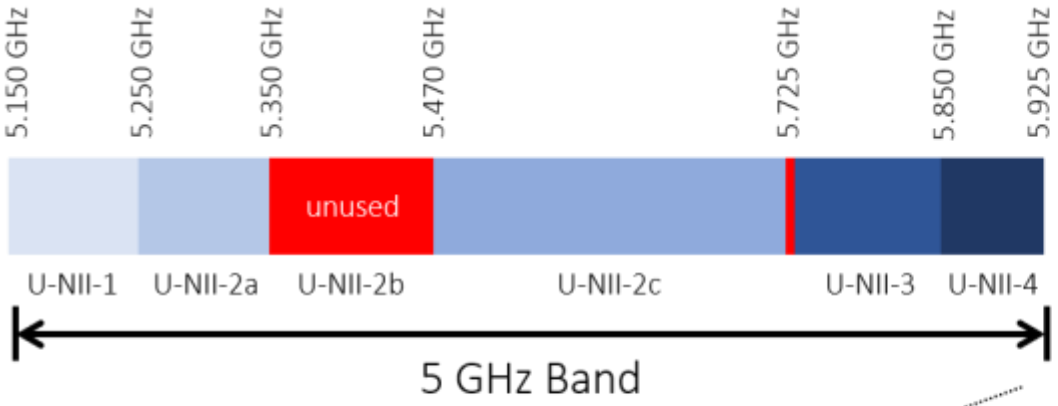
- 6 GHz band covering 5,925–7,125 GHz
- The combination of 2,4; 5 and now 6 GHz potentially creates over 1 GHz of spectrum for 5G use.
- 5G NR-U Specified in Release 16.

6 GHz Harmonizace

- V evropském prostoru komise CEPT připravuje harmonizaci pro pásmo: 5,925 – 6,425 GHz

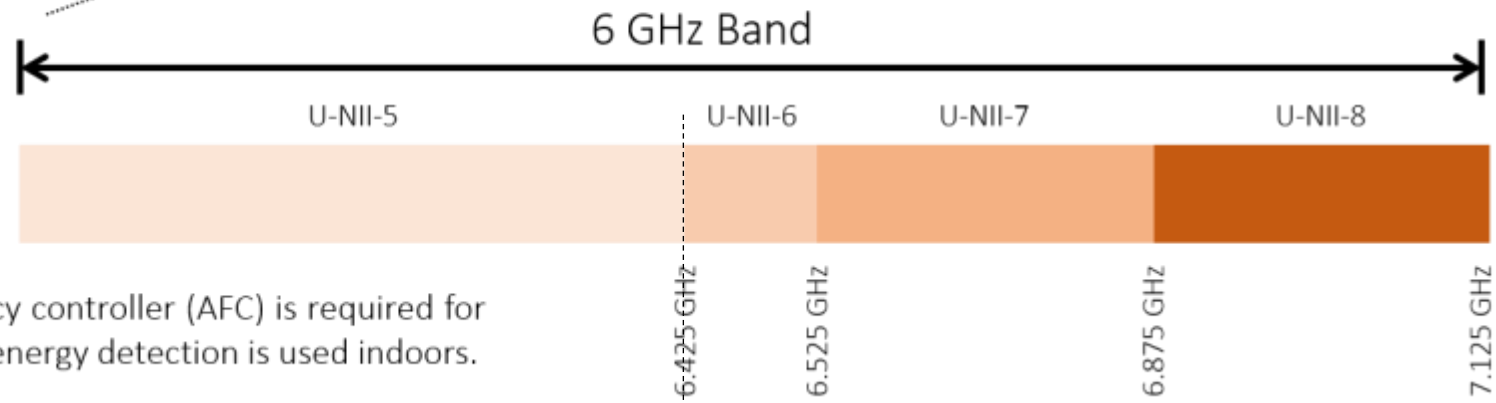
- v USA, Kanadě a Brazílii se zpřístupňuje pásmo 5,925 – 7,125 GHz

5 GHz, 6 GHz a 7 GHz



Heavily utilized. NR-U requires harmonious coexistence with Wi-Fi and LTE/LAA using comprehensive listen before talk (LBT) techniques.

1 W 250 mW 1 W 250 mW

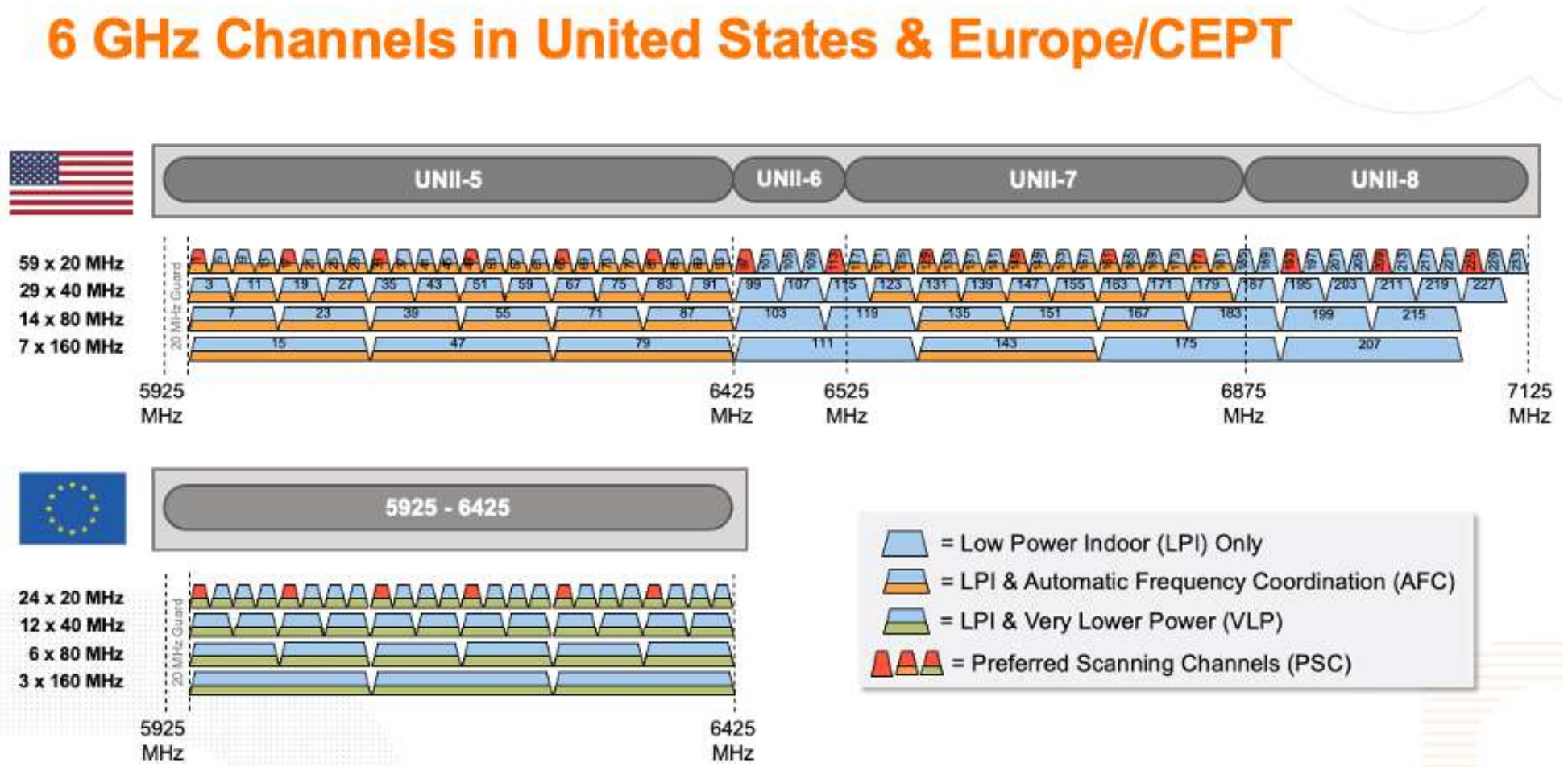


Greenfield band. An automated frequency controller (AFC) is required for outdoor operation (U-NII-5 and 7) while energy detection is used indoors.

EU 5,925 – 6,425 GHz

USA 5,925 – 7,125 GHz

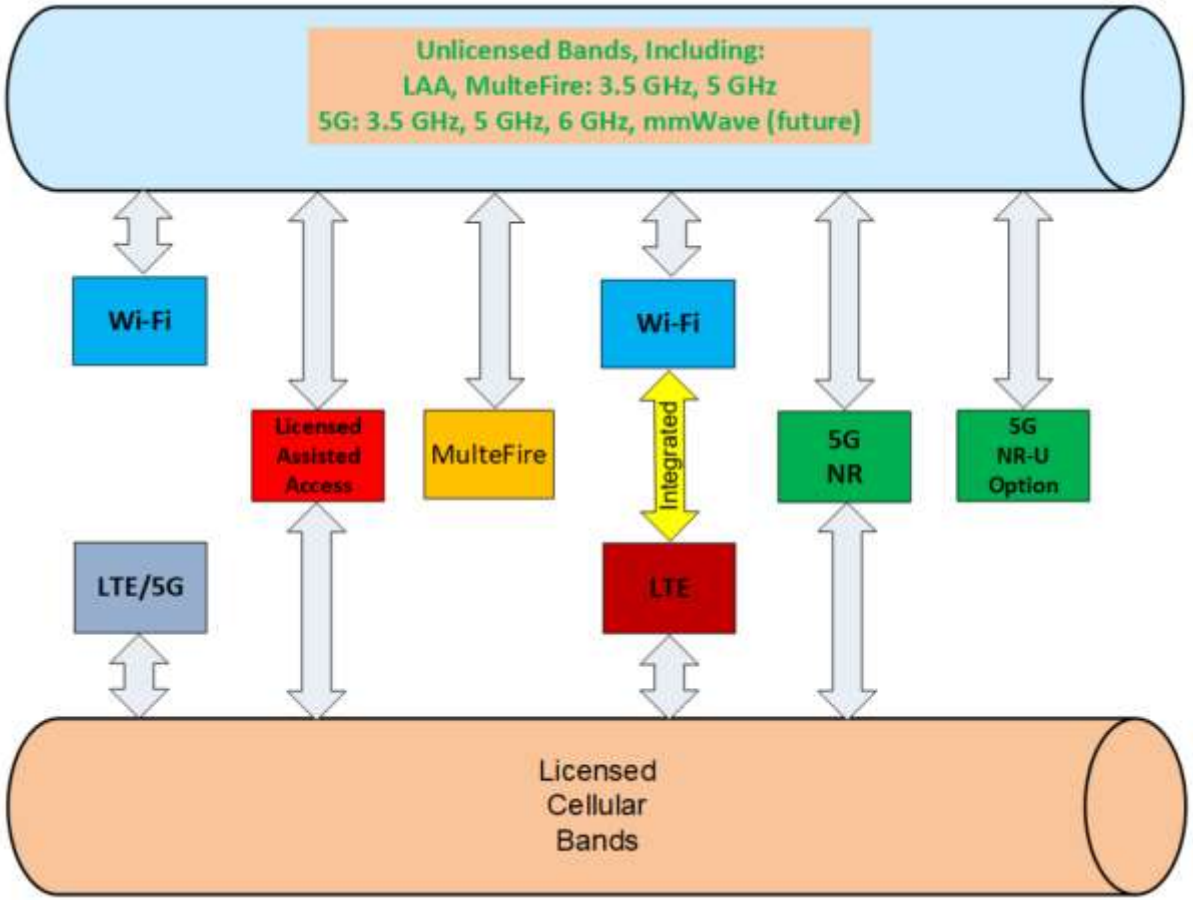
6 GHz harmonizace



LTE a NR-U v nelicencovaném pásmu

- 3GPP pracuje na přizpůsobení LTE a NR pro provoz v nelicencovaném spektru přibližně od roku 2013.
- V nelicencovaném provozu v rámci LTE bylo cílem zavedení režimu provozu s licencovaným asistovaným přístupem (LAA) pomocí nelicencovaného pásma, kde je primární buňka v licencovaném pásmu.
- V Relase 13 byla představena první verze LAA s nelicencovaným pásmem jako doplňkovým downlinkem (DL) pro zlepšení propustnosti DL jako agegace CA (Carrier Agregation).
- V 5G NR-U je ve 5G Phase Two (Release 16)

Licenced vs Unlicenced



5G device using unlicensed spectrum

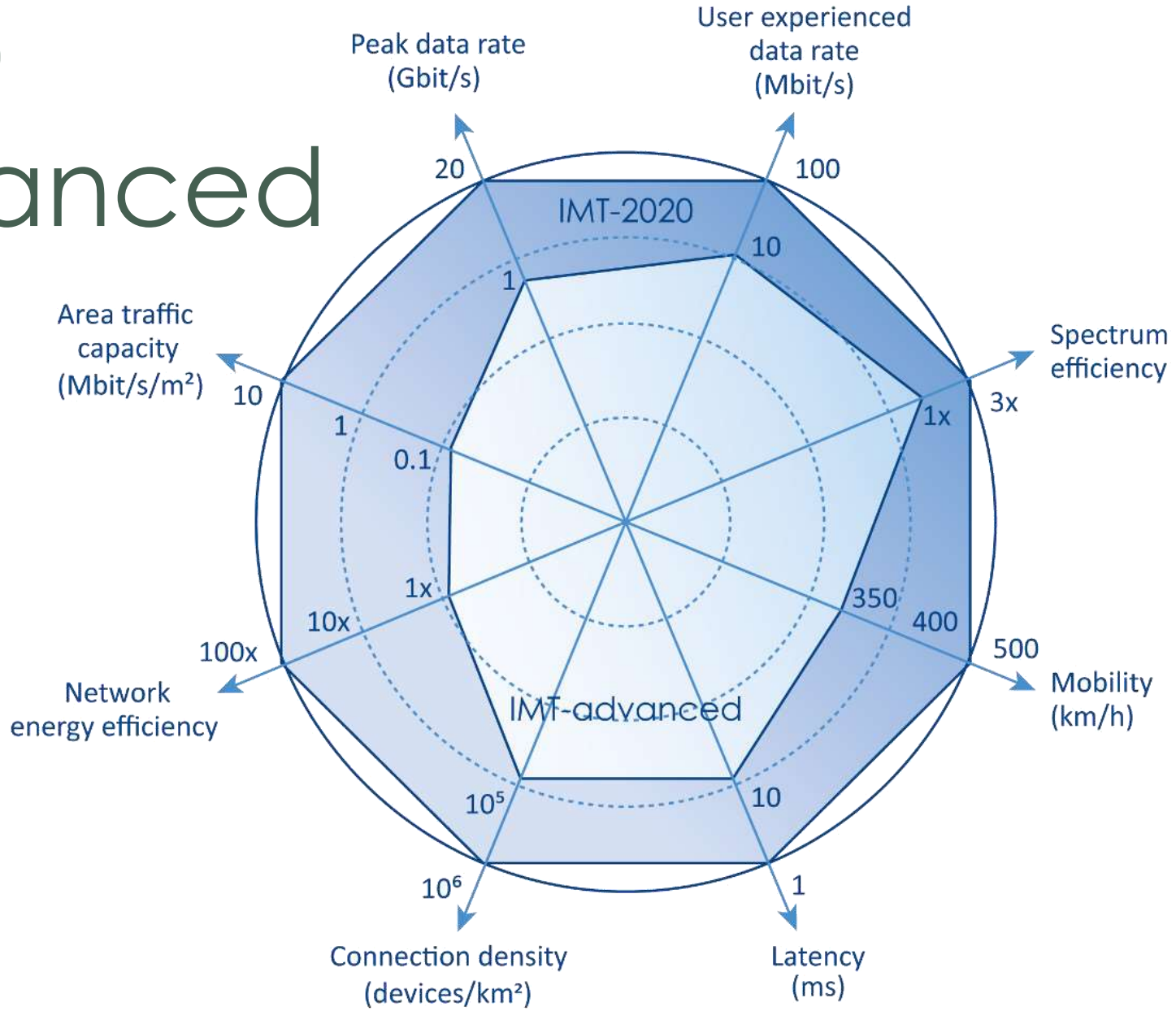
Any 5G device using unlicensed spectrum must:

- Comply with lower power emission requirements that limit signal propagation and in-band interference, constraining the coverage area
- Share spectrum with incumbent users, adding technical complexity to 5G terminals so that all devices can coexist
- Make use of Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC) techniques to facilitate coexistence, like Wi-Fi devices do today
- Likely adopt the LTE or 4G coexistence techniques, such as Listen Before Talk (LBT), to work side-by-side with Wi-Fi devices

5G současný stav

- Současný stav 5G – NonStandelone + 4G EPC core
- Standalone x nonstandalone
- 5G core x 4G EPC core
- 5G architektura
- Pásma 5 , 6 a 7 GHz
- Carrier agregation – dual conectivity

IMT-2020
IMT-advanced



Comparison 5G and 6G

KPIs	5G	6G
Peak data rate	20 Gbit/s	1 Tbit/s
User experienced data rate	100 Mbit/s	1 Gbit/s
Peak spectral efficiency	30 bit/s/Hz	60 bit/s/Hz
Experienced spectral efficiency	0,3 bit/s/Hz	3 bit/s/Hz
Maximum bandwidth	1 GHz	100 GHz
Area traffic capacity	10 Mbit/s/m^2	1 Gbit/s/m^2
Connection density	10^6 devices/km^2	10^7 devices/km^2
Energy efficiency	Not specified	1 Tbit/J
Latency	1 ms	100 µs
Reliability	10^{-5}	10^{-9}
Jitter	Not specified	1 µs
Mobility	500 km/h	1000 km/h

End

e-mail: michal.poupa@gmail.com
+420 603 404 371

Backup

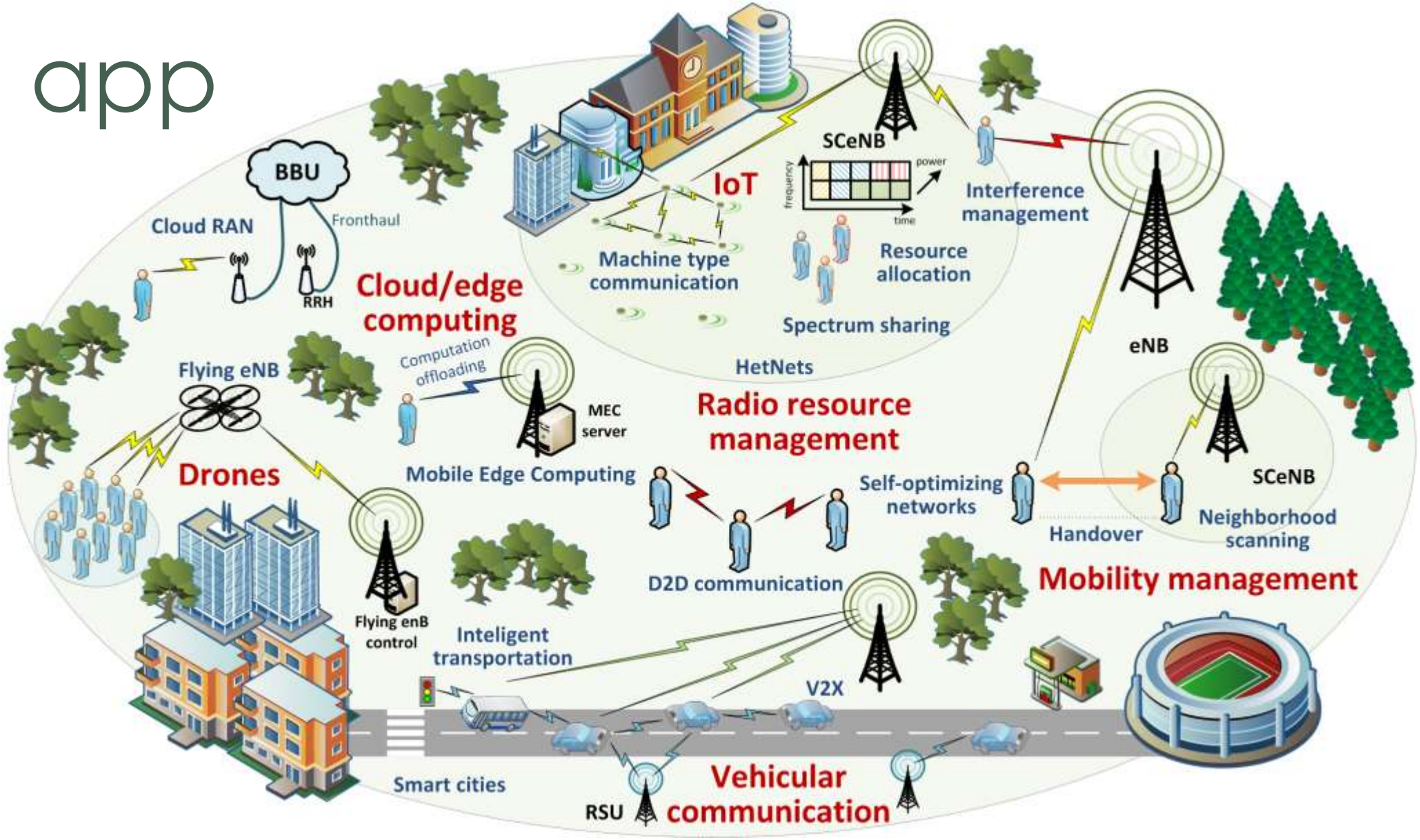
Wi-Fi 6 - IEEE 802.11ax

- 2,4 and 5 GHz bands
- Orthogonal frequency-division multiple access (OFDMA)
- Modulation 1024-QAM
- MIMO and MU-MIMO (8x8, 6x6, 3x3)
- WPA3 (Wi-Fi Protected Access v3)
- Wi-Fi 6E also support 6 GHz band

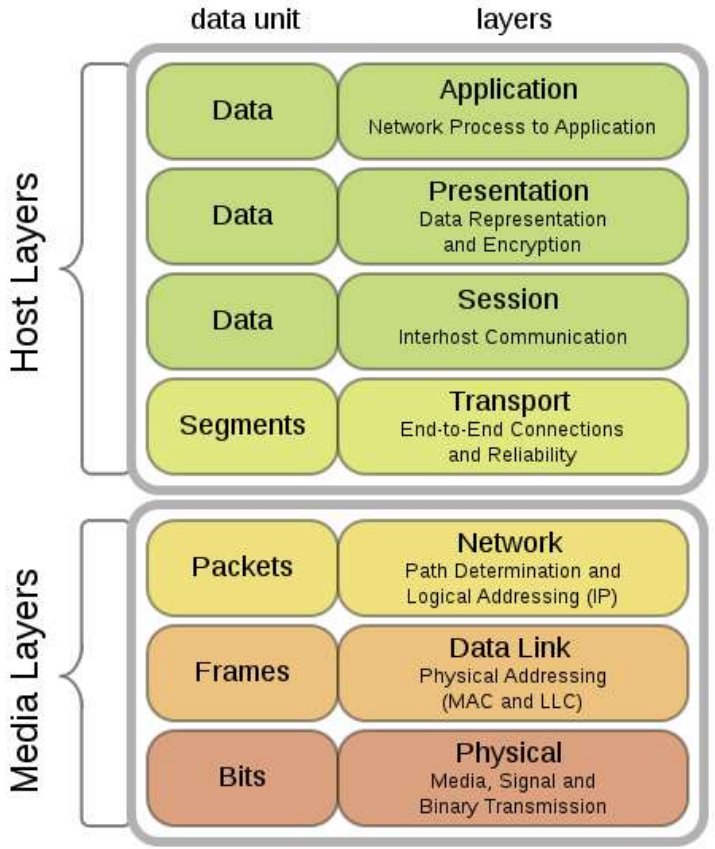
Porovnání Wi-Fi 6 x Wi-Fi

Standard	IEEE 802.11n	IEEE 802.11ac	IEEE 802.11ax
Frekvence [GHz]	2,4 + 5	5	2,4 + 5
Šířka kanálu [MHz]	40 MHz	20, 40, 80, 80+80, 160	20, 40, 80, 80+80, 160
Modulace	64 QAM	256 QAM	1024 QAM
Kódování	OFDM	OFDM	UL a DL OFDMA
Podpora MIMO	(3×3) DL MIMO	4×4 DL MIMO	8×8 DL+UL MIMO
Šířka sub-nosné [kHz]	312,5	312,5	78,125
Max. přenosová kapacita jednoho streamu	150 Mb/s (40 MHz, 1 SS)	433 Mb/s (80 MHz, 1 SS)	600,4 Mb/s (80 MHz, 1 SS)

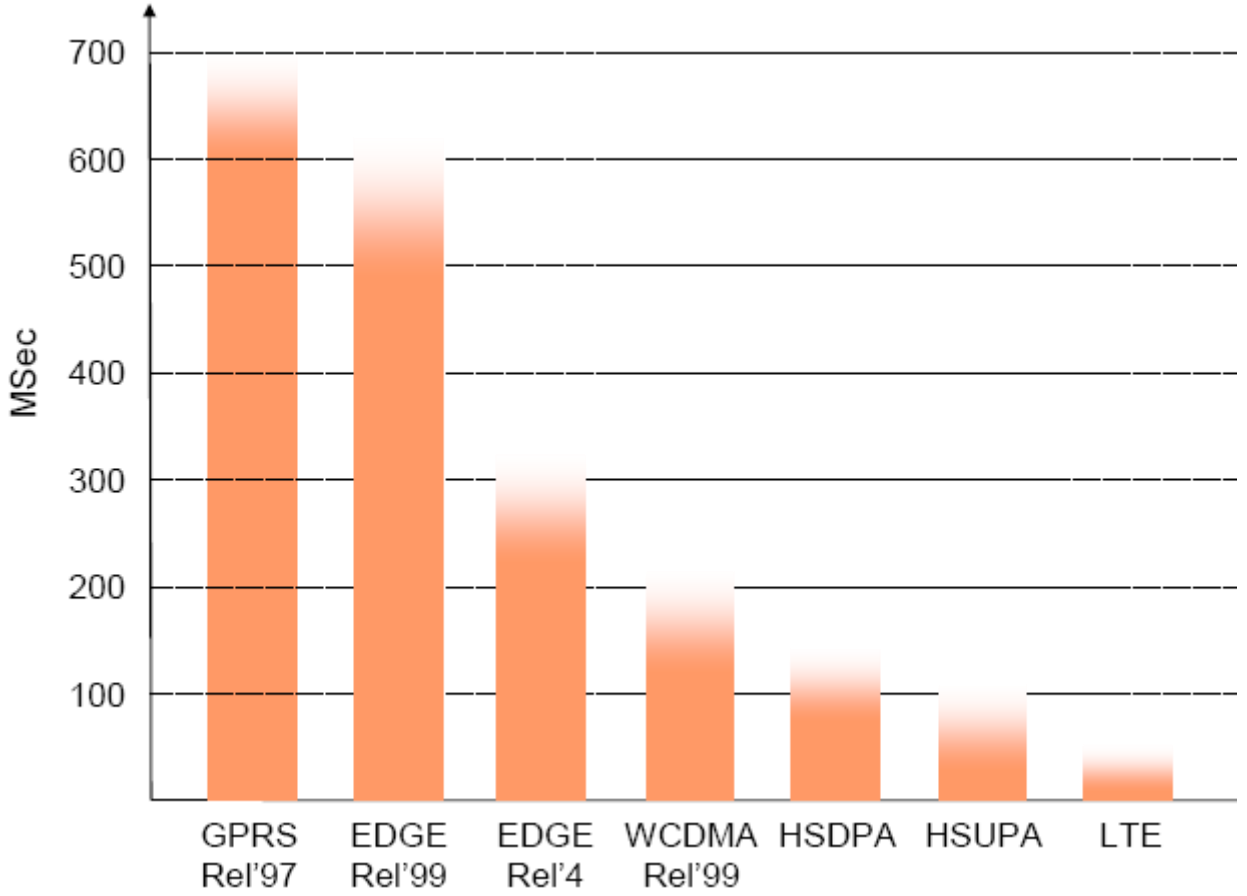
5G app


BBU
Cloud RAN
Fronthaul
RRH
Cloud/edge computing
Flying eNB
Computation offloading
MEC server
Mobile Edge Computing
Drones
Flying enB control
Inteligent transportation
Smart cities
RSU
Vehicular communication
V2X
D2D communication
IoT
Machine type communication
SCeNB
frequency
power
time
Interference management
Resource allocation
Spectrum sharing
HetNets
Radio resource management
eNB
SCeNB
Self-optimizing networks
Handover
Neighborhood scanning
Mobility management

ISO/OSI model



Latence



5G 1 ms

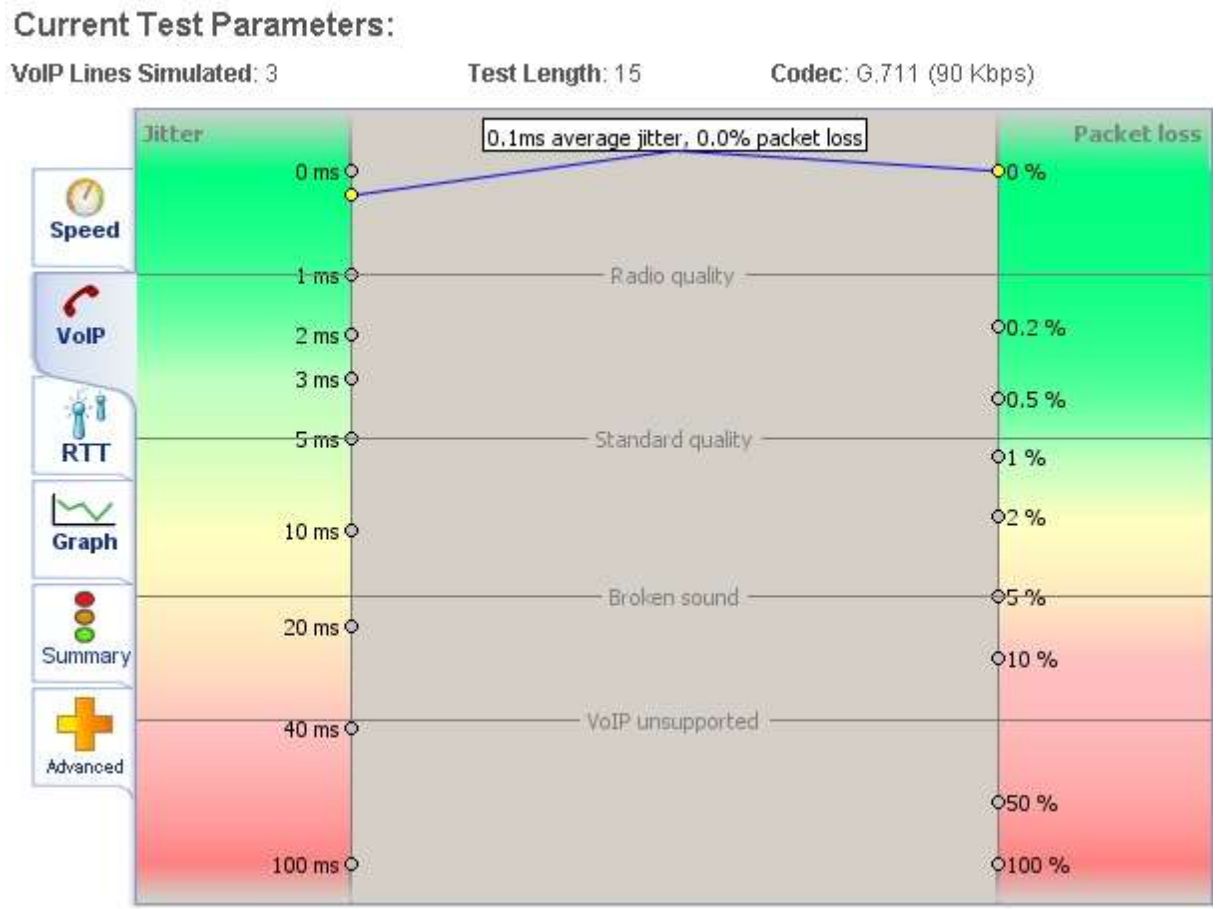
QoS Latence a Jitter

Latence:

- do 25 ms On-line hry
- do 250 ms, telefonie VoIP
- při latenci nad 500 ms se již obtížně komunikuje
- při 700 ms je už dialog prakticky nemožný

Jitter je kolísání velikosti zpoždění paketů při průchodu sítí (vzniká např. na směrovačích (routerech) jako důsledek změn routování, chování interních front routeru atd.) VoIP do ztrátovost paketů max. do 0,5 % cokoliv and je problém.

Jitter and Packet loss



Ping – Packet InterNet Gropr

Round Trip Time – RTT

Echo request and Replay

Používá - TCP/IP – protokol ICMP

Časy:

- 0 – 30 ms – výborný ping – hry … on line služby
- 30 – 150 ms OK pro VoIP
- 150 – 250 již problém s kvalitou VoIP
- Nad 250 ms nepoužitelné pro VoIP

Jitter

Jitter is technically the measure of the variability over time of the latency across a network:

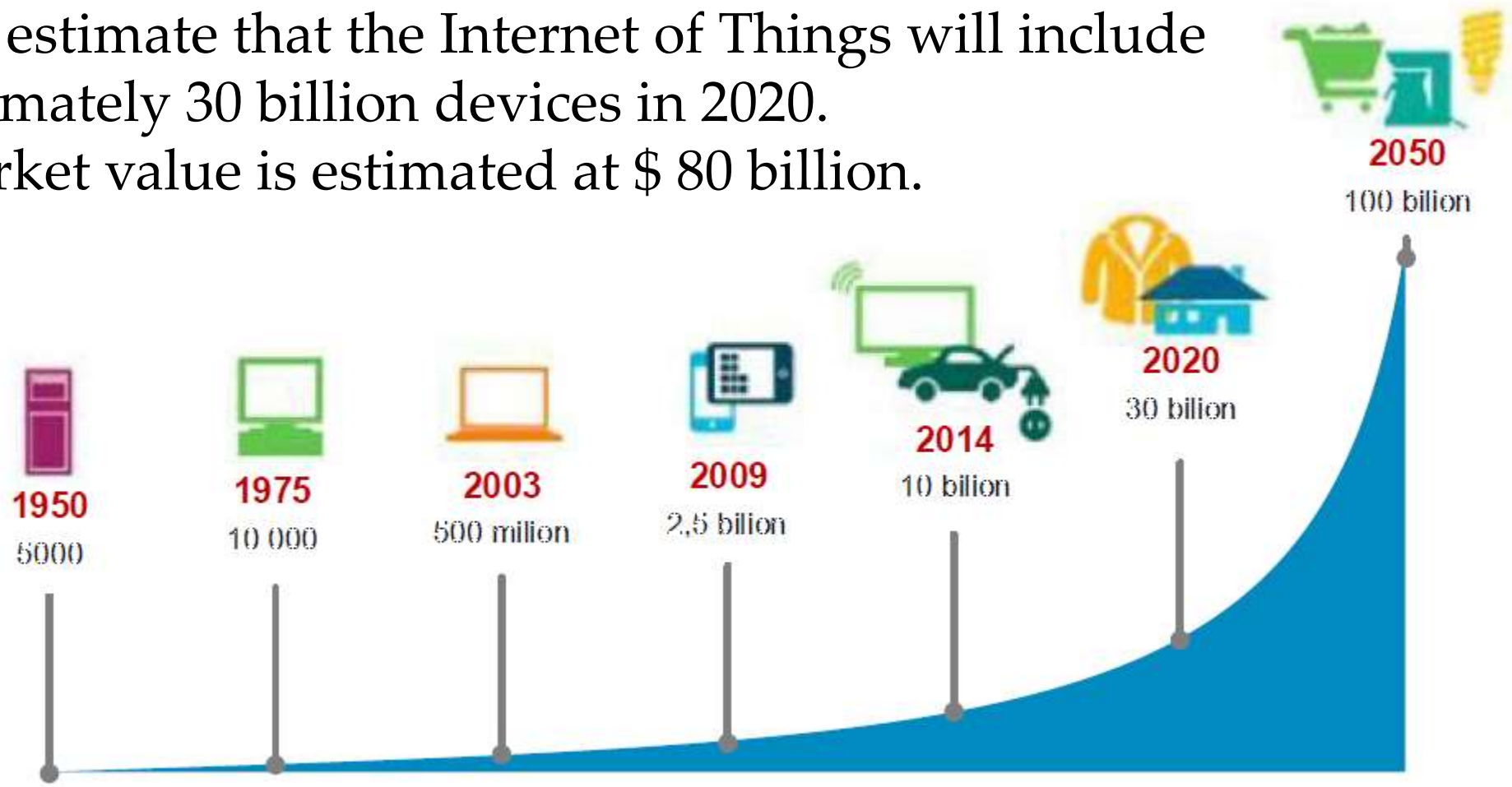
- 0 – 1 ms – radio quality
- 1 – 5 ms – standard telephone quality
- 5 – 15 ms – broken sound
- 15 ms and more – VoIP unsupported

Industry 4.0, Industrial robots, Co-Bots

- Industry 4.0
- IIoT – Industrial Internet of Things
- MQTT – Message Queuing Telemetry Transport
- Industrial Robots
- Co-Bots (Collaborative robots)

The Internet of Things IoT

Experts estimate that the Internet of Things will include approximately 30 billion devices in 2020.
The market value is estimated at $ 80 billion.



Smart Grid

Smart Chargers for EV

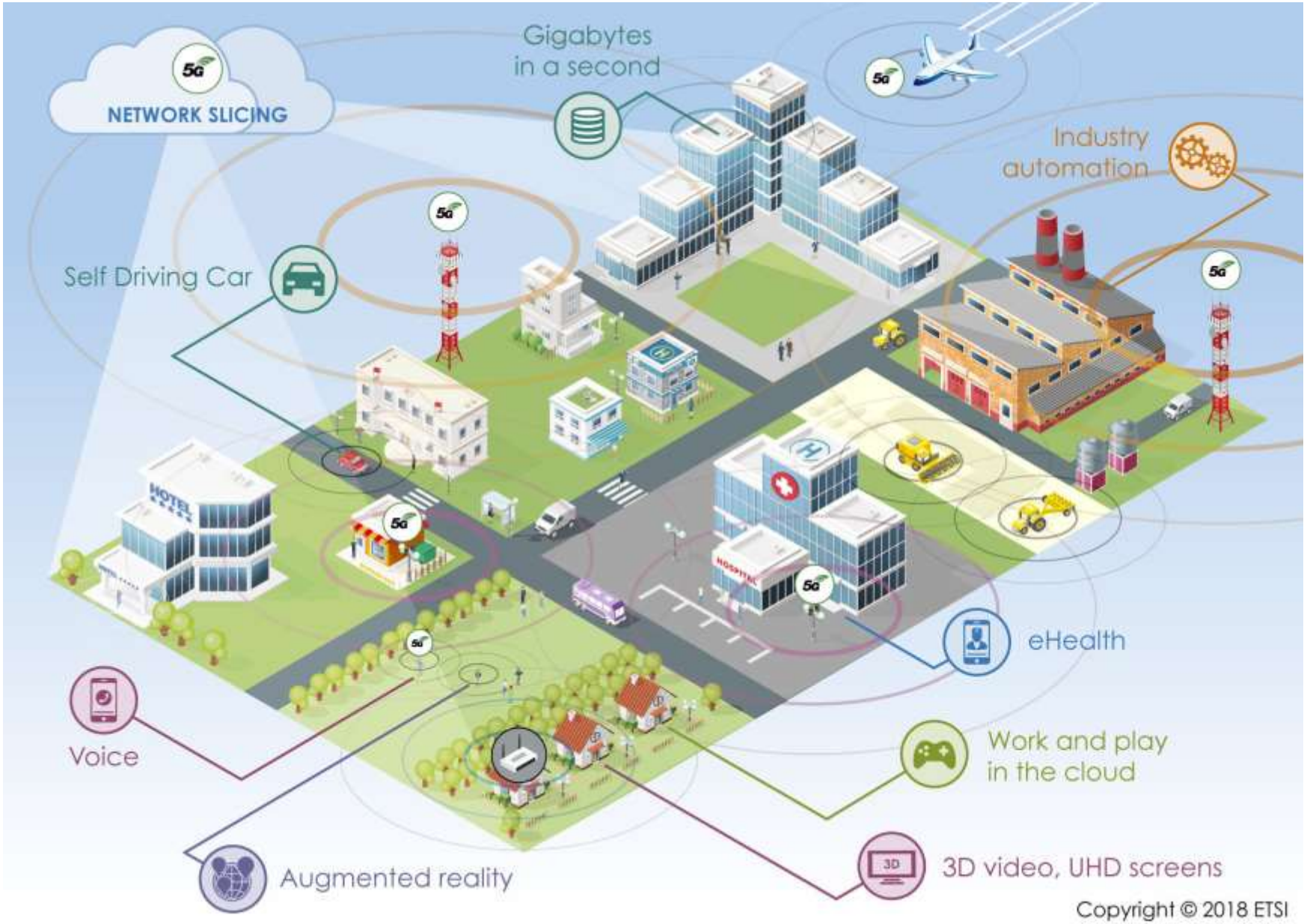
Open Charge Point Protocol (OCPP) - Application protocol for communication between EV (Electric vehicle) charging stations and a central management system

- Device Management
- Transaction handling
- Security
- Load balancing
- RFID
- Tariff & Costs

Smart City

Innovation economy	Urban infrastructure	Governance
Innovation in industries, clusters, districts of a city	Transport	Administration services to the citizen
Knowledge workforce: Education and employment	Energy / Utilities	Participatory and direct democracy
Creation of knowledge-intensive companies	Protection of the environment / Safety	Services to the citizen: Quality of life

5G


NETWORK SLICING
Gigabytes
in a second
Industry
automation
Self Driving Car
HOTEL
HOSPITAL
eHealth
Voice
Work and play
in the cloud
Augmented reality
3D video, UHD screens
Copyright © 2018 ETSI

IoT applications

Consumer applications:

- Smart Home
- Elder care

Commercial applications:

- Medical and healthcare
- Transportation
- V2X communications (Vehicle-to-everything)
- Building and home automation
- Industrial applications - IIoT - Industry 4.0 - fourth industrial revolution
- Agriculture

Smart Home – Home automation

Applications like:

- Lighting control system
- Heating (Thermostats), ventilation and air conditioning (HVAC)
- Home security, access systems and cameras
- Smart grid and a smart meter (energy, water, gas …)
- Pet and Baby Care
- Smart Kitchen and Connected Cooking
- Leak detection, smoke and CO detectors
- Home robots

Examples of use 5G 1/2

- High-definition and ultra-high-definition, such as 4K and 8K, and 3D video.
- Augmented and immersive virtual reality. Ultra-high-fidelity virtual reality can consume 50 times the bandwidth of a high-definition video stream.
- The tactile internet, bringing real-time, immediate sensing and control, enabling a vast array of new applications.
- Automotive functions, including autonomous vehicles, driver-assistance systems, vehicular internet, infotainment, inter-vehicle information exchange, and vehicle pre-crash sensing and mitigation.
- Monitoring of critical infrastructure, such as transmission lines, using long battery life and low-latency sensors.

Examples of use 5G 2/2

- Smart transportation using data from vehicles, road sensors, and cameras to optimize traffic flow.
- Mobile health and telemedicine systems that rely on ready availability of high-resolution and detailed medical records, imaging, and diagnostic video.
- Public safety, including broadband data and mission-critical voice.
- Sports and fitness enhancement through biometric sensing, real-time monitoring, and data analysis.
- Fixed broadband replacement.

5G NR-U (New Radio Unlicensed)

Band	Freq Range	Max Power
U-NII Low / U-NII-1 / U-NII Indoor	5.150–5.250	50 mW
U-NII Mid / U-NII-2A	5.250–5.350	250 mW
U-NII-2B	5.350–5.470	—
U-NII Worldwide / U-NII-2C / U-NII-2-Extended / U-NII-2e	5.470–5.725	250 mW
U-NII Upper / U-NII-3	5.725-5.850	1 W
DSRC/ITS / U-NII-4	5.850–5.925	—
U-NII-5	5.925 – 6.425	1 W
U-NII-6	6.425 – 6.525	250 mW
U-NII-7	6.525 – 6.875	1 W
U-NII-8	6.875 – 7.125	250 mW

5G Cell types, users, coverage

Cell types		Deployment environment	Max. number of users	Output power (mW)	Max. distance from base station
5G NR FR2 > 24 GHz	Femtocell	Homes, businesses	Home: 4–8	indoors: 10–100	10s of meters
			Businesses: 16–32	outdoors: 200–1000	
	Pico cell	Public areas like shopping malls,	64 to 128	indoors: 100–250	10s of meters
		airports, train stations, skyscrapers		outdoors: 1000–5000	
	Micro cell	Urban areas to fill coverage gaps	128 to 256	outdoors: 5000–10000	few hundreds of meters
	Metro cell	Urban areas to provide additional capacity	more than 250	outdoors: 10000–20000	hundreds of meters