5G Fundamental

A Timeline The Evolution of Mobile Communication

Who decides about vision and requirements of upcoming mobile technology !

International Telecommunication Union

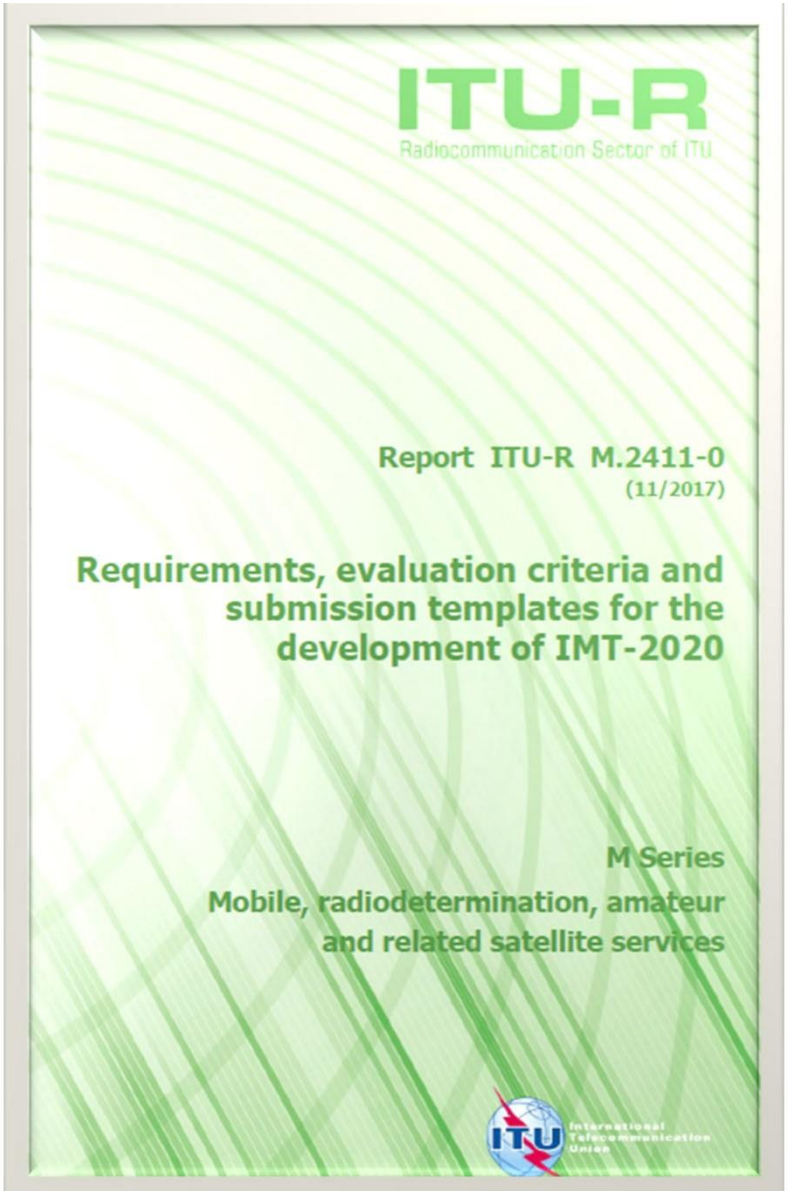

ITU-R
Radiocommunication Sector of ITU
Recommendation ITU-R M.2083-0
(09/2015)
IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond
M Series
Mobile, radiodetermination, amateur and related satellite services


ITU-R
Radiocommunication Sector of ITU
Report ITU-R M.2410-0
(11/2017)
Minimum requirements related to technical performance for IMT-2020 radio interface(s)
M Series
Mobile, radiodetermination, amateur and related satellite services

Who can develop a candidate technology !

ARIB atis CCSA ETSI tsdsi TTA TTC

3GPP A GLOBAL INITIATIVE



What is IMT !

IMT – International Mobile Telecommunications

IMT-2000 technologies (Marketed as 3G):

- 3GPP Family: UMTS – WCDMA (GSM Evolution)
- 3GPP2 Family: CDMA2000 (1xEV-DO Rev A, EV-DO Rev B)

IMT-Advanced technologies (Marketed as 4G):

- 3GPP Family: LTE Advanced (E-UTRA)
- IEEE Family: WiMAX (802.16m)

IMT 2020 (5G)

- 3GPP NR

1G

1980s

Analog Voice

Human-to-human
Early Mobile Phones

2G

1990s

Digital Voice

Low-Speed Data
Voice and Some Text

3G

2000s

Mobile Broadband

High-Speed Data
Internet Access

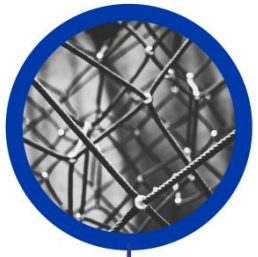
4G

2010s

Faster/Better 3G

IP-Based Network
High-Speed Internet,
Streaming, Apps

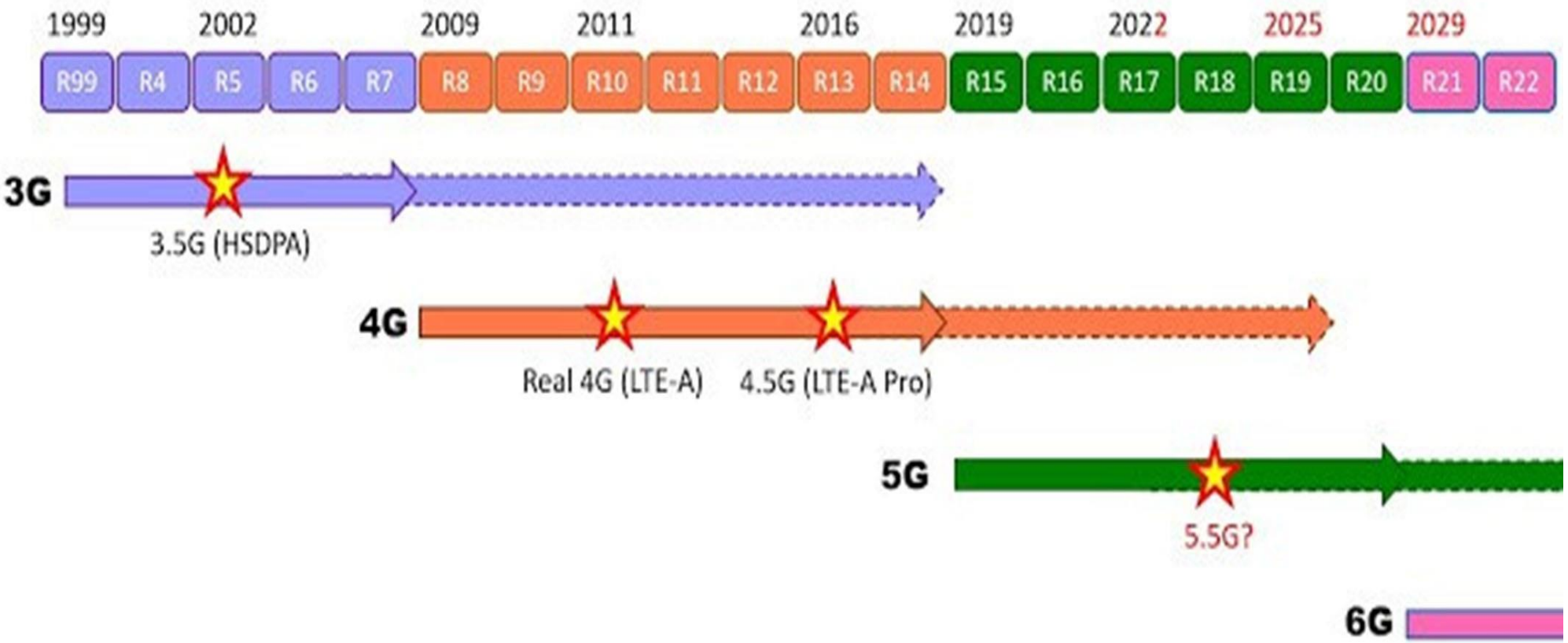
5G



2020s

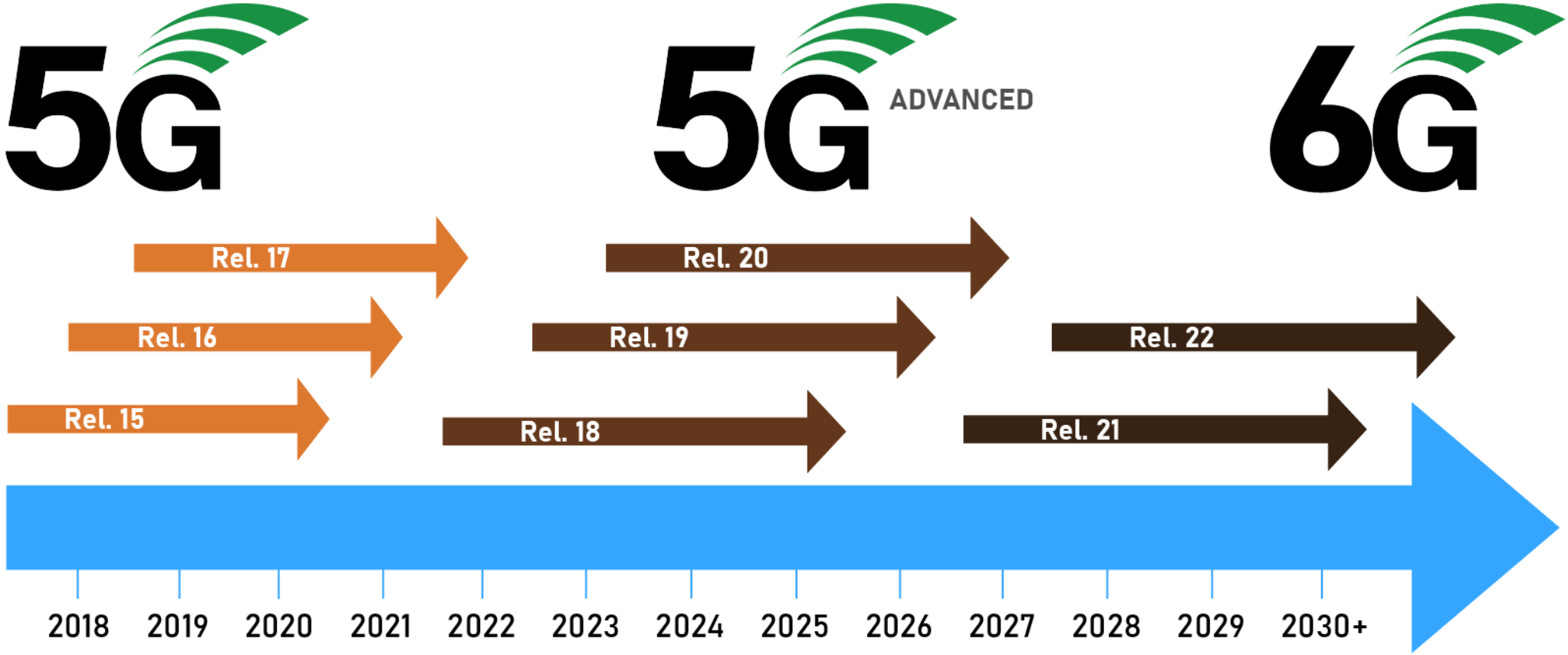
Interconnected Devices, Sensors, and Systems

For Consumers, Governments, and Businesses


1999
2002
2009
2011
2016
2019
2022
2025
2029
R99
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
R21
R22
3G
3.5G (HSDPA)
4G
Real 4G (LTE-A)
4.5G (LTE-A Pro)
5G
5.5G?
6G

Cellular network evolution by generation

	INTRODUCTION YEAR	TOP DOWNLOAD SPEED	TIME TO DOWNLOAD A 3GB MOVIE
1G	1979	2 Kbps	6 days
2G	1991	100 Kbps	2.5 hours
3G	1998	8 Mbps	2 minutes
4G	2008	150 Mbps	20 seconds
5G	2018	10 Gbps	300 milliseconds
6G	2030	1 Tbps	3 milliseconds



Release 15
Extreme Mobile Broadband

Release 16
URLLC

Release 17
Wider Ecosystem Expansion

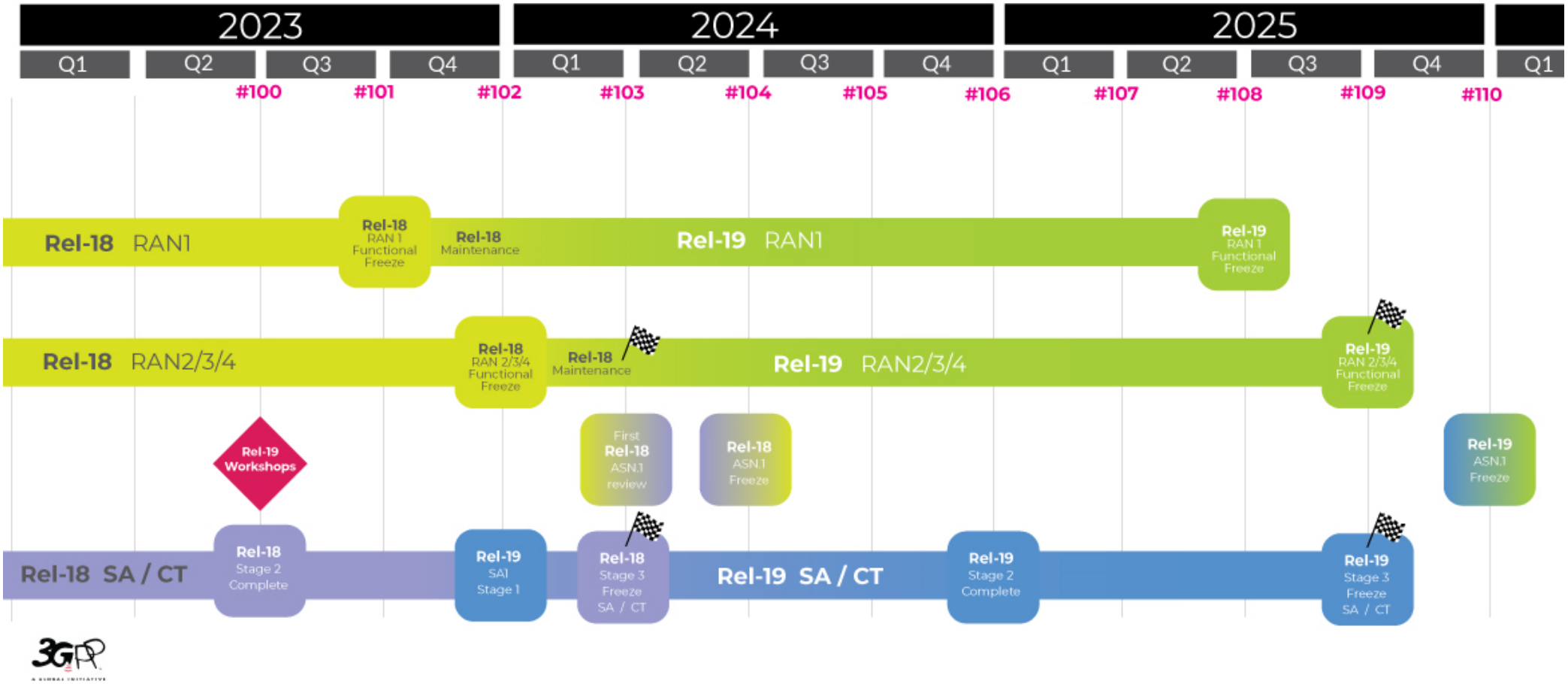
Release 18
5G Advanced

Release 19
5G Advanced

Release 20
5G Advanced
6G Studies

Release 21
6G Standarization

Release 22
6G Enhancements


2023
2024
2025
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
#100
#101
#102
#103
#104
#105
#106
#107
#108
#109
#110
Rel-18 RAN1
Rel-18 RAN 1 Functional Freeze
Rel-18 Maintenance
Rel-19 RAN1
Rel-19 RAN 1 Functional Freeze
Rel-18 RAN2/3/4
Rel-18 RAN 2/3/4 Functional Freeze
Rel-18 Maintenance
Rel-19 RAN2/3/4
Rel-19 RAN 2/3/4 Functional Freeze
Rel-19 Workshops
First Rel-18 ASN.1 review
Rel-18 ASN.1 Freeze
Rel-19 ASN.1 Freeze
Rel-18 SA / CT
Rel-18 Stage 2 Complete
Rel-19 SA1 Stage 1
Rel-18 Stage 3 Freeze SA / CT
Rel-19 SA / CT
Rel-19 Stage 2 Complete
Rel-19 Stage 3 Freeze SA / CT

Rel 15 : eMBB Focus

- **Released in June 2019**
- NR foundation
- SBA
- NSA and SA Mode
- Slicing
- Massive IoT
- uRLLC
- API Exposure
- V2X

Rel 16: Industry Focus

- **Released July 3, 2020**
- E uRLLC
- IIoT (Industrial IOT)
- NB IoT
- UL Spectrum
- Side Link
- IAB (Integrated Access and Backhaul)
- Positioning
- Enhancements

Rel 17: NTN

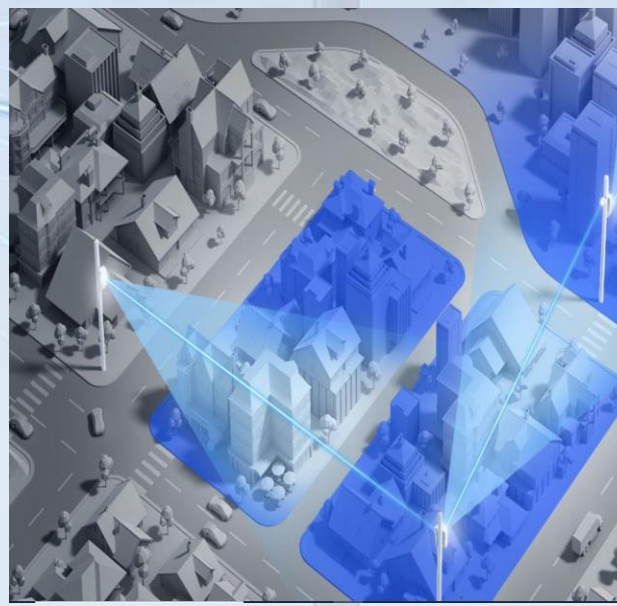
- **Released in June 2022**
- NR upto 71 GHz
- NTN
- Mobile IAB
- NR Light / Red Cap
- Multicast /Broadcast
- RAN Slicing
- Enhancements
- ATSSS

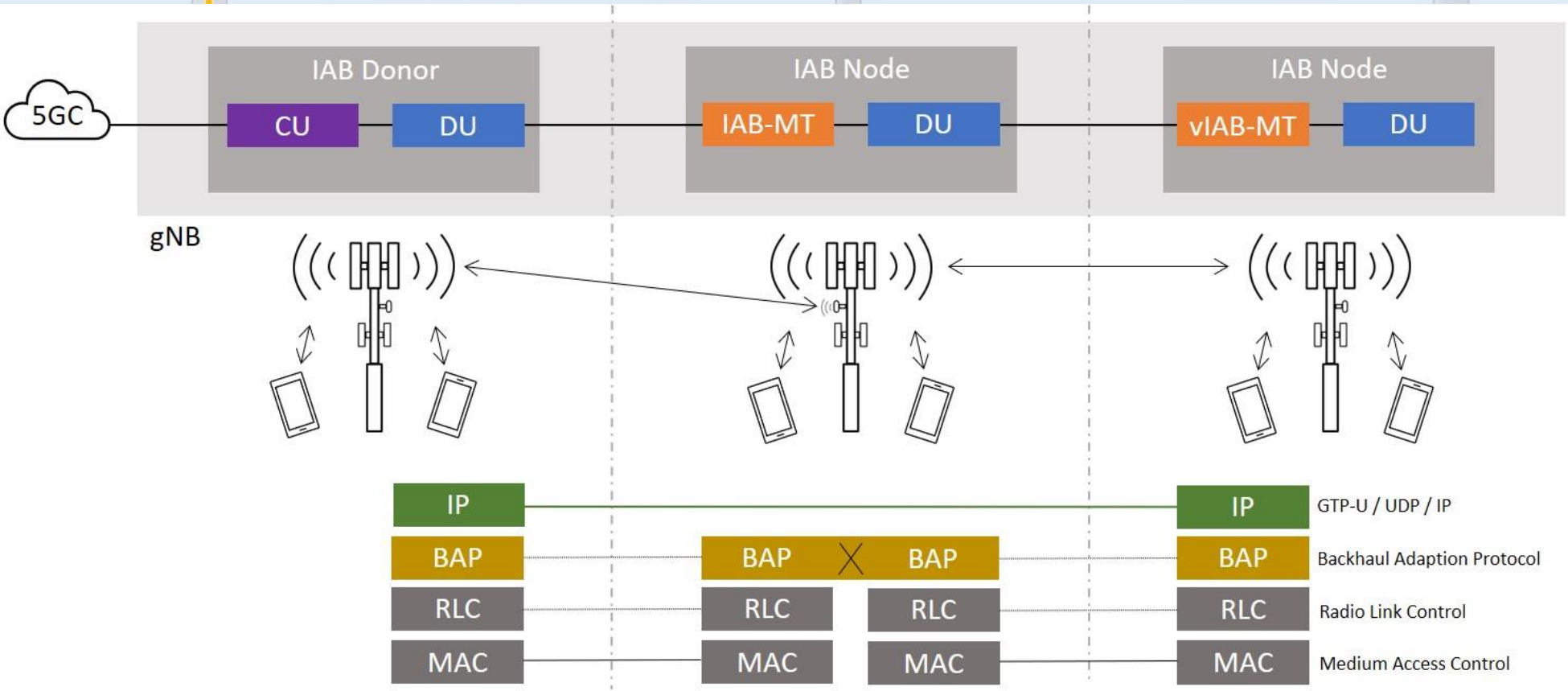
Rel 18: 5G Advanced

- **Work in Progress**
- AI/ML based Radio
- Drone /Satellite
- Positioning
- Green Network
- Smart Repeater
- Full Duplex in TDD
- Many more

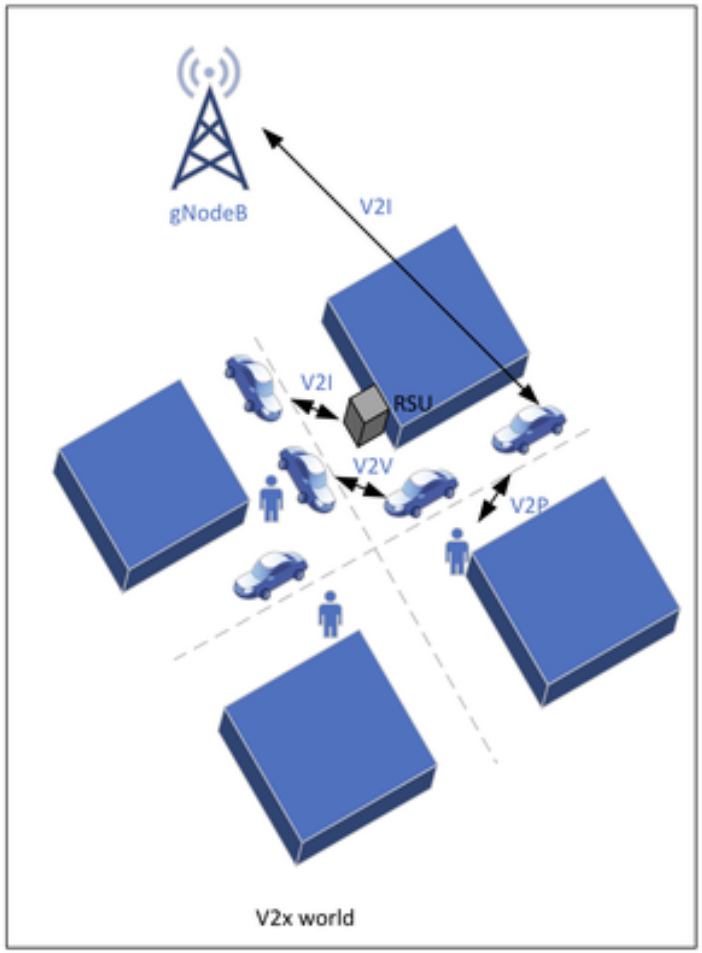
5G Key Technologies and Features

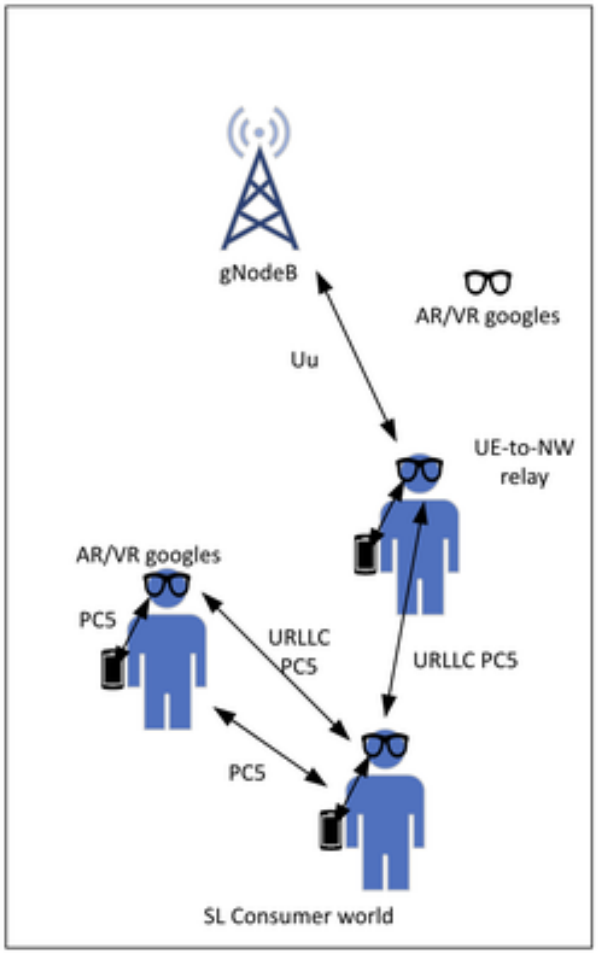
Integrated Access and Backhaul (IAB)

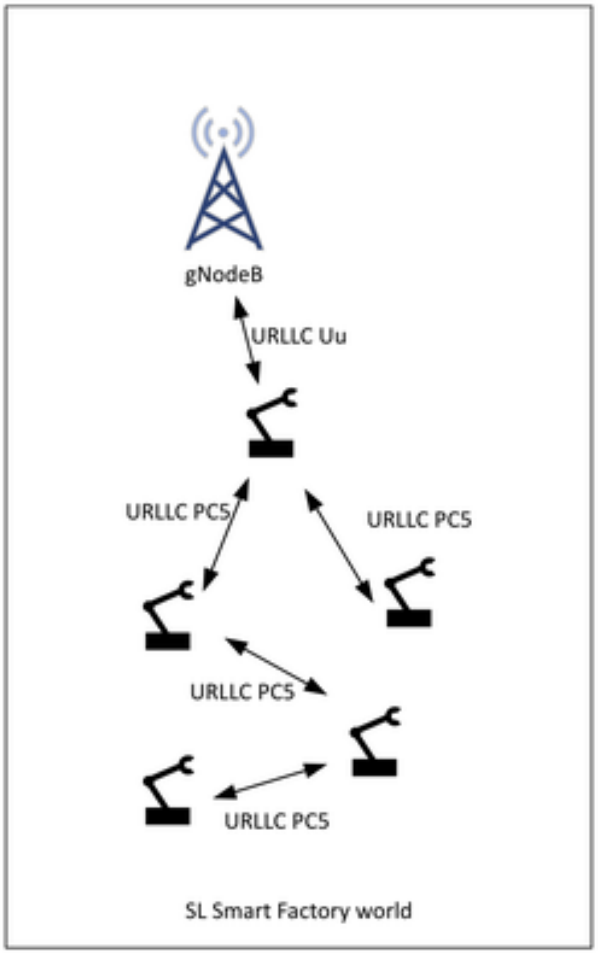




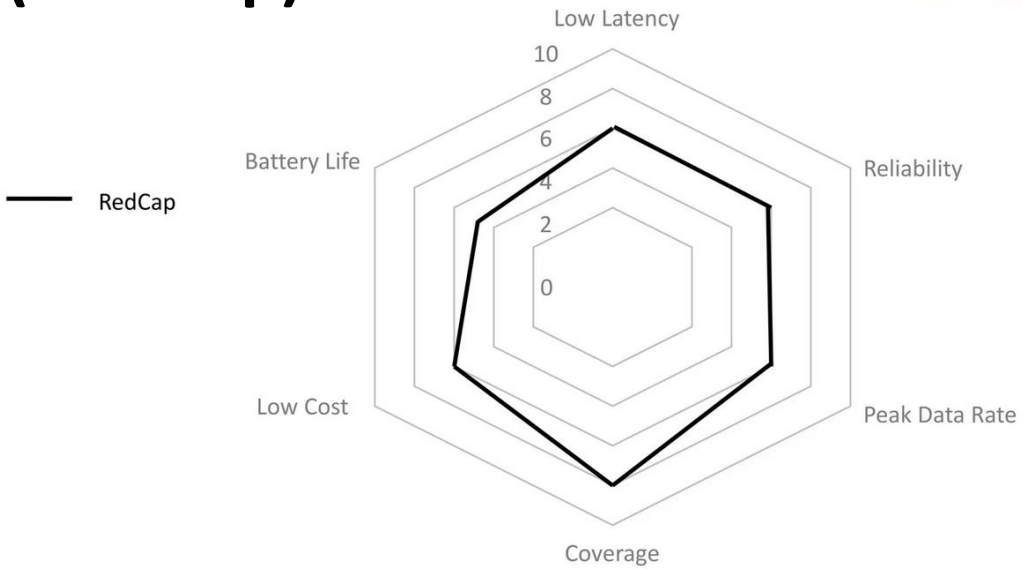
Side Link

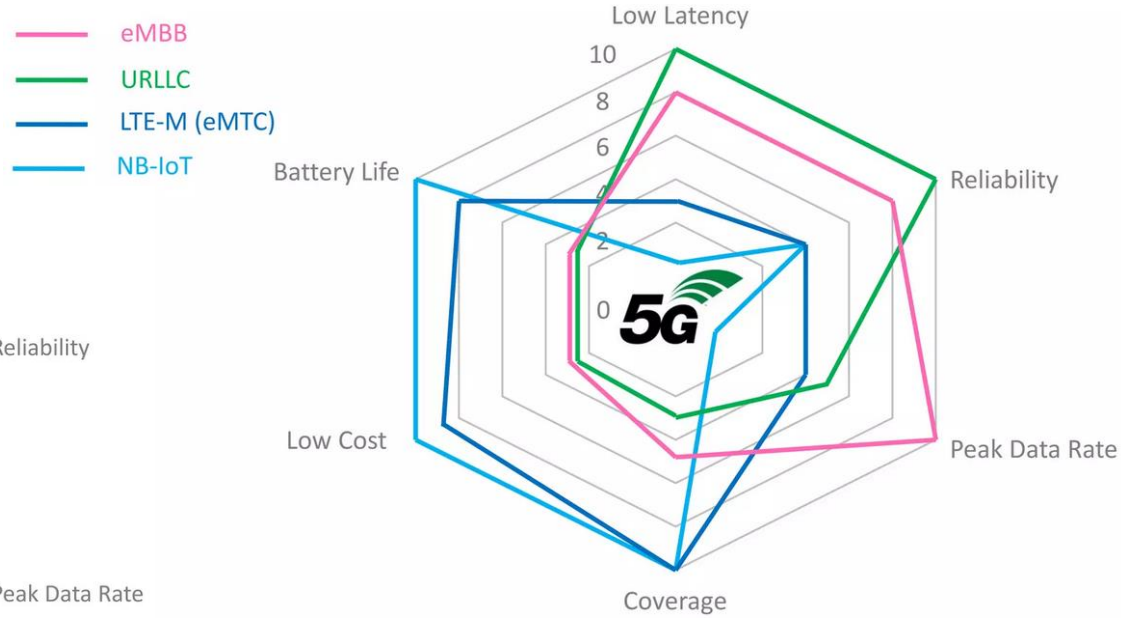

gNodeB
V2I
V2I
RSU
V2V
V2P
V2x world


gNodeB
AR/VR googles
Uu
UE-to-NW relay
AR/VR googles
PC5
URLLC PC5
URLLC PC5
PC5
SL Consumer world


gNodeB
URLLC Uu
URLLC PC5
URLLC PC5
URLLC PC5
URLLC PC5
SL Smart Factory world

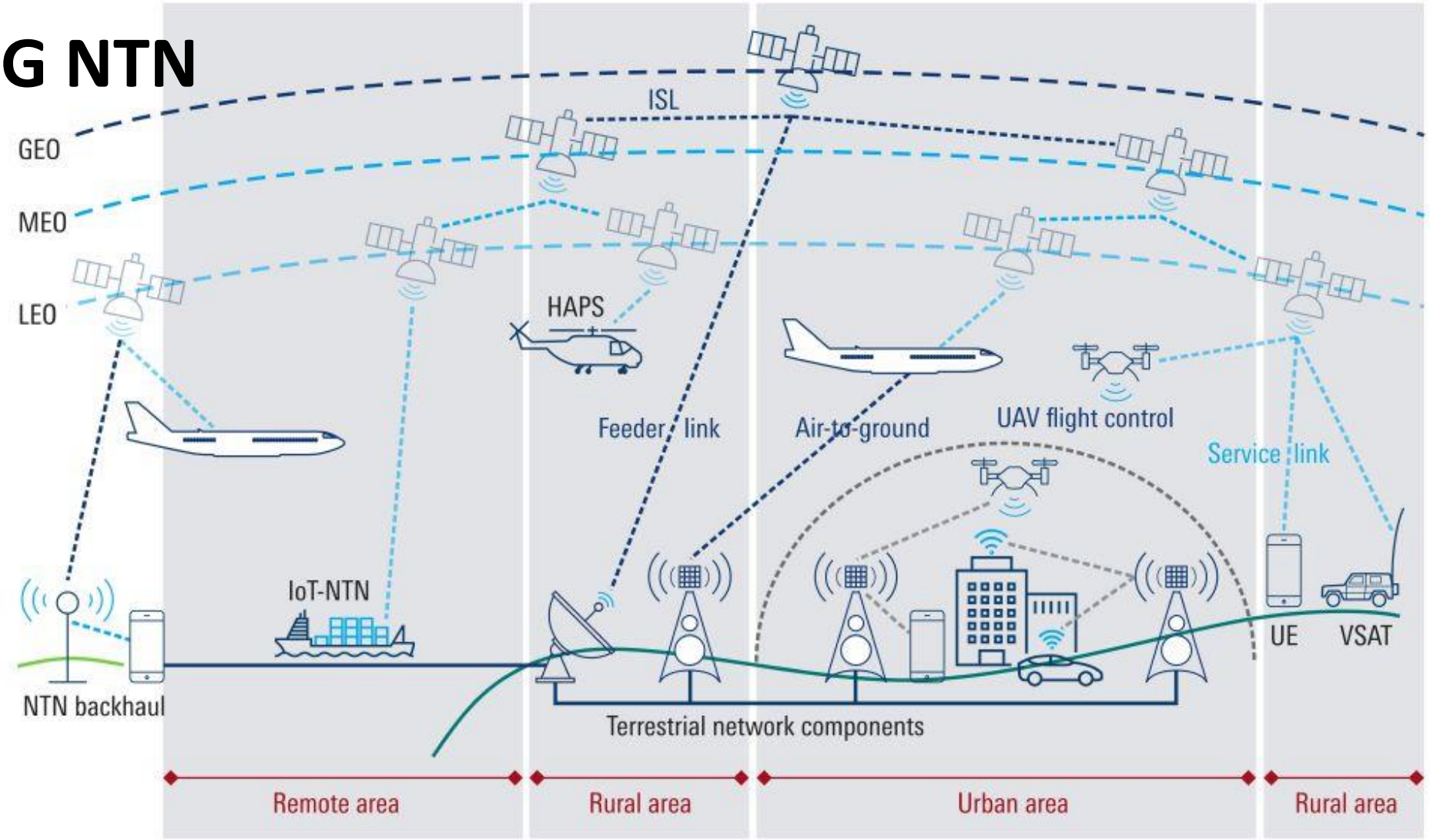
5G Reduced Capability (Red Cap)

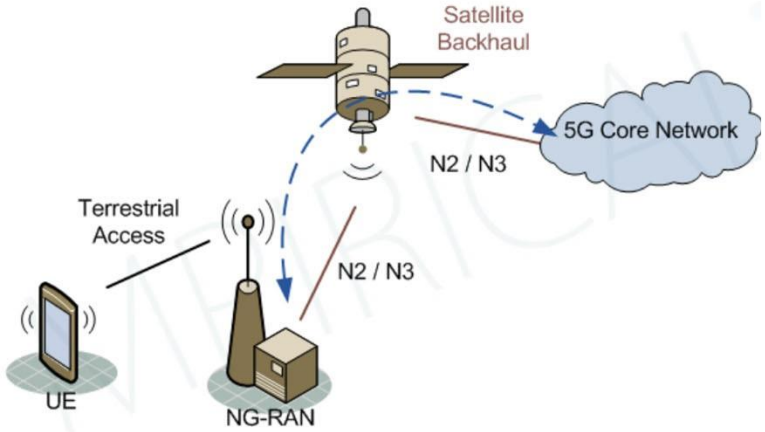


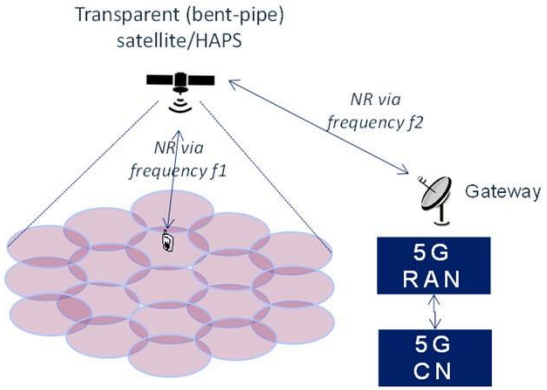


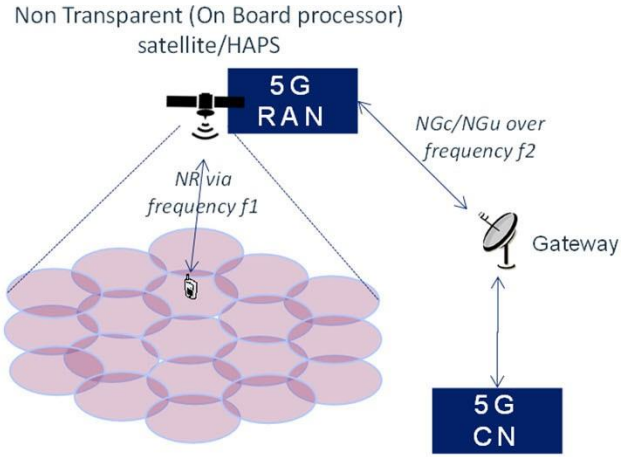
Requirements & Characteristics	Premium 5G UEs		Low tier 5G UEs			Very low end
	eMBB	URLLC	Industrial sensors / video monitoring	Low end wearables	Relaxed IoT	LPWA mMTC
Latency	Low	Ultra Low	Medium	Medium	Low/medium	High
Reliability	High	Ultra high	Medium	Medium/High	High /ultra high	Low
Data rate	High	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

5G NTN

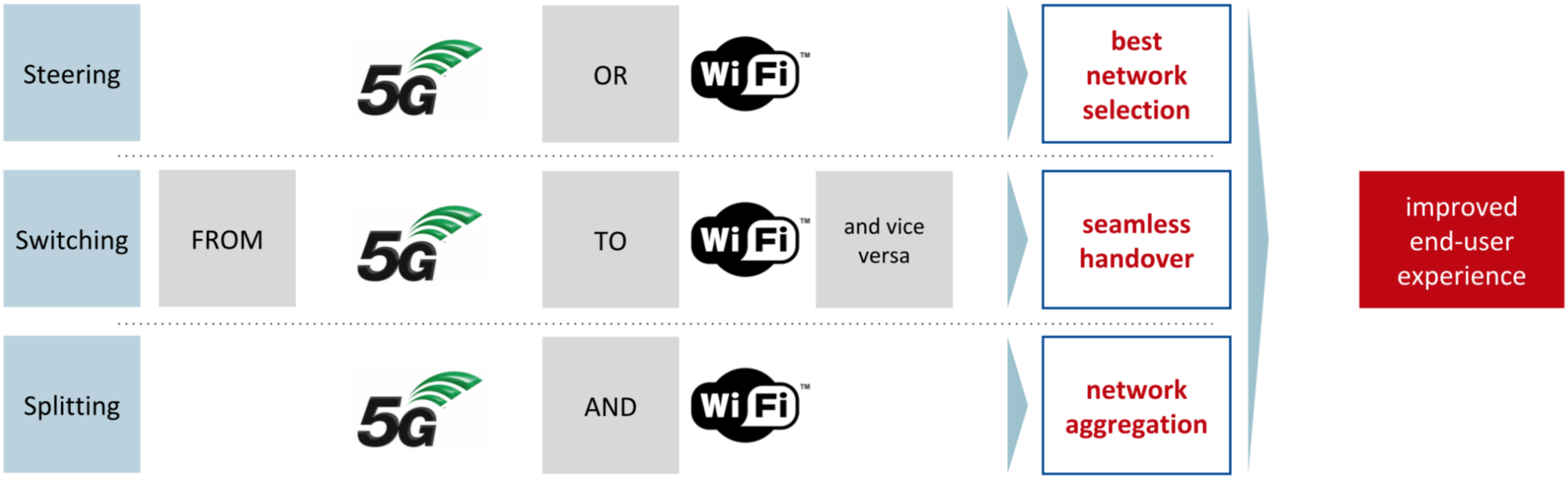

GEO
MEO
LEO
ISL
HAPS
Feeder link
Air-to-ground
UAV flight control
Service link
IoT-NTN
NTN backhaul
UE
VSAT
Terrestrial network components
Remote area
Rural area
Urban area
Rural area


Satellite Backhaul
5G Core Network
N2 / N3
Terrestrial Access
N2 / N3
UE
NG-RAN

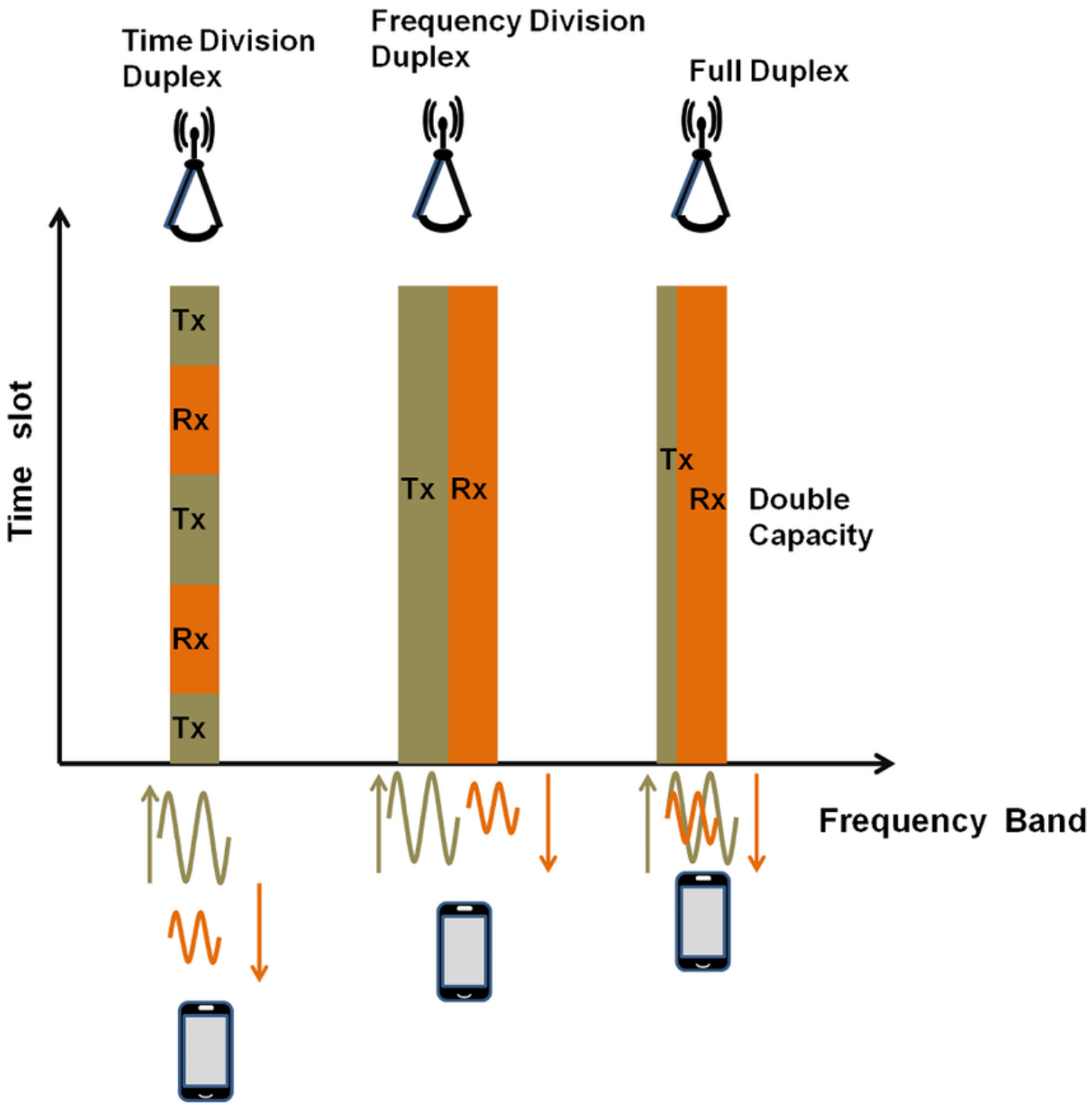

Transparent (bent-pipe) satellite/HAPS
NR via frequency f2
NR via frequency f1
Gateway
5G RAN
5G CN


Non Transparent (On Board processor) satellite/HAPS
5G RAN
NGc/NGu over frequency f2
NR via frequency f1
Gateway
5G CN

Access Traffic Steering-Switching-Splitting (ATSSS)

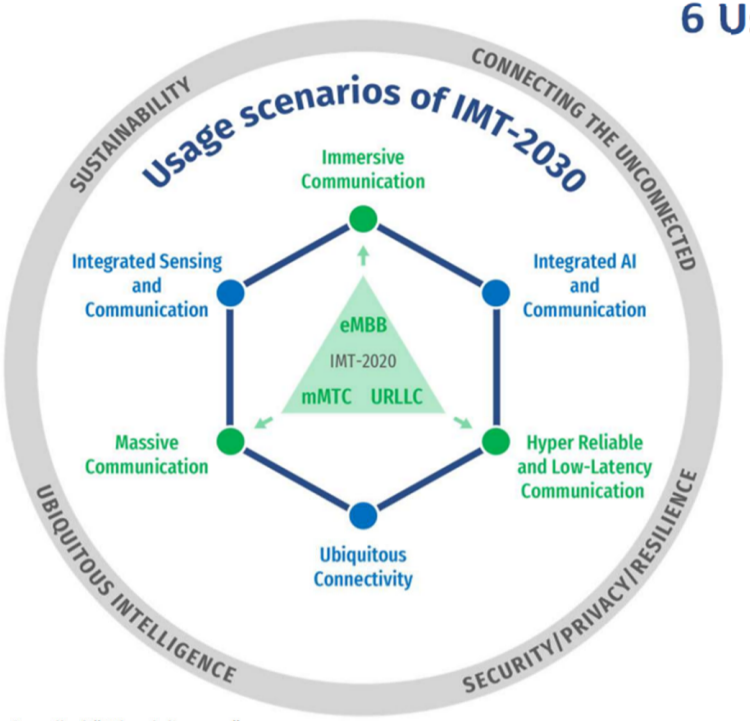


Full Duplex in TDD




6G

6 Usage scenarios



So called "Wheel diagram"

Extension from IMT-2020 (5G)

- eMBB → Immersive Communication
- mMTC → Massive Communication
- URLLC → HRLLC (Hyper Reliable & Low-Latency Communication)

New

- Ubiquitous Connectivity
- Integrated AI and Communication
- Integrated Sensing and Communication

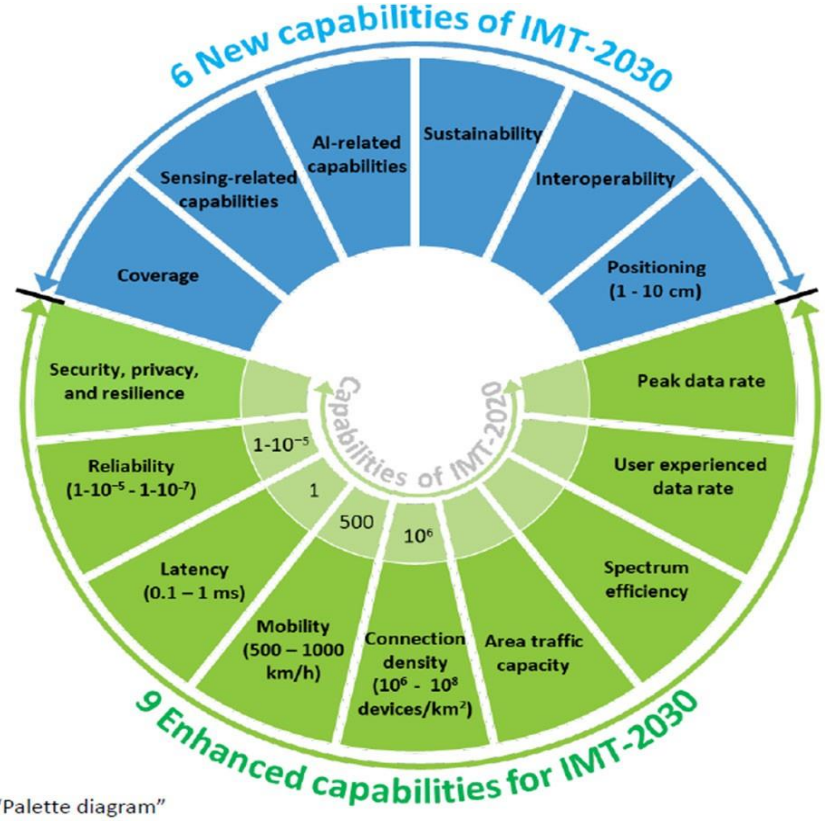
4 Overarching aspects:

act as design principles commonly applicable to all usage scenarios

Sustainability, Connecting the unconnected,
Ubiquitous intelligence, Security/privacy/resilience

9 Enhanced capabilities

6 New Capabilities

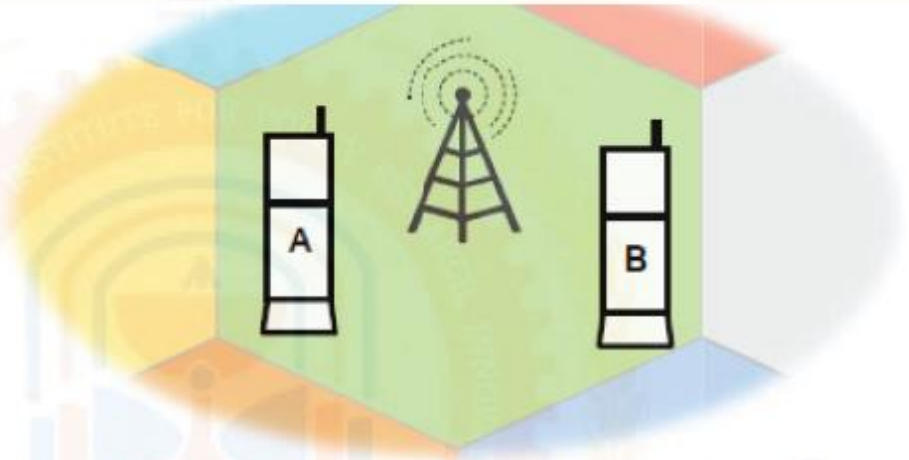


So called "Palette diagram"
Source: Document 5/131

Ashok Kumar Director General, Department of Telecom, ITU T

1G Radio Characteristics

Frequency	• 800 MHz and 900 MHz
Access technique	• FDMA
Channels Bandwidth	• 30 KHz
Modulation	• Frequency Modulation (FM)
Service	• Analog voice



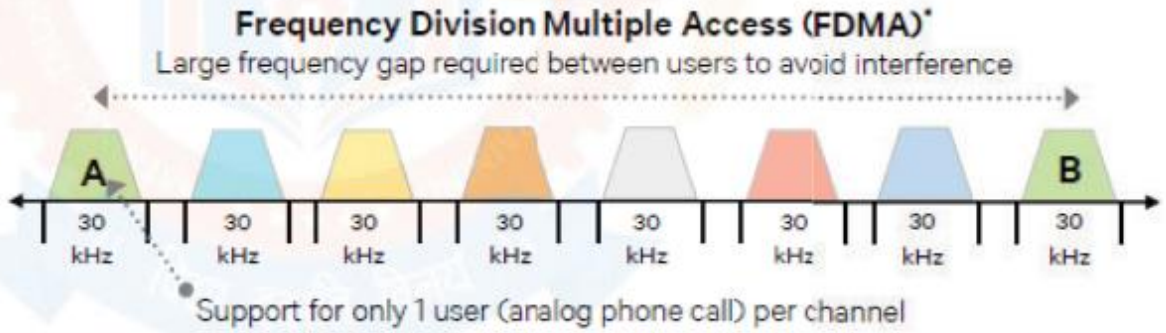


Image Source : Qualcomm

1G Network

Licensed Spectrum

Cleared spectrum for exclusive use by mobile technologies

RX 824-849 MHz TX 869-894 MHz

Operator-deployed **base stations** provide access for subscribers

Frequency Reuse

Reusing frequencies without interference through geographical separation

Neighboring **cells** operate on different frequencies to avoid interference

Mobile Network

Coordinated network for seamless access and seamless mobility

Integrated, transparent **backhaul network** provides seamless access

https://youtu.be/d6X_1PcR_gs

Image Credit : Qualcomm

1G Network and features

Mobile Network

Coordinated network for seamless access and seamless mobility

Integrated, transparent **backhaul network** provides seamless access

- Foundation of Mobile
- Analog Voice
- Poor voice quality
- Large phone size
- Poor battery life
- Limited capacity
- Poor reliability

Image Credit : Qualcomm

Evolution to 2G

Mobile 1G (Analog)
AMPS, NMT, TACS

Mobile 2G (Digital)
D-AMPS

Standardized as IS-54 by TIA in 1992
Mainly in North America
No longer utilized

Mobile 2G (Digital)
GSM

Standardized by ETSI in 1990 (phase 1)
Initiated in Europe

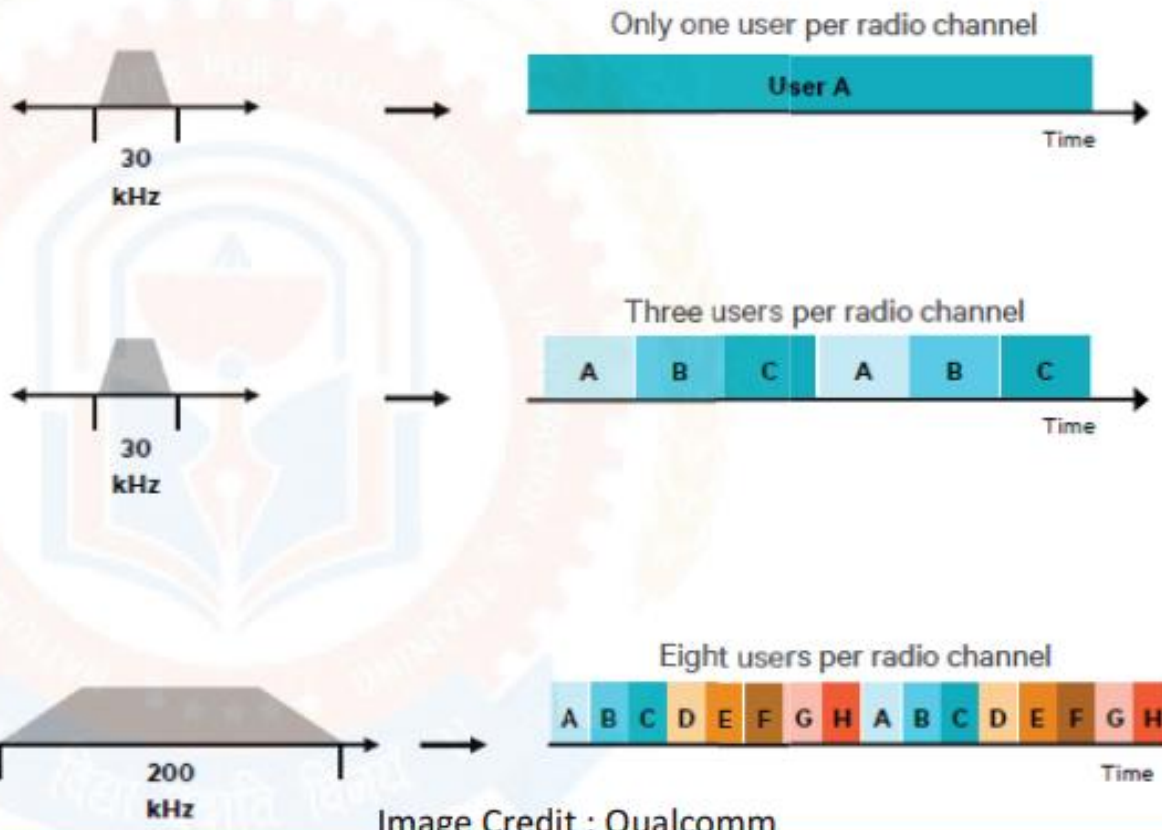
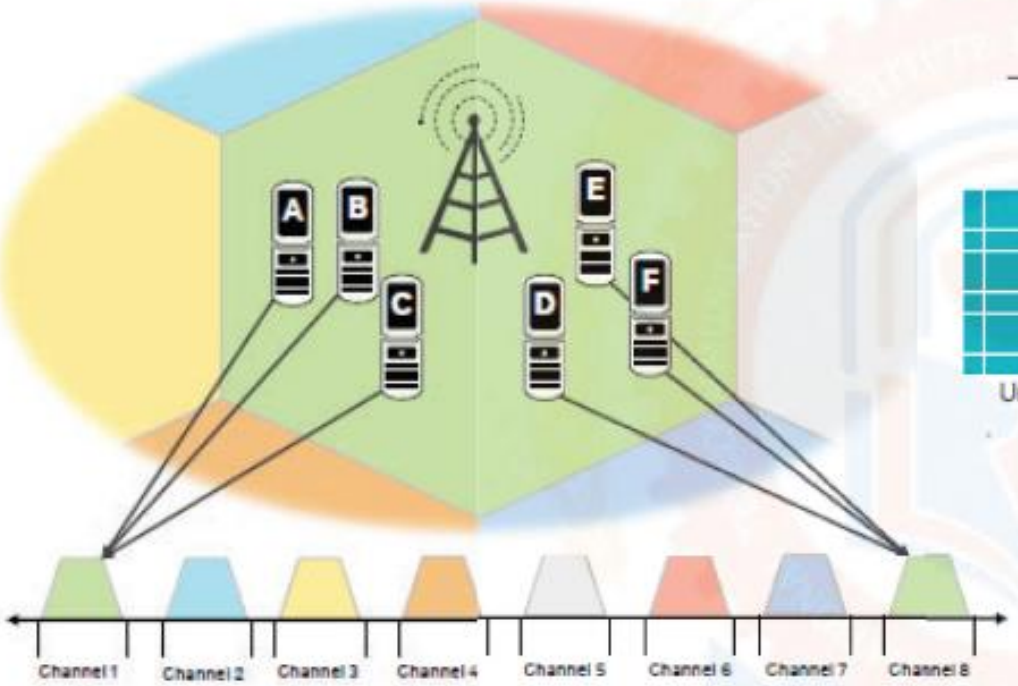


Image Credit : Qualcomm

Evolution to 2G



Frequency re-use in 2G

More Voice Capacity

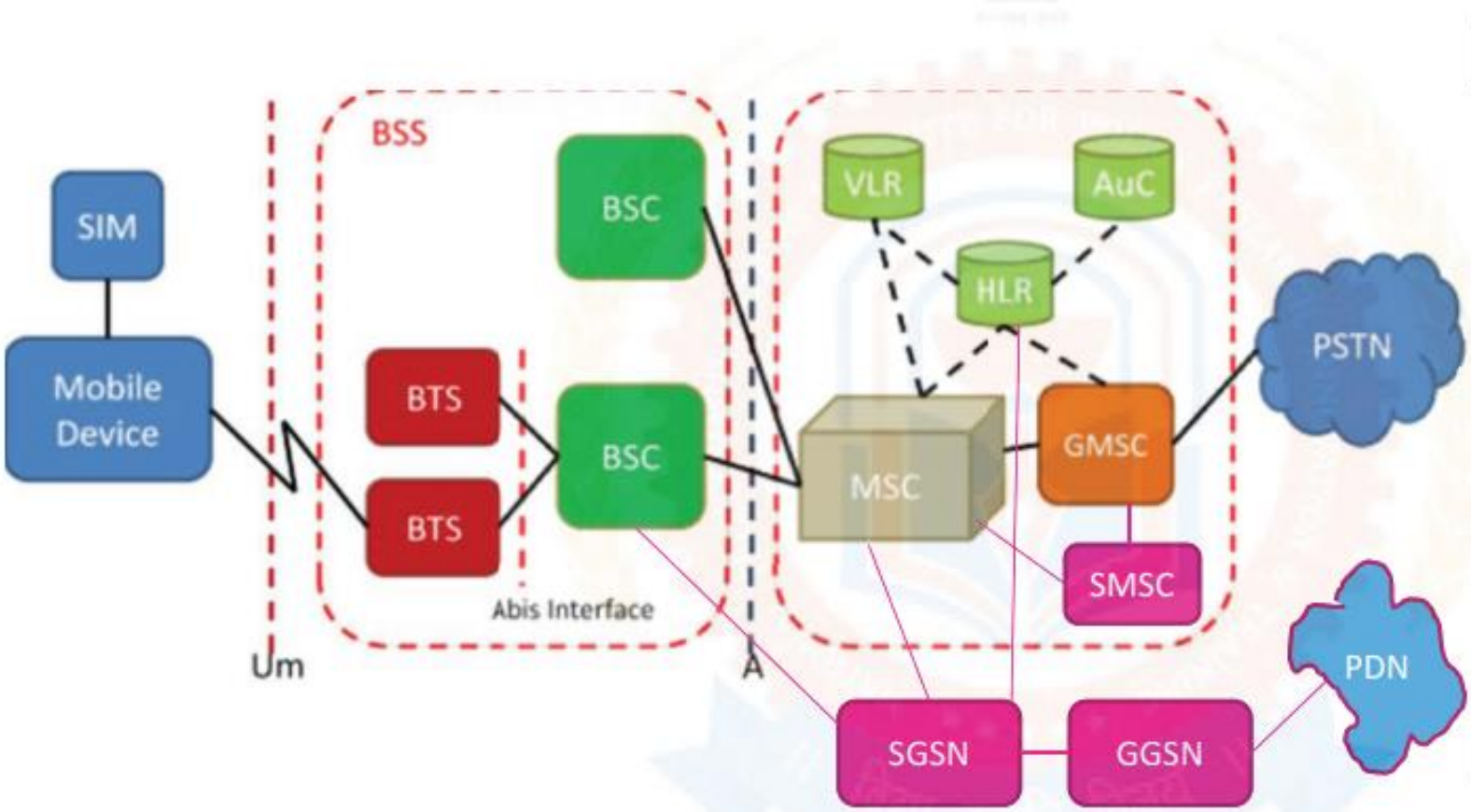
Digital transmissions enable compressed voice and multiplexing multiple users per channel

Uncompressed Voice Signal
64 kb per second

Compressed Voice Signal
8 kb per second

Image Credit : Qualcomm

2G Network and features



- Digital Voice
- Increased System Capacity
- Mobility
- SMS
- Limited Data with GPRS/EDGE
- GPRS (2.5G) up to 40kbps , evolved up to 171 kbps
- EDGE (2.75G) up to 384kbps

Evolution to 3G Network

WCDMA (UMTS)

Uses 5 MHz carrier; leverages GSM core network

June 2001 (Release 99)

HSPA (High Speed Packet Access)

Optimized data channel for WCDMA providing mobile broadband services

June 2004 (Release 5)

3GPP

A GLOBAL INITIATIVE

Evolution to 3G Network

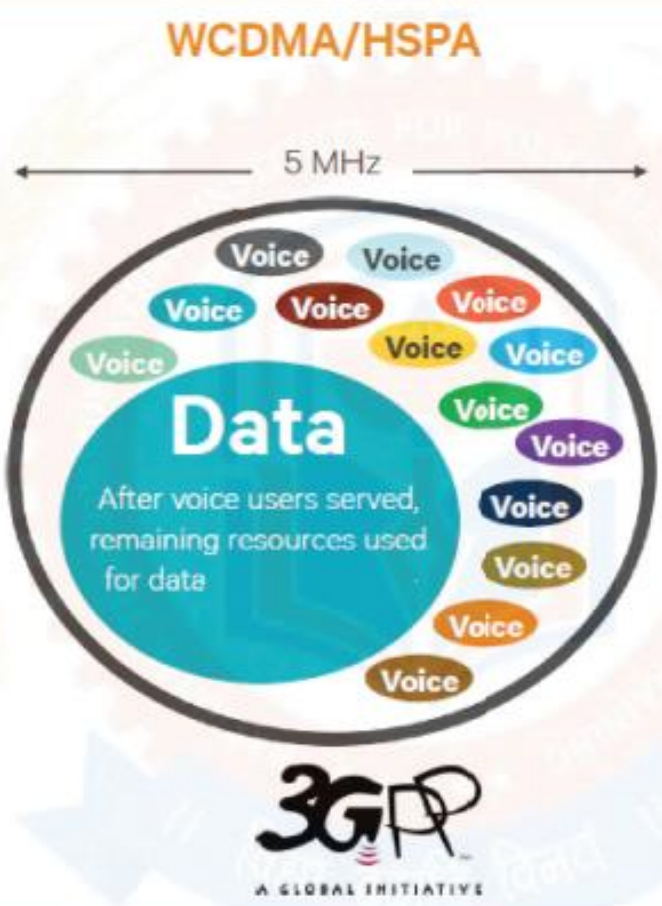
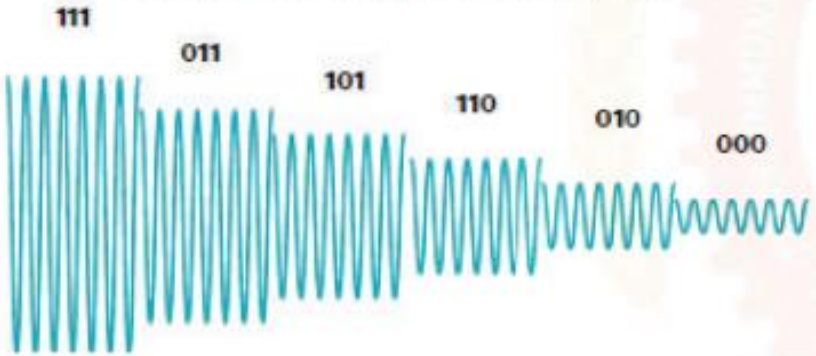


Image Credit : Qualcomm

Evolution of 3G to HSPA+

Higher Order Modulation (HOM)

Introduces 64-QAM enabling 50% more bits per second per Hz (bps/Hz)



Carrier Aggregation

Aggregating spectrum enabling increased user and peak data rates

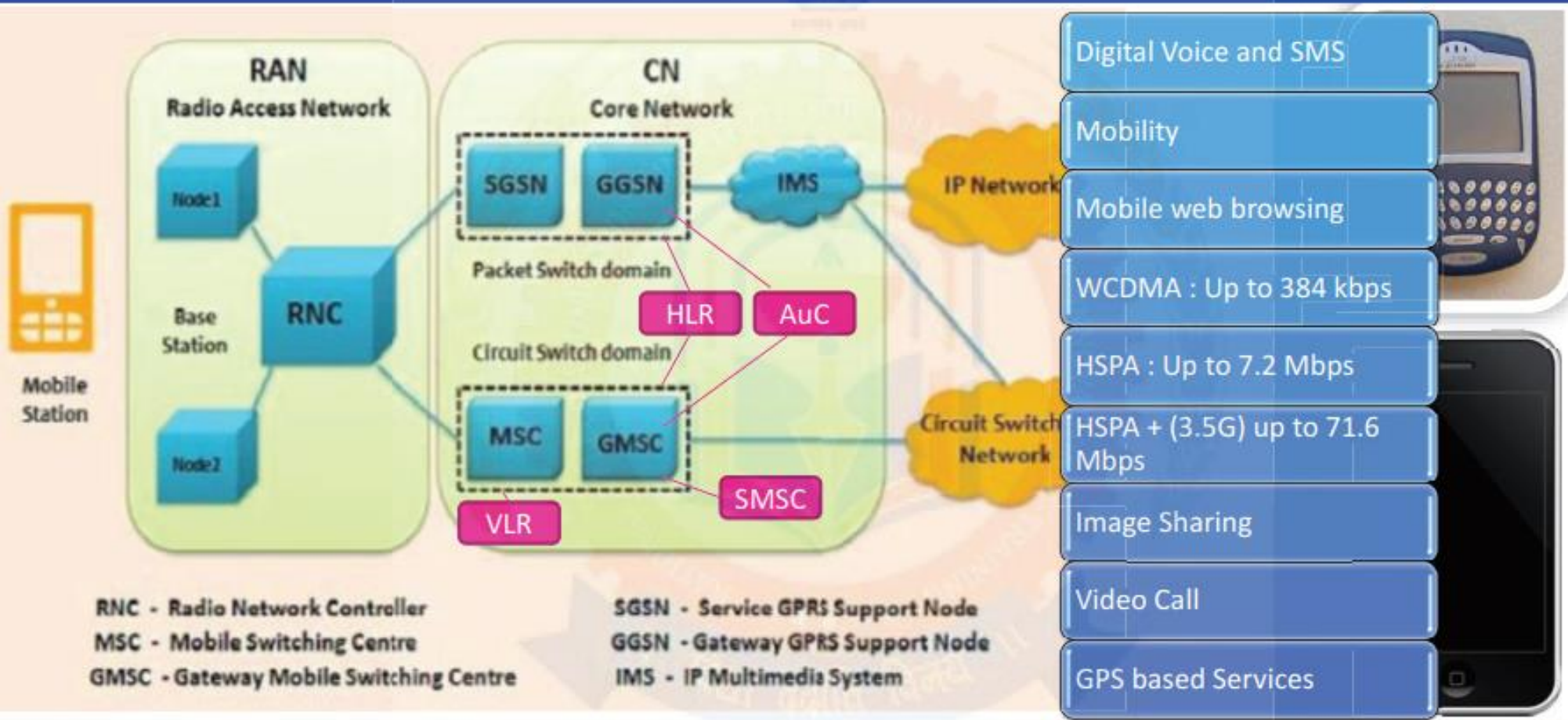
Image Credit : Qualcomm

3GPP releases of 3G

3G HSPA SPEED & HIGHLIGHT FEATURES

3GPP RELEASE	TECHNOLOGY	DOWNLINK SPEED (MBPS)	UPLINK SPEED (MBPS)
Rel 5	HSDPA	14.4	0.384
Rel 6	HSUPA	14.4	5.7
Rel 7	2xdata capacity 2x voice capacity	28	11
Rel 8	Multi-carrier	42	11
Rel 9	Multicarrier, 10 MHz, 2x2 MIMO UL, 10 MHz & 16-QAM D/L	84	23
Rel 10	20 MHz 2x2 MIMO in UL, 10	168	23
Rel 11	40 MHz 2x2 / 4x4 MIMO UL, 10 MHz 64-QAM MIMO DL	336 - 672	70

3G Network and features



Evolution to 4G

Wider Channels

Flexible support for channels up to 20 MHz enabled with OFDMA

More Antennas

Advanced MIMO techniques to create spatially separated paths: 2x2 MIMO mainstream

Carrier Aggregation

Aggregate up to 100 MHz for higher data rates – 2 carrier (2C) commercial; 3C announced[1]

Evolution to 4G

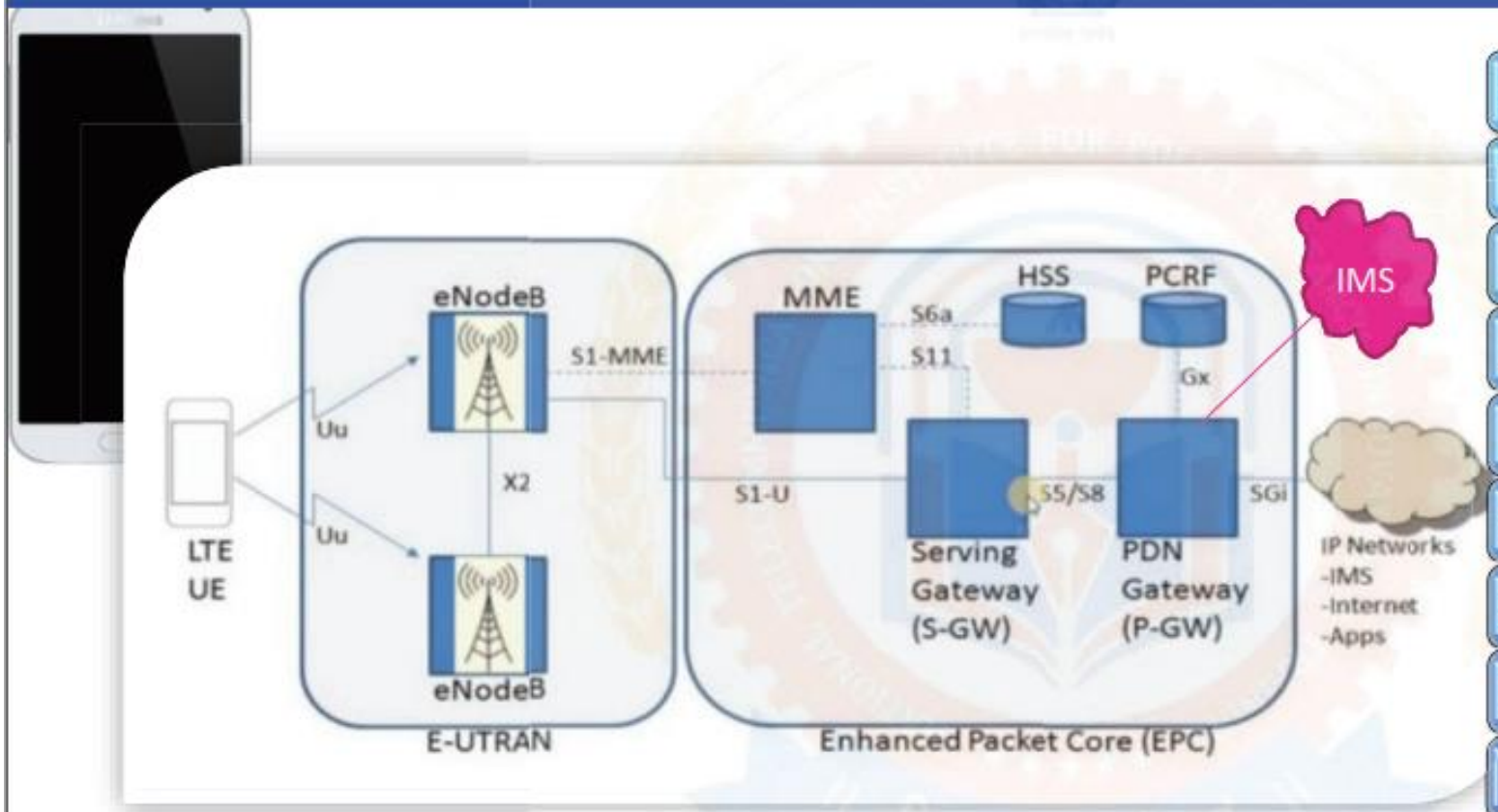
LTE FDD & LTE TDD

Two modes, common standard, same ecosystem

Frequency Division Duplex (FDD)
Paired spectrum enables
better coverage

Time Division Duplex (TDD)
Unpaired spectrum enables asymmetrical
DL/UL for more DL capacity

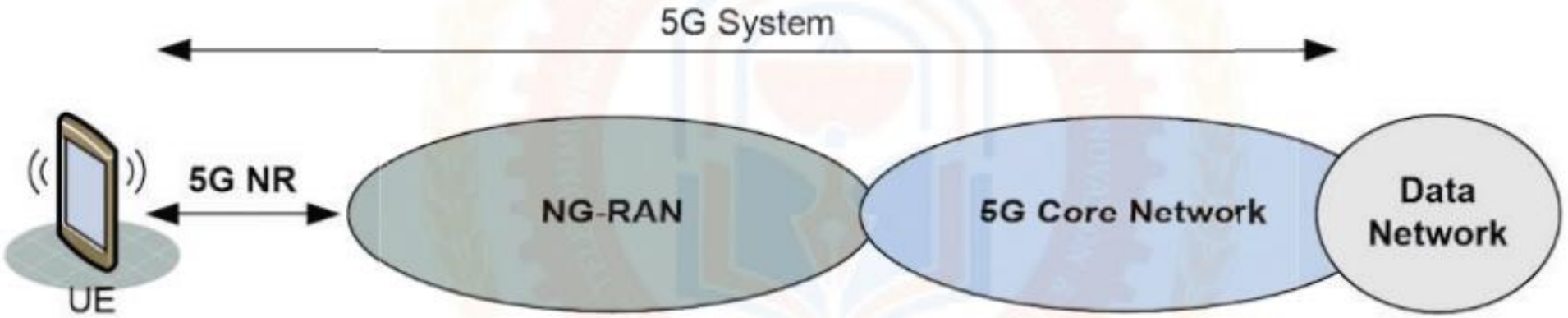
4G Network and features



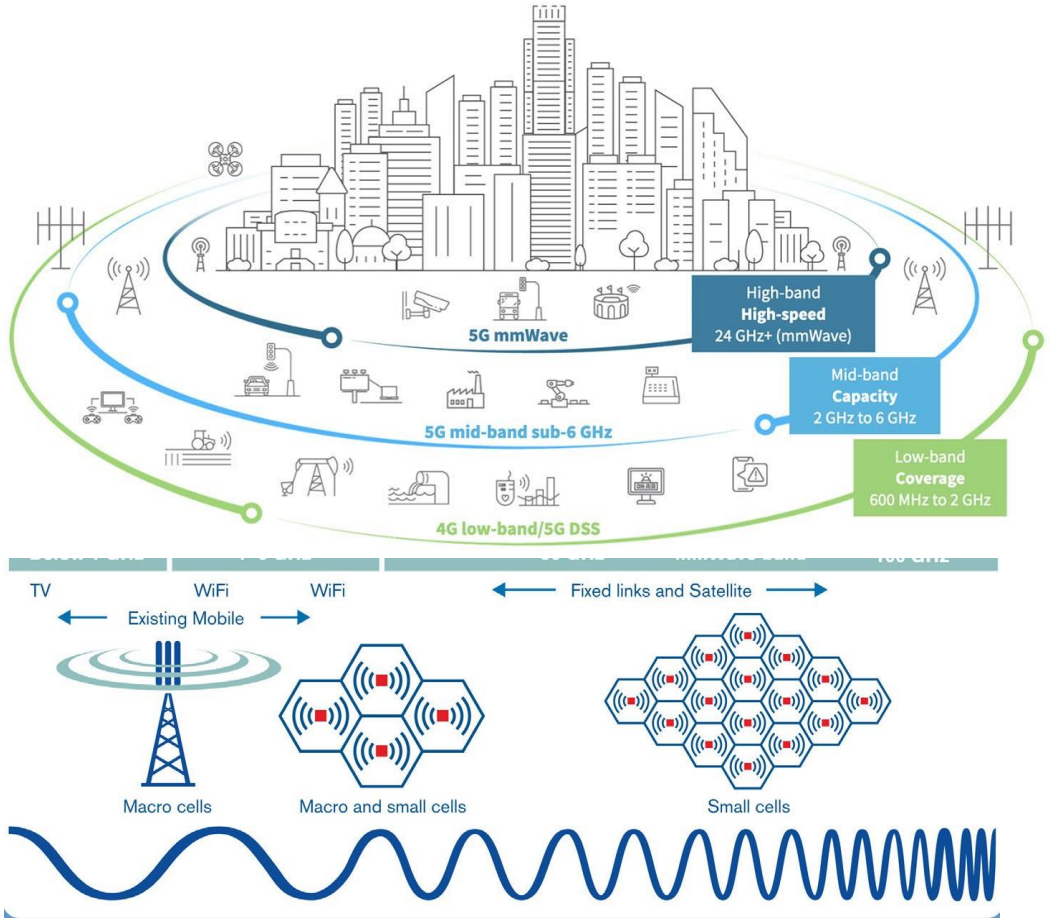
- Data Only Technology
- Voice over LTE
- Mobility
- SMS
- Mobile Broadband
- High data Rate
- Smart Phone
- Mobile APPs
- Social Media
- High Video Consumption

5G is the fifth generation of cellular networks, bringing new capabilities that will create opportunities for people, businesses and society.

High Level 5G System



5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices.

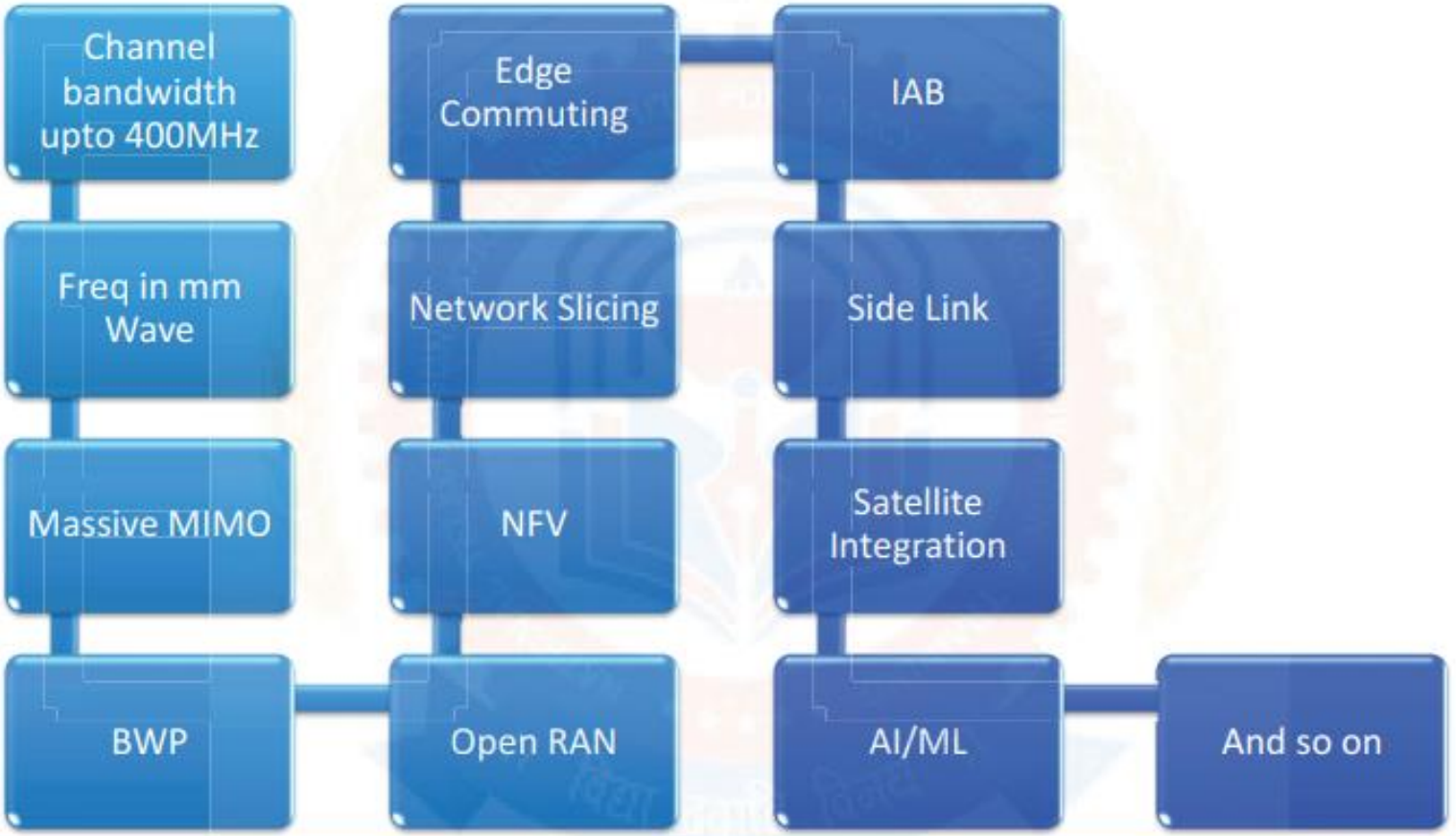


Low band Frequency band (< 1GHz) for Coverage of Rural and Remote areas and IoT

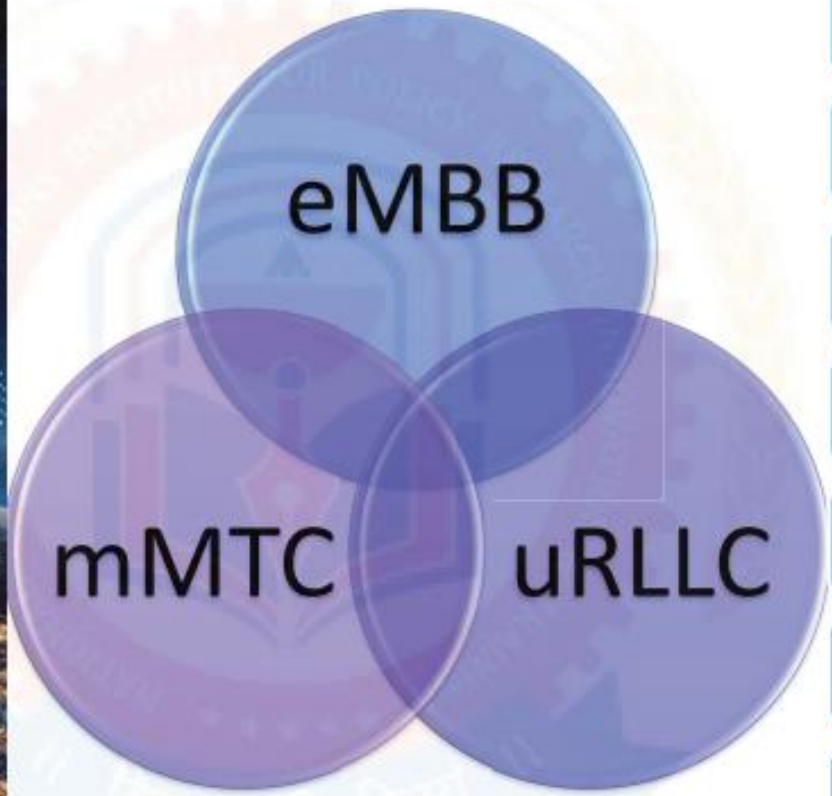
Mid Frequency band (1GHz-7GHz) for Capacity requirement (eMBB and uRLLC)

High Frequency band (Above 7GHz) for hot spot /small cell for ultra high speed

5G Technologies



5G Use cases

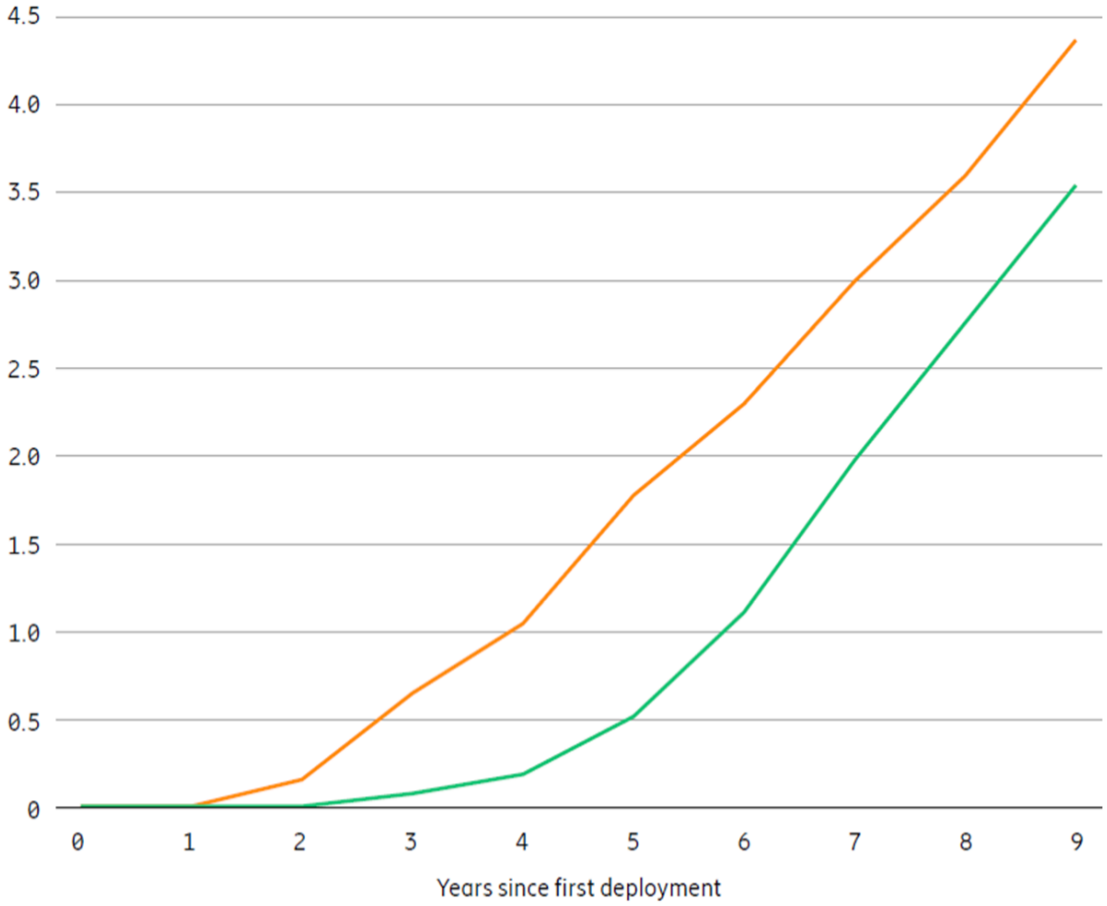


- Public Safety
- Agriculture
- Health
- Transport
- Logistics
- Education
- Entertainment

5G Adoption and Proliferation

5G Adoption is faster

Figure 2: Comparison of 5G and 4G subscription uptake in the first years of deployment (billion)



5G subscription uptake is faster than for 4G.

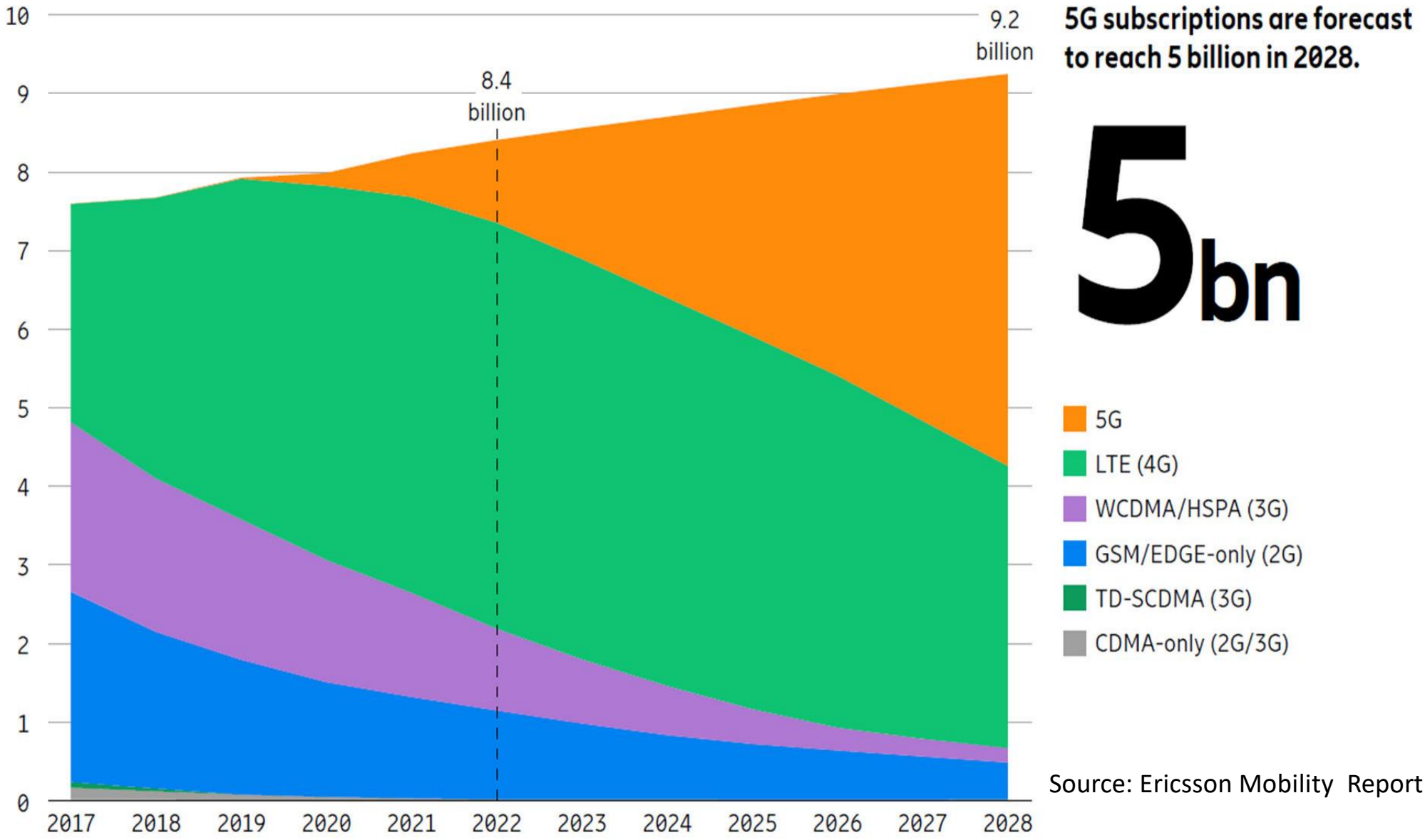
5G (2018–2027)

4G (2009–2018)

5G mobile subscriptions to surpass 1 billion in 2022

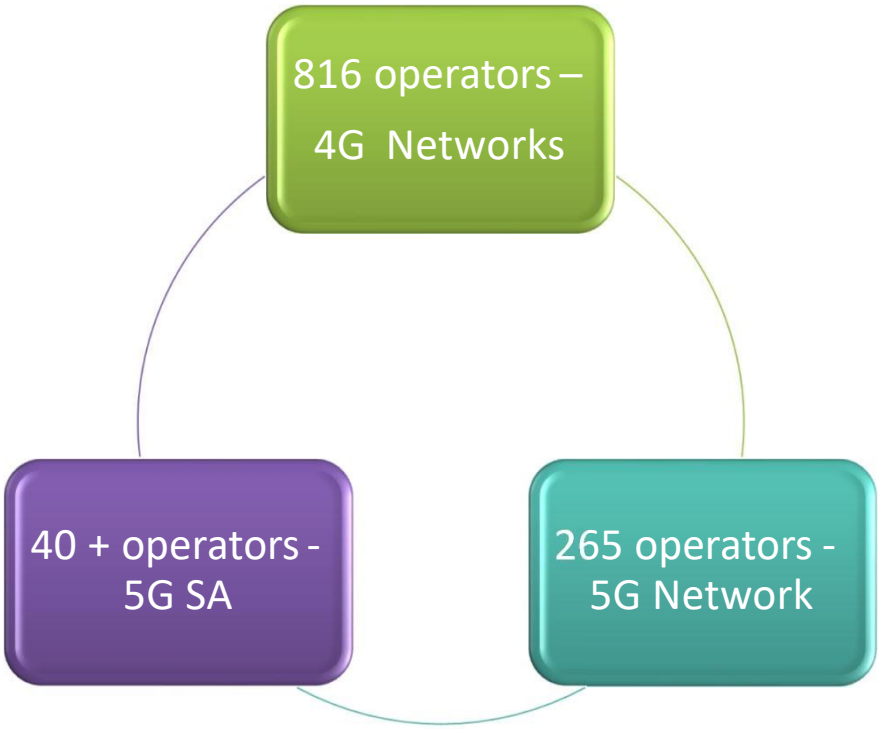
5G mobile subscriptions are set to reach 1.5 billion globally by the end of 2023.

1.5bn



Source: Ericsson Mobility Report

GSA Report August 2023



https://gsacom.com

5G Key Capabilities 5G Usage Scenarios and Key Capabilities

ITU defined 5G Usage Scenarios

5G Enhanced Mobile Broadband (eMBB)

Peak Data Rate

- Downlink 20 Gbit/s.
- Uplink 10 Gbit/s.

a movie in few Seconds

20 X faster than 4G

Peak Spectral Efficiency

- Downlink 30 bit/s/Hz.
- Uplink 15 bit/s/Hz.

3X

More spectral efficient than 4G

User Experience Data Rate

- Downlink 100 Mbit/s.
- Uplink 50 Mbit/s.

×10

Times faster speed than 4G
even at edge of the network

Mobility

- 500 Km/Hour

Mobile will work even in Bullet Train

Peak Data Rate	• Downlink 20 Gbit/s. • Uplink 10 Gbit/s.
Peak Spectral Efficiency	• Downlink 30 bit/s/Hz. • Uplink 15 bit/s/Hz.
User Experience Data Rate	• Downlink 100 Mbit/s. • Uplink 50 Mbit/s.
Mobility	• 500 Km/Hour

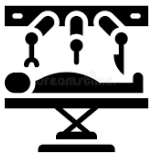
Source : Qualcomm

5G Ultra Reliable Low Latency Communications (uRLLC)

Latency

- 1ms

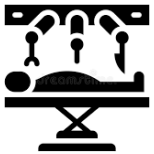
A typical human response time is **200 to 300 milliseconds**



Reliability

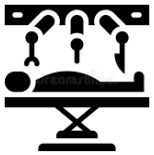
- Ultra Reliable

99.9999 % reliability and availability.

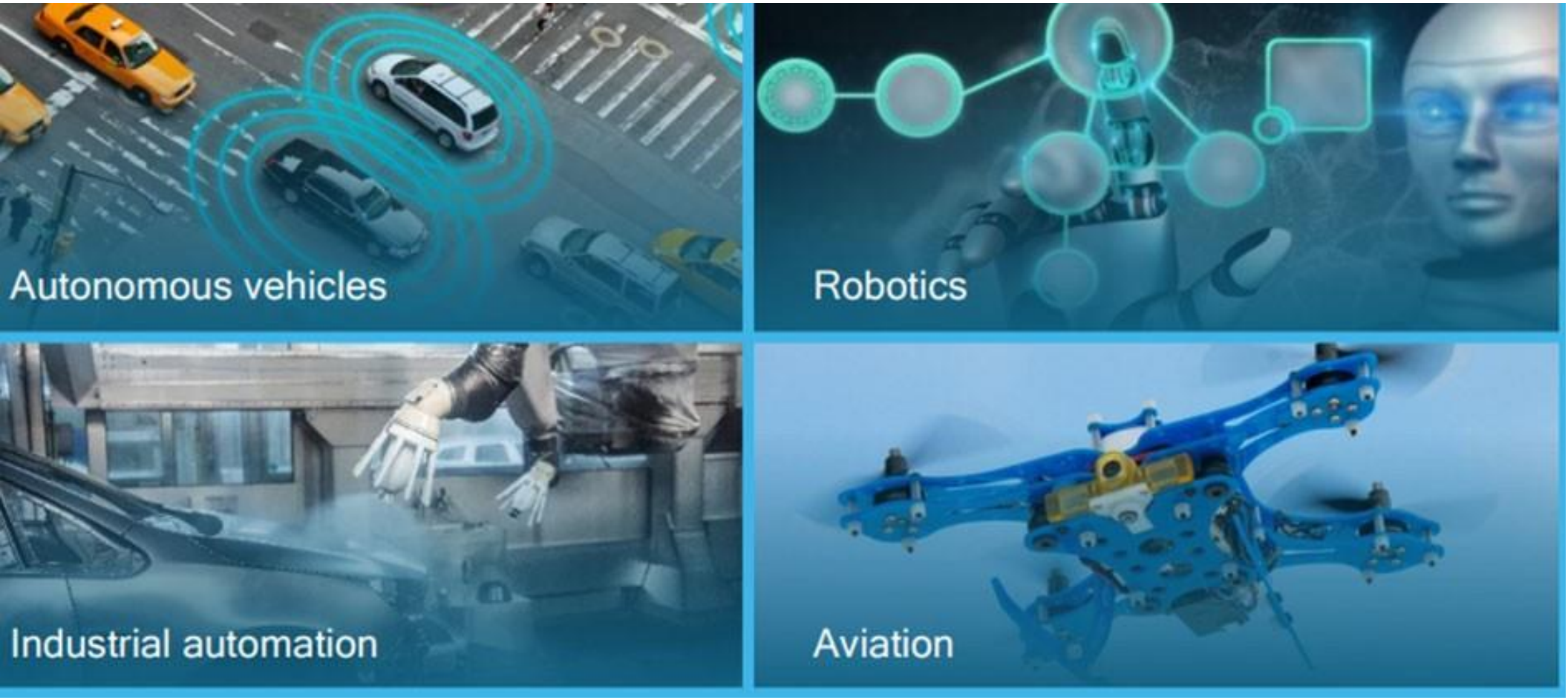


Mobility Interruption

- 0ms



User Plane Latency	• 1ms
Reliability	• Ultra Reliable
Mobility Interruption	• 0ms

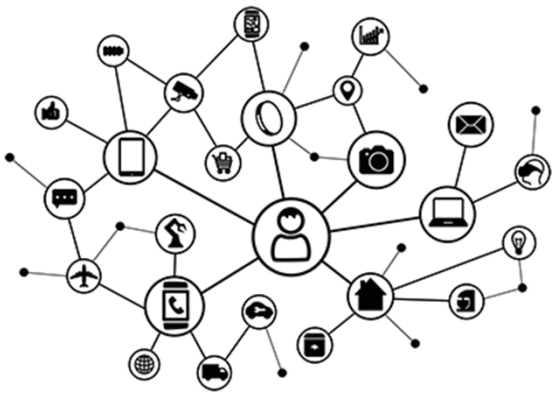


Source : Qualcomm

5G Massive Machine Type Communications (mMTC)

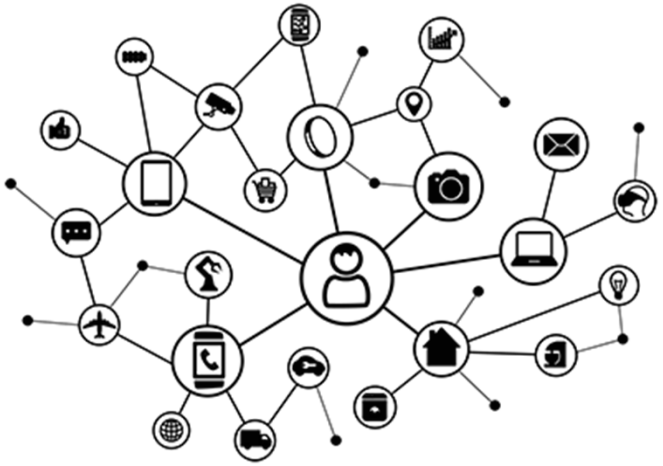
Connection Density

- 1,000,000 devices per km^2



Energy Efficiency

- Efficient data transmission in a loaded case;
- Low energy consumption when there is no data.



Connection Density

- 1 000 000 devices per km^2

Energy Efficiency

- Efficient data transmission in a loaded case;
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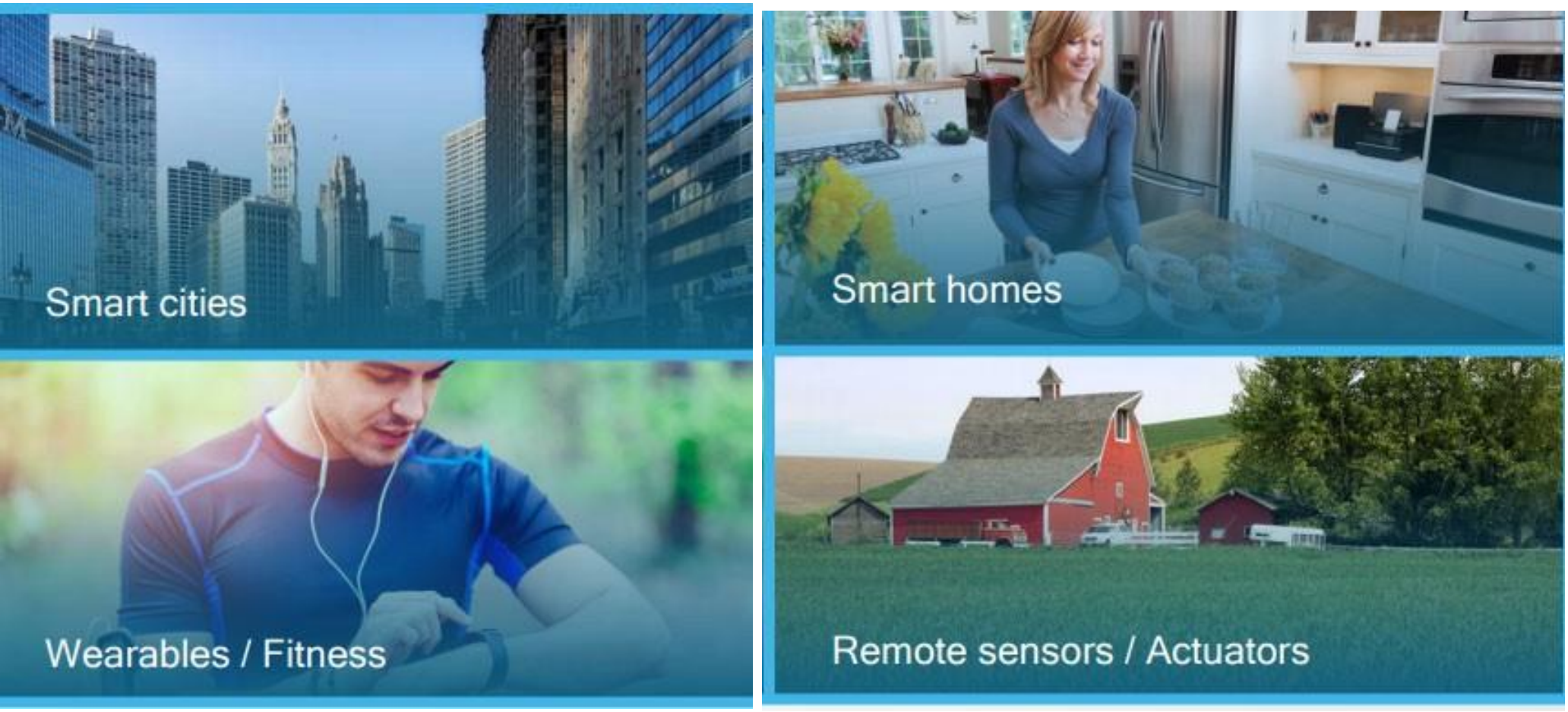
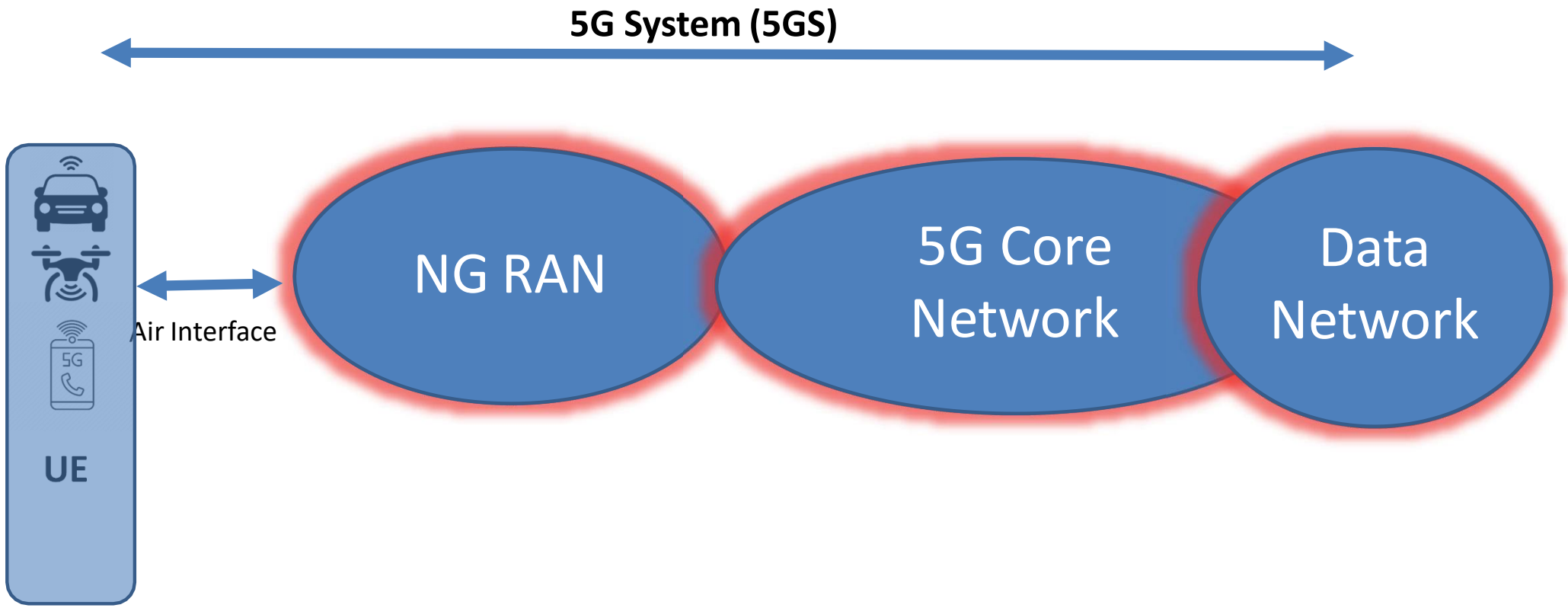
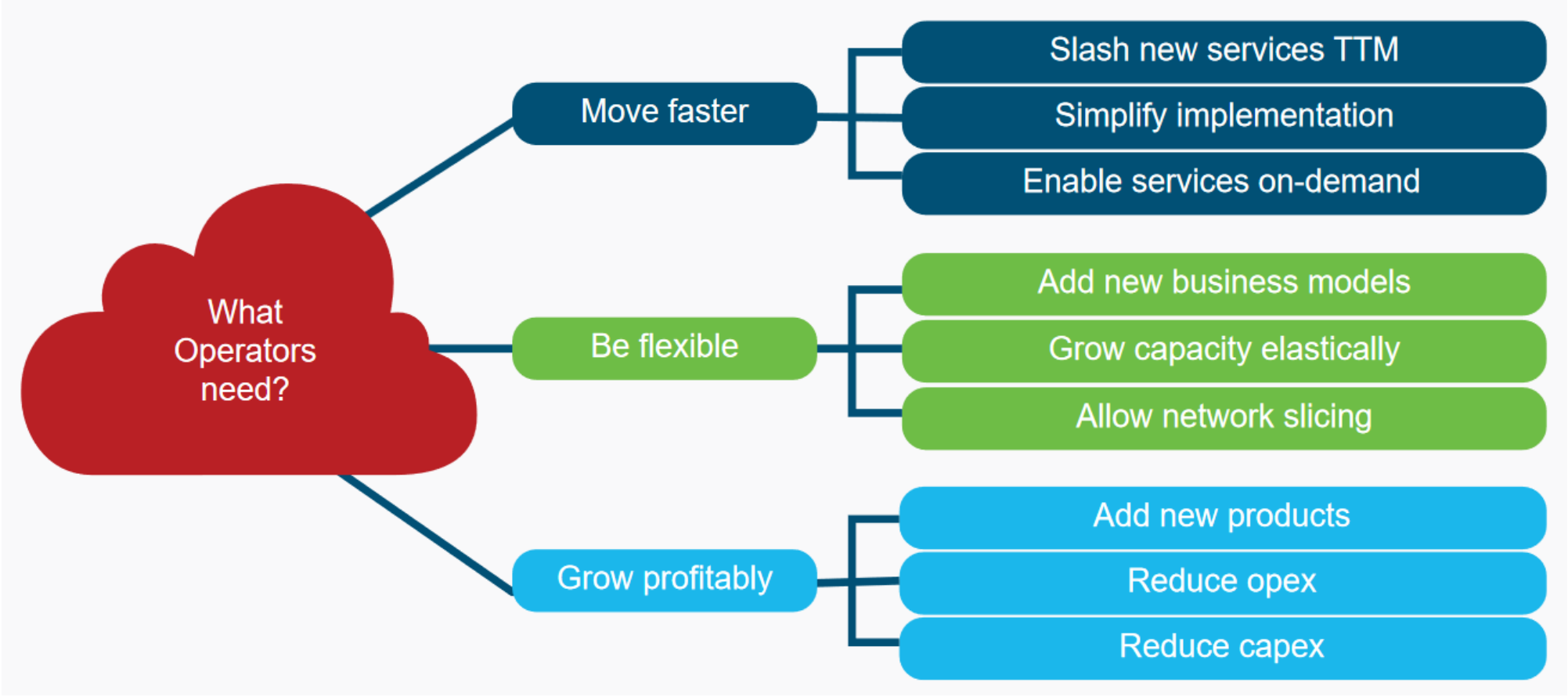


Source : Qualcomm


5G System (5GS)
UE
Air Interface
NG RAN
5G Core Network
Data Network

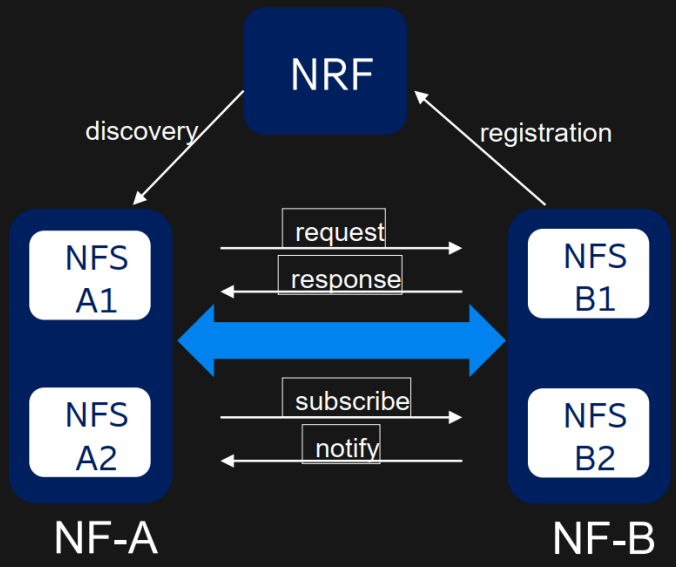
Why does the 5G Core need a service-based



“ 5G is not just about new devices, new use cases and higher speeds. The core network needs to be modernized to be able to support demanding performance requirements. eMBB, mMTC and URLLC are all different use cases that can't be satisfied by a **monolithic architecture**. We're expecting a massive increase in high-bandwidth content, low-latency applications and huge volumes of small data packets from IoT sensors.”

Service Based Architecture

- A Network Function provides one or more NF services
- An NF can be both Consumer and Producer at the same time
- NF Services
  - Target self-contained and loosely coupled services
  - Expose capabilities to consumers
  - Interact via request-response or subscribe-notify model
- HTTP2/TCP as common control protocol



SBA Benefits

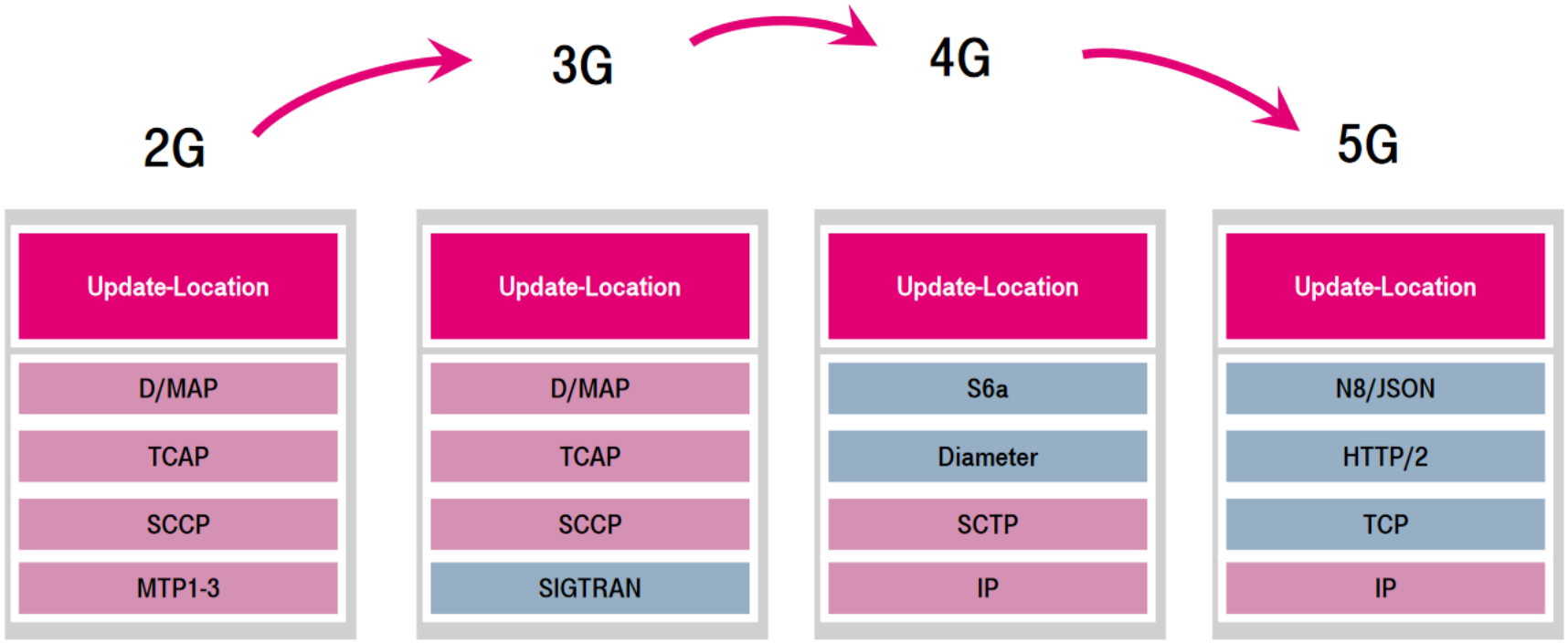
- Enables more reusability
- Simpler extensibility due to light-weight SBI
- Openness / exposure without protocol conversions

Architecture / Criterion	SOA	µ-service architecture	SBA	Monolithic
Agility	Low	High	Medium	Low
Deployment	Low	High	Medium	Low
Testability	Low	High	Medium	Medium
Scalability	Medium	High	Medium	Low
Performance	Low	Medium	Medium	High
Simplicity	Low	Medium	Medium	High

PROTOCOL EVOLUTION

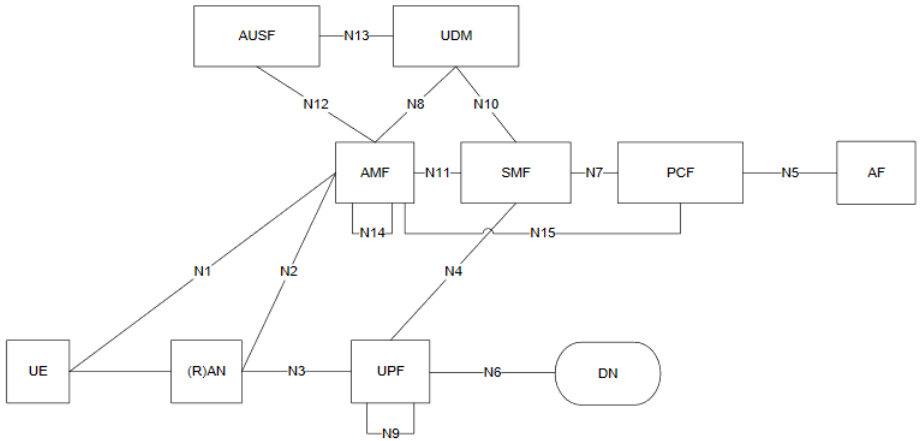
EXAMPLE: UPDATE LOCATION REQUEST

5G Core procedures run on top of web technologies



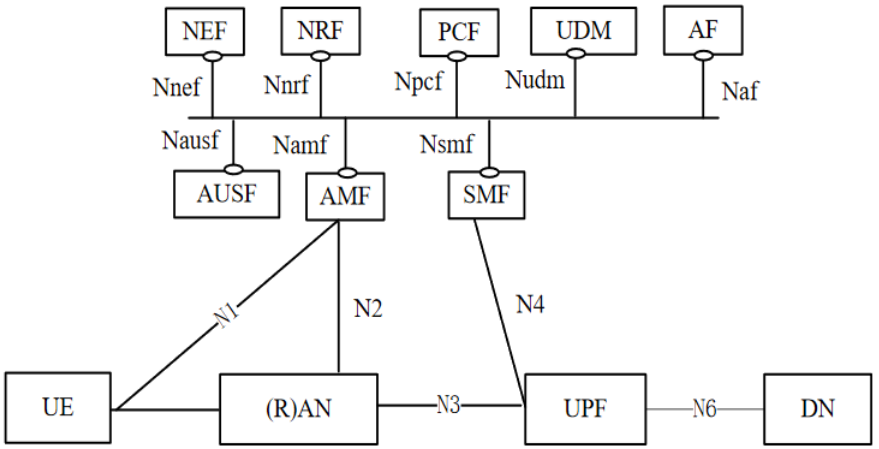
Reference point representation.

shows the *interaction that exist between the NF services* in the network functions described by point-to-point reference point (e.g. N11) between any two network functions (e.g. AMF and SMF).



Service-based representation,

where network functions (e.g. AMF) within the control plane enables other authorized network functions to access their services



Authentication Server Function (AUSF)
Core Access and Mobility Management Function (AMF)
Data network (DN), e.g. operator services, Internet access or 3rd party services

Network Exposure Function (NEF)
NF Repository Function (NRF)
Policy Control function (PCF)

Session Management Function (SMF)
Unified Data Management (UDM)
User plane Function (UPF)
Application Function (AF)
User Equipment (UE)

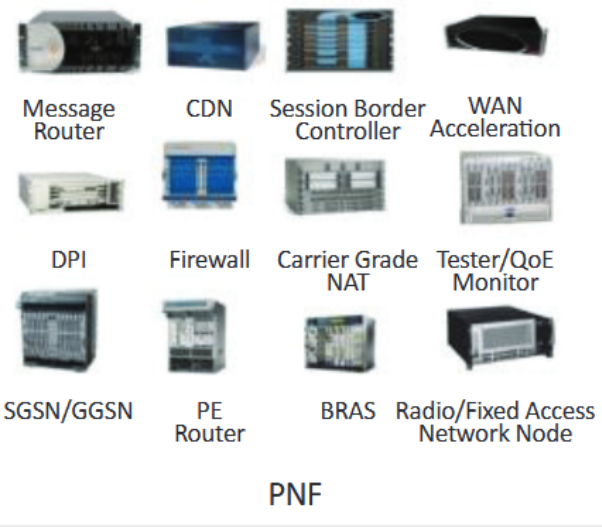
Interfaces are exposed as RESTful APIs. 5G SBA has adopted the web's client-server model but a client is called Service Consumer and a server is called Service Provider.

https://devopedia.org/5g-service-based-architecture#Allan-2015

5G SBA is described by a reference point representation that names the points by which each NF connects to other NFs. In practice, the reference points are implemented by corresponding NF Service-Based Interfaces (SBIs). Instead of point-to-point connections, NFs interconnect on a logically shared infrastructure or service bus. For instance, AMF and SMF are connected via the N11 reference point for which the corresponding SBIs are Namf and Nsmf.

SBIs are defined only for the control plane. Thus, the reference point between SMF and UPF is N4. It has no equivalent SBI. Likewise, SBIs are defined for 5G Core functionality. Thus, reference points N1, N2 and N3 that involve the UE or RAN don't have SBIs.

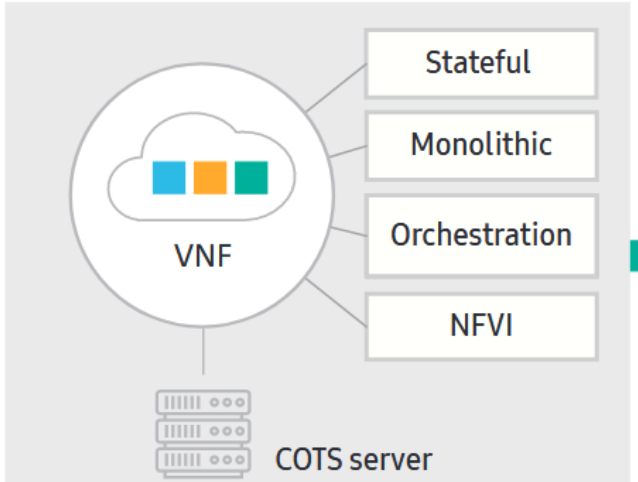
Classical Network Appliance

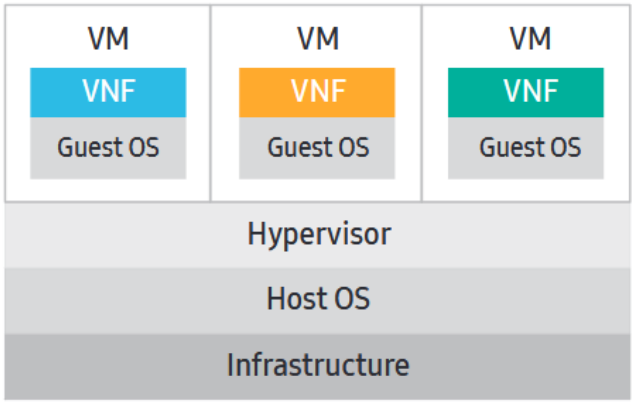


Network functions on dedicated H/W

PNF: Physical Network Function

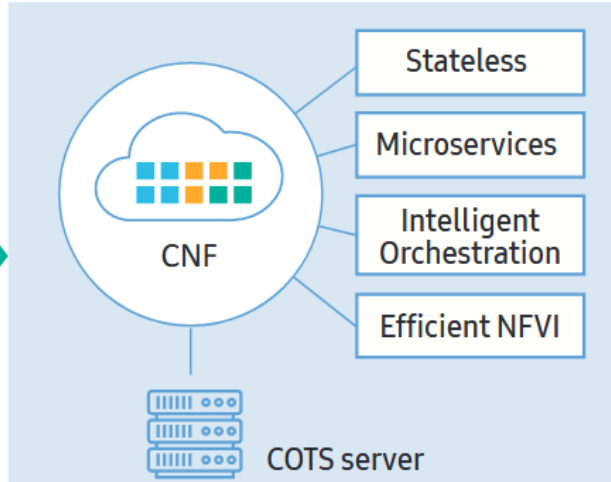
NFV

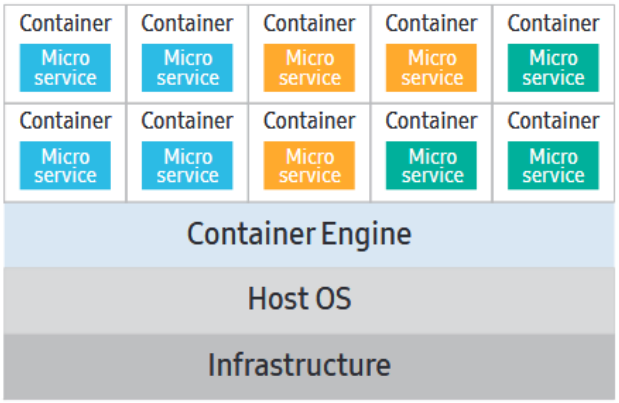




VNF: Virtualized Network Function
VM: Virtual Machine

Cloud Native



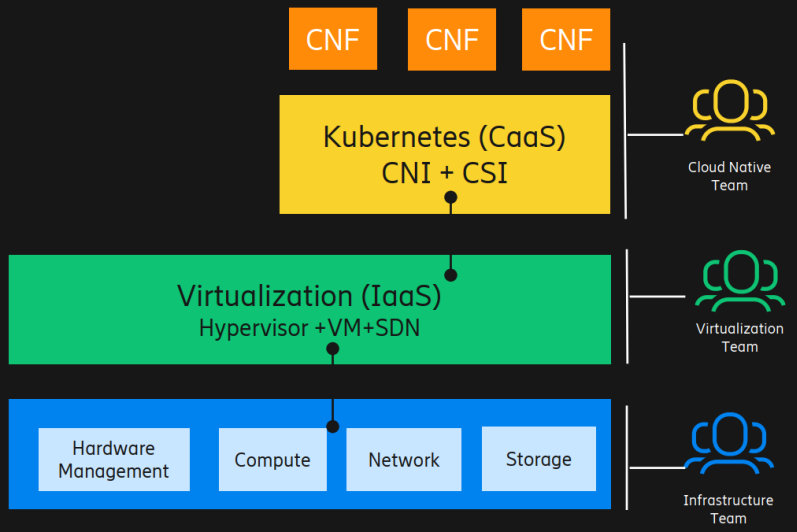


CNF: Cloud Native Network Function

BareMetal CaaS - An optimized infrastructure for Cloud Native

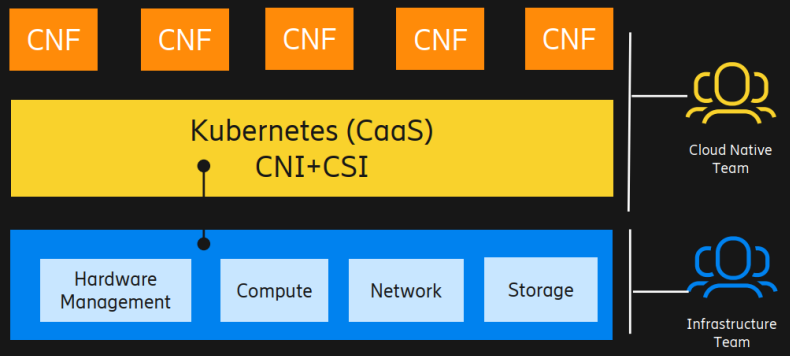
NFVI approach

- Virtualized Cloud Infrastructure is complex
- Deploying Kubernetes over virtual machines adds additional cost and complexity
- Dependencies drives the need for optimization
- Key S/W components : SDI , **VIM** , CaaS , **SDN** , SDS

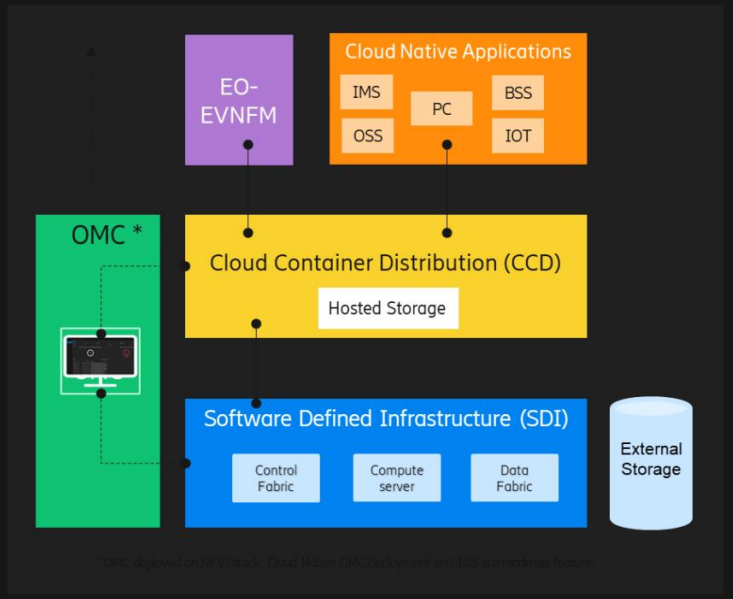


CNIS approach

- Radically simplified Cloud Native Infrastructure by deploying Kubernetes over Bare-Metal servers
- One architecture for central, edge & private network deployments
- Substantial TCO savings over time
- Key S/W components : SDI , CaaS , SDS



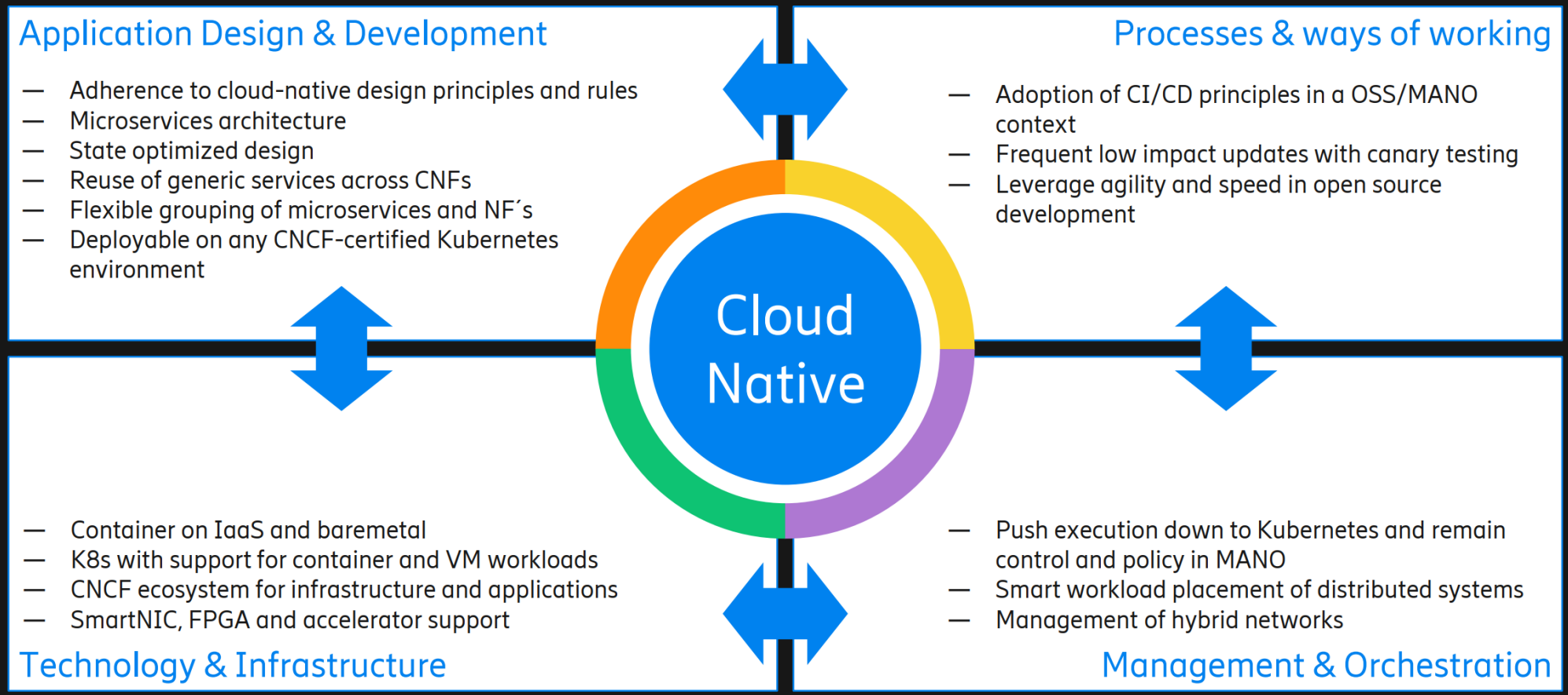
SK Telecom goes live with bare-metal cloud-native 5G Core with Ericsson



Park Jong-kwan, VP and Head of Infra Tech, SK Telecom, says: "With this achievement, cloud-native and 5G will bring **many new services, faster, to a broad range of industries**. SK Telecom will continue to collaborate with industry leaders like Ericsson on cutting edge technologies that provide the best customer experience."

Vision for Cloud Native Transformation

Across cloud platform, applications and MANO



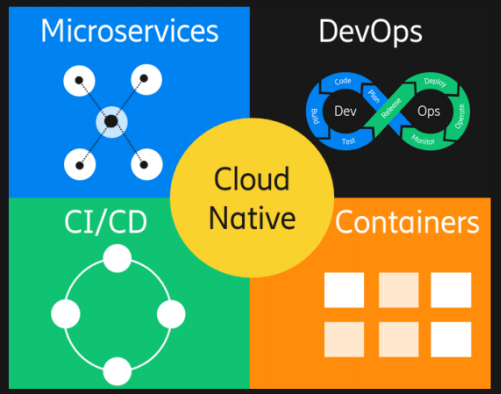
Drivers for Cloud Native Infrastructure

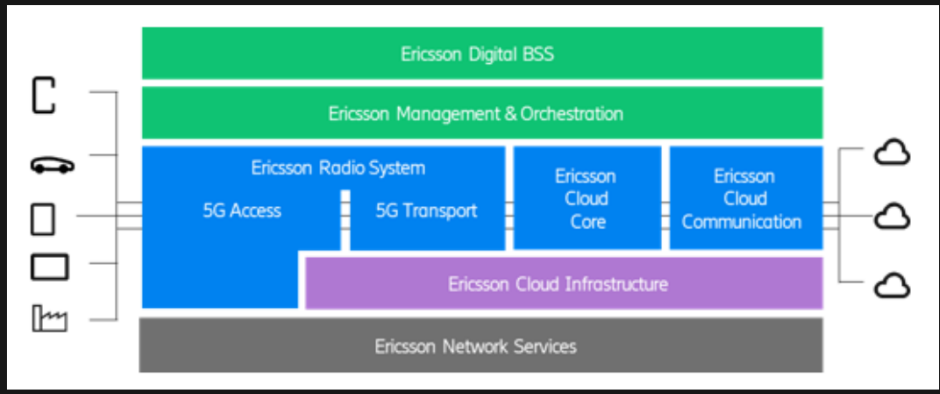
5G applications designed using Cloud Native principles

CNCF community is driving Cloud Native across industries

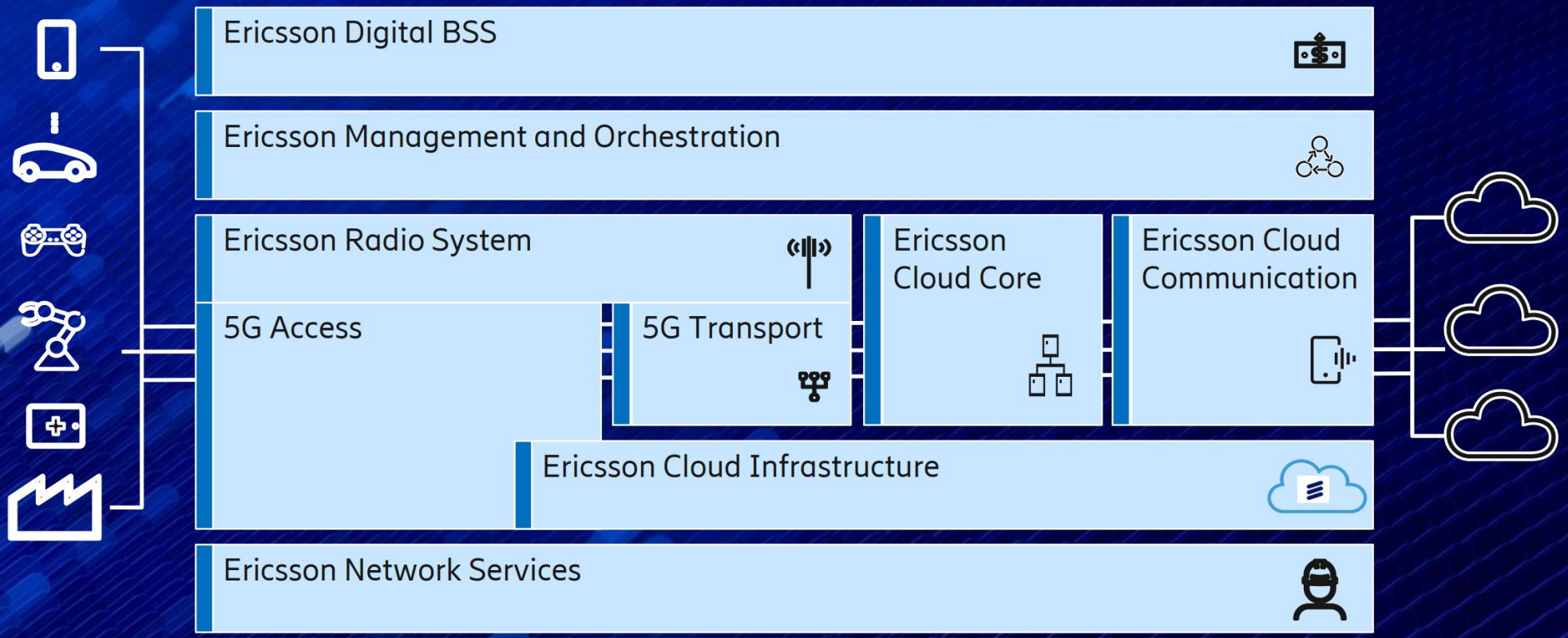
New 5G usecases needs distributed cloud infrastructure

Optimized infrastructure for Cloud Native Telco applications

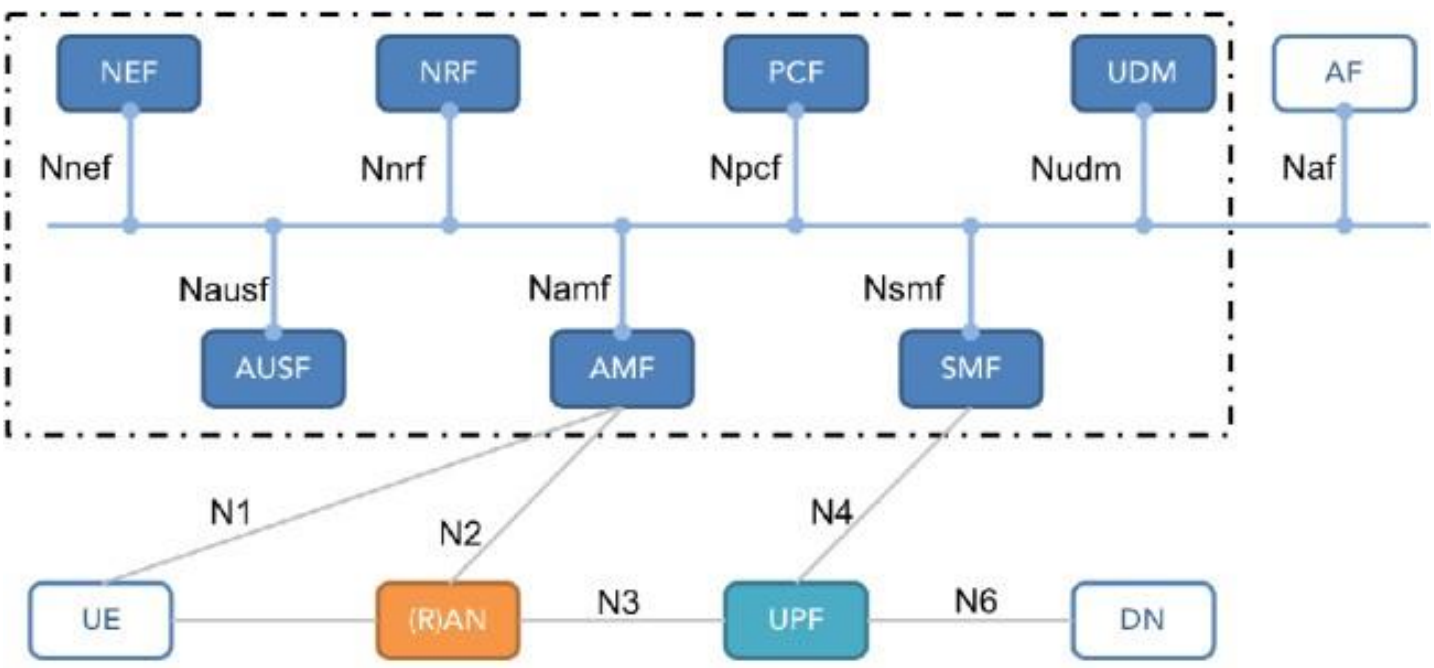




Ericsson evolving platform for 5G network and business



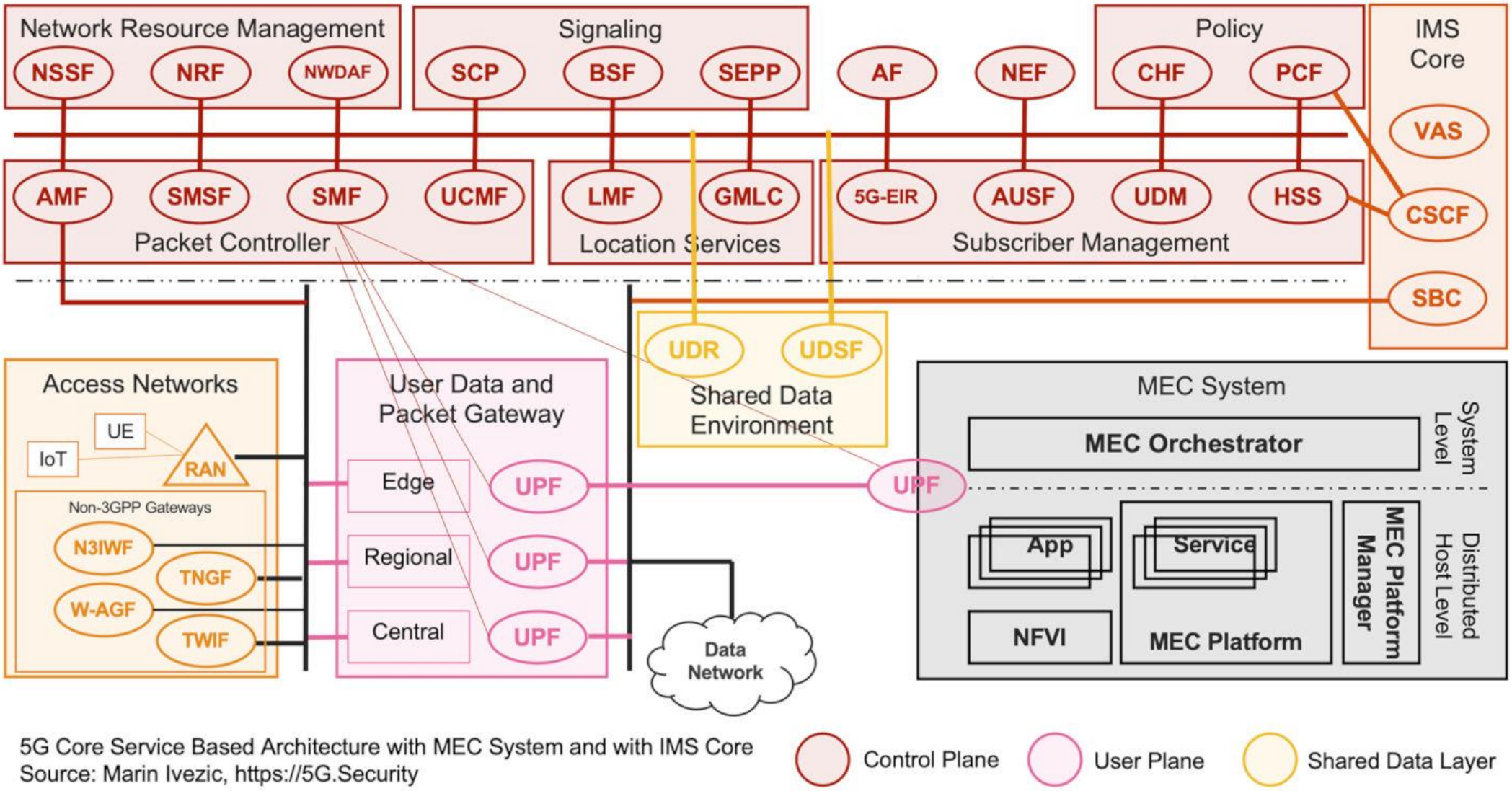
5G Architecture



Core Access and Mobility Management Function (AMF)
Authentication Server Function (AUSF)
Session Management Function (SMF)
Unified Data Management (UDM)
Network Exposure Function (NEF)
Radio Access Network ((R)AN)

Policy Control function (PCF)
NF Repository Function (NRF)
User plane Function (UPF)
Data network (DN)
User Equipment (UE)
Application Function (AF)

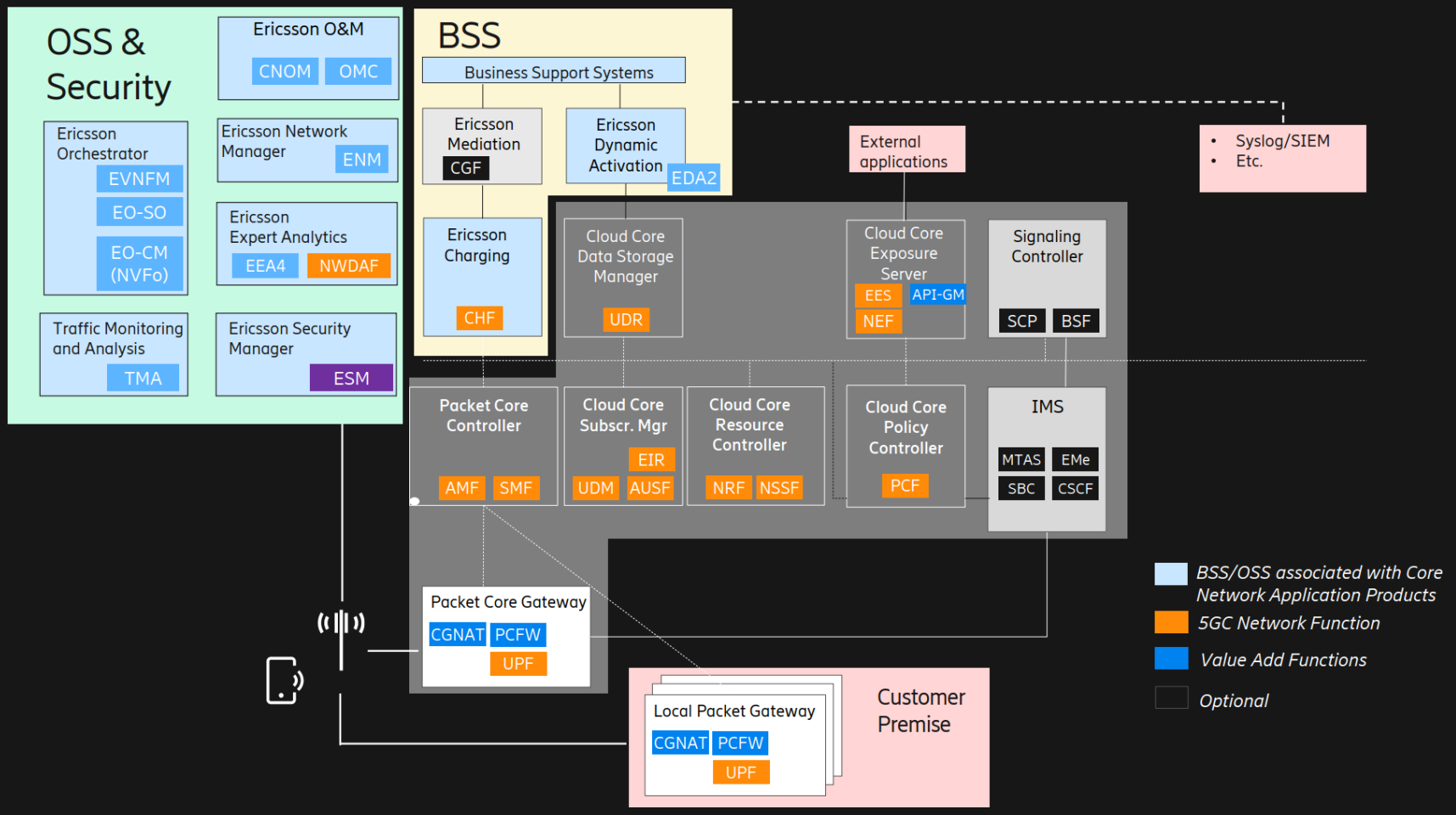
- Hardware and Software Disaggregated
- Network Functions are Virtualizes
- User Plane Disaggregated
- Mobile Edge Computing
- Can be deployed on Cloud
- Containerised Deployment
- Management and Orchestration

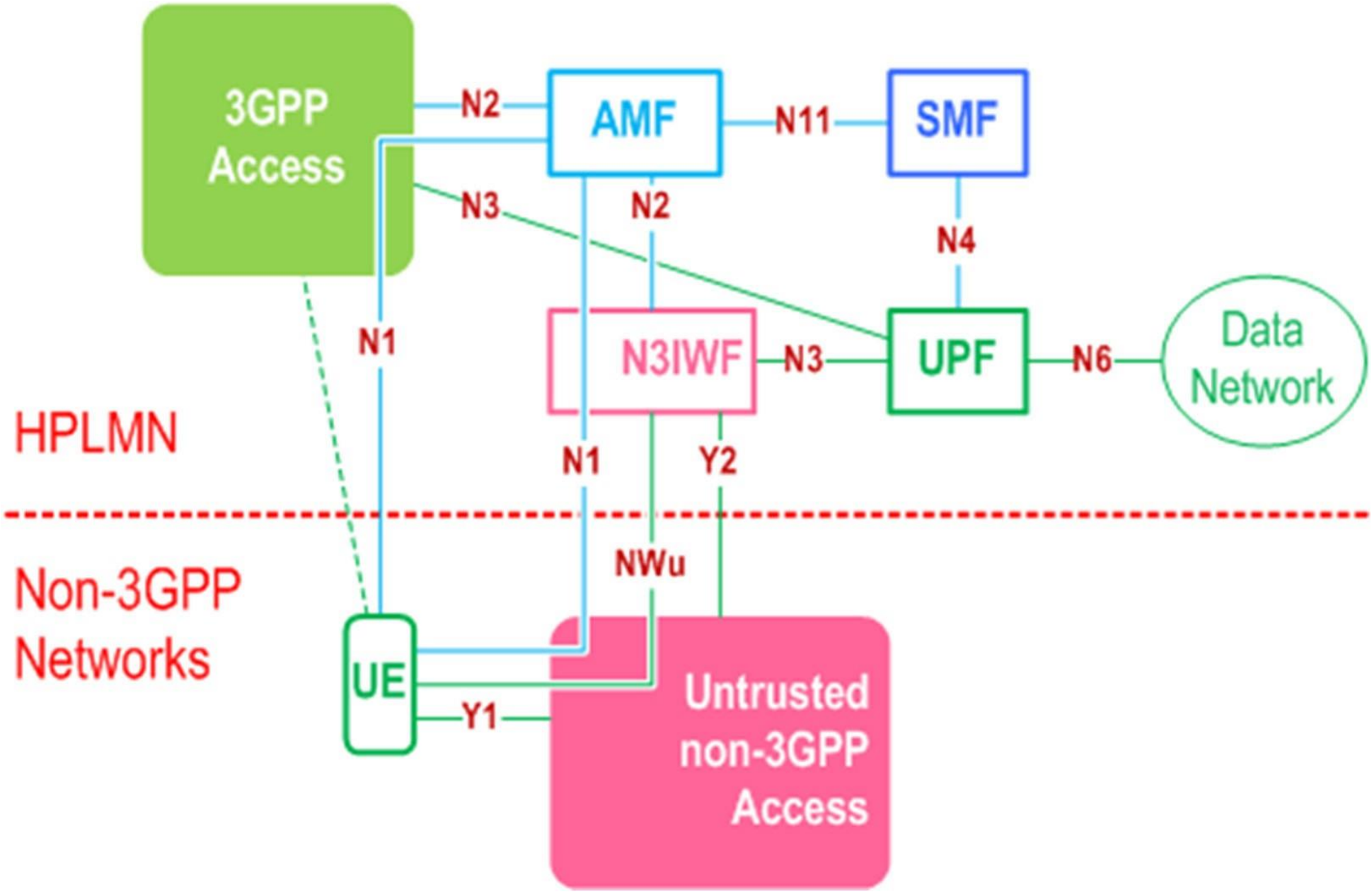


5G Core Service Based Architecture with MEC System and with IMS Core
Source: Marin Ivezic, https://5G.Security

"5G Core needs to be flexible, agile and scalable. User plane and control plane need to be scaled independently."

5G Core System Overall Picture




3GPP Access
N2
AMF
N11
SMF
N3
N2
N4
N1
N3IWF
N3
UPF
N6
Data Network
HPLMN
N1
Y2
NWu
Non-3GPP Networks
UE
Y1
Untrusted non-3GPP Access

2G/3G 4G 5G

Wireless unlicensed, shared

Fixed

Core Portfolio

Common core solution across 5G SA, NSA, 4G, fixed etc.

Ne(optional)w Function in 5G SA

Data plane

Shared Data Layer / OneNDS: UDR, UDSF, BE DB

Control plane

Registers: UDM, AUSF, EIR, HSS, HLR, EIR

Network Data Analytics: NWDAF

Network Exposure Function: NEF, SCEF

Voice: TAS, SMSF, IMS

Policy Controller: PCF, PCRF

Converged Charging: CHF, OCS/MD

Cloud Signaling Director: SCP, SEPP, DRA, DEA

Cloud Mobility Manager: AMF, MME, SGSN

Cloud Mobile Gateway - C: SMF, SP-GW

Cloud Network Resource Director: NRF, NSSF

User plane

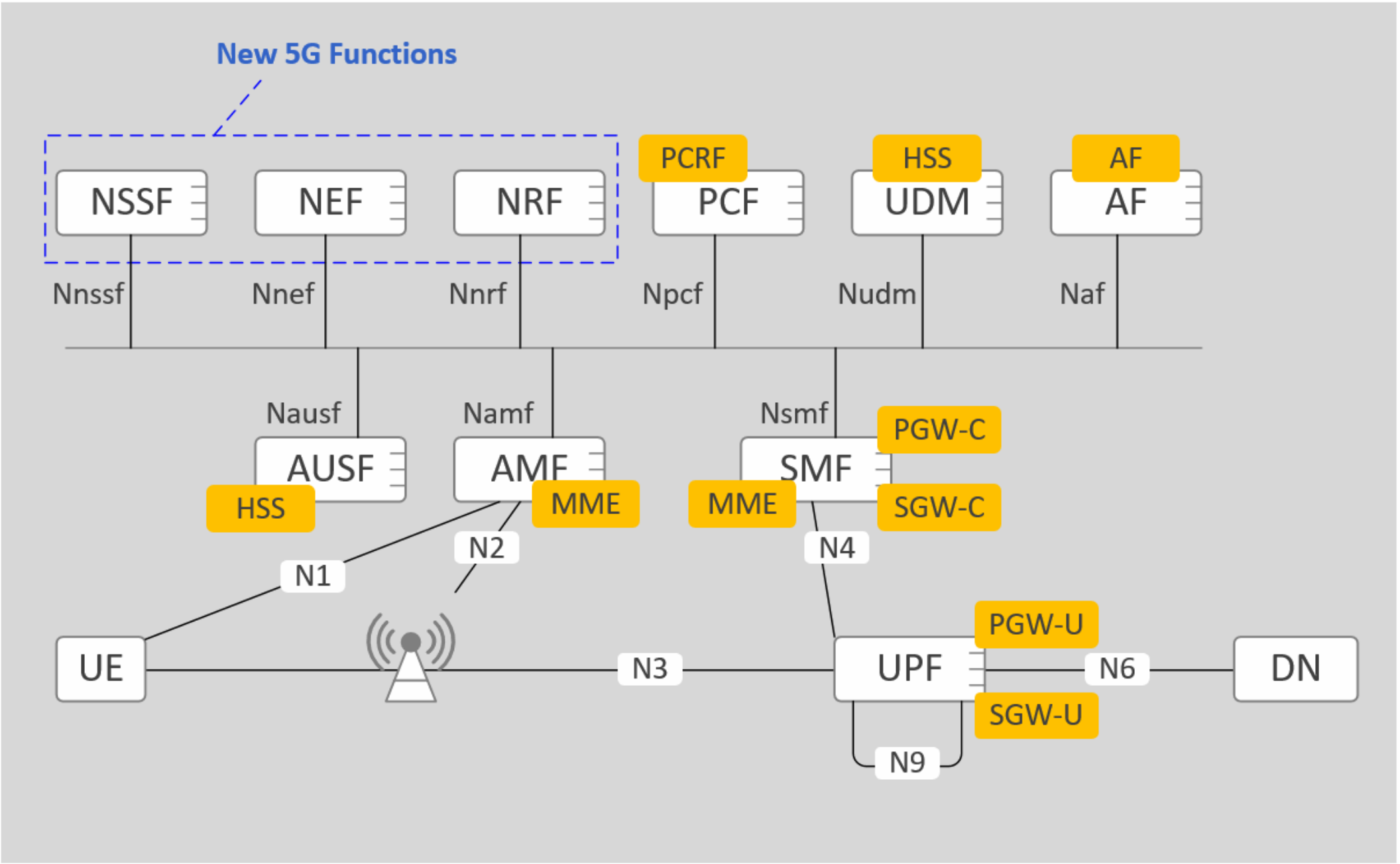
Broadband Network Gateway: W-AGF

Cloud Mobile Gateway - U: TWAG, UPF, N3IWF, SP-GW, GGSN, ePDG

Session Border Controller: BGW, SGW

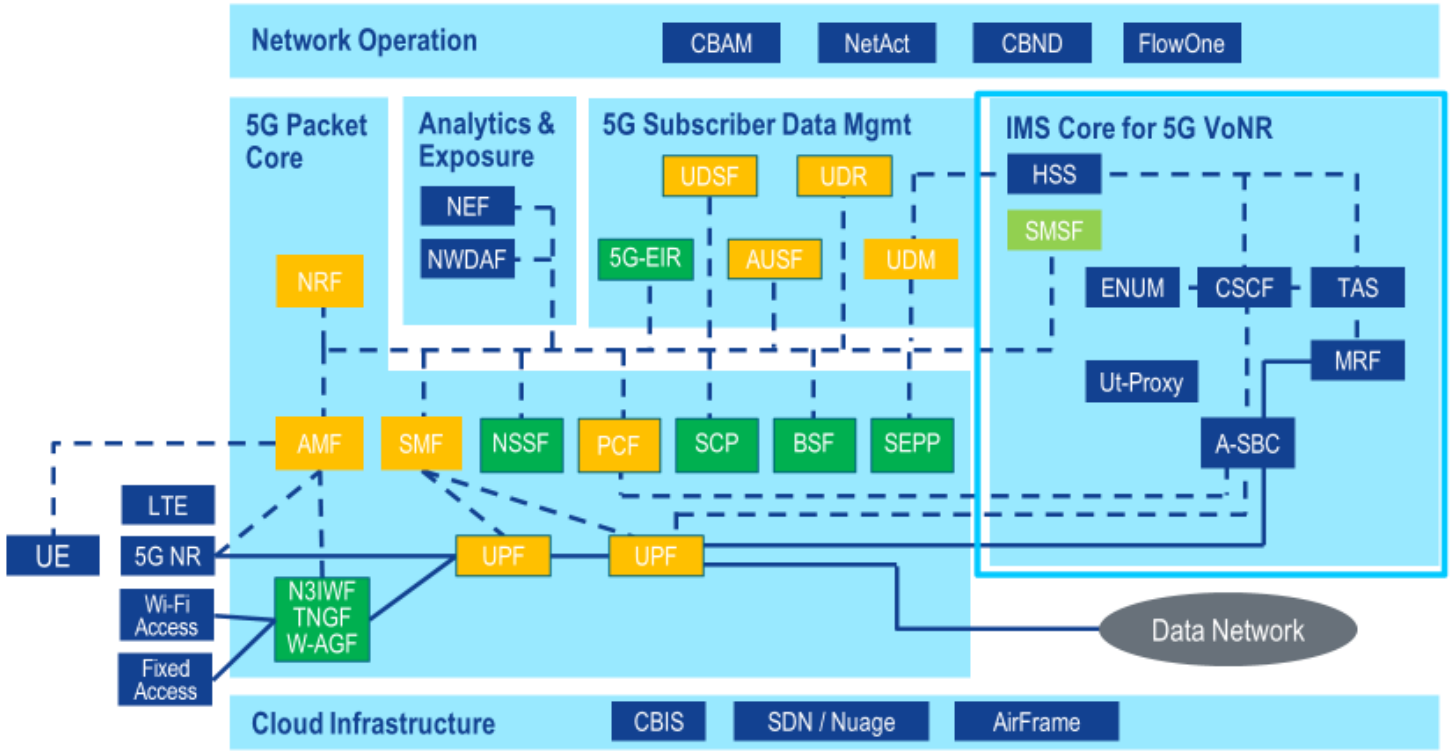
2G/3G, 4G, 5G NSA3x | 5G SA (Mandatory) | 5G SA (Optional)

NOKIA



4G EPC functions mapped to 5G core network functions

Full 5G Core Portfolio



AMF Access and mobility Management Function
AUSF Authentication Server Function
CBAM Cloudband Application Manager
CBIS Cloudband Infrastructure
CBND Cloudband Network Director
BSF Binding Support Function
EIR Equipment Identity Register
LMF Location Management Function
NEF Network Exposure Function

NRF Network Function Repository
NSSF Network Slice Selection Function
NWDAF Network Data Analytics Function
N3IWF Non-3GPP Interworking Function
SCP Service Communication Proxy (R16)
PCF Policy Control Function
SEPP Security Edge Protection Proxy
BSF Binding Support Function
SMF Session Management Function

SMSF Short Message Service Function
TNGF Trusted Non-3GPP Gateway Function (R16)
UDM Unified Data Management
UDR Unified Data Repository
UDSF Unstructured Data Storage Function
UPF User Plane Function
W-AGF Wireline Access Gateway Function (R16)

Existing node Mandatory node Optional node

Area	Core Functions	Nokia Product
Packet Core	AMF	CMM
	SMF	CMG
	UPF	CMG
	PCF	SPS
Convergence	N3IWF	CMG
	TNGF	CMG
	W-AGF	CMG
Service-based Architecture	NRF	CMG
	NSSF	CMG
	SCP	CSD
	SEPP	CSD
	BSF	CSD
Subscriber Data Mgmt	UDR	One-NDS/SDL
	UDM	Registers
	HSS	Registers
	AUSF	Nokia AUS
	UDSF	One-NDS/SDL
	5GEIR	One-EIR
Applications including the Voice Core	NEF	NEF
	NWDAF	CA4MN
	SMSF	Nokia TAS
	LMF	NLS
	A-SBC, I-SBC	Nokia SBC
	CSCF	CFX-5000
	TAS	Nokia TAS
	MRF	Radisys MRF
	ENUM, Ut-Proxy	NN Titan

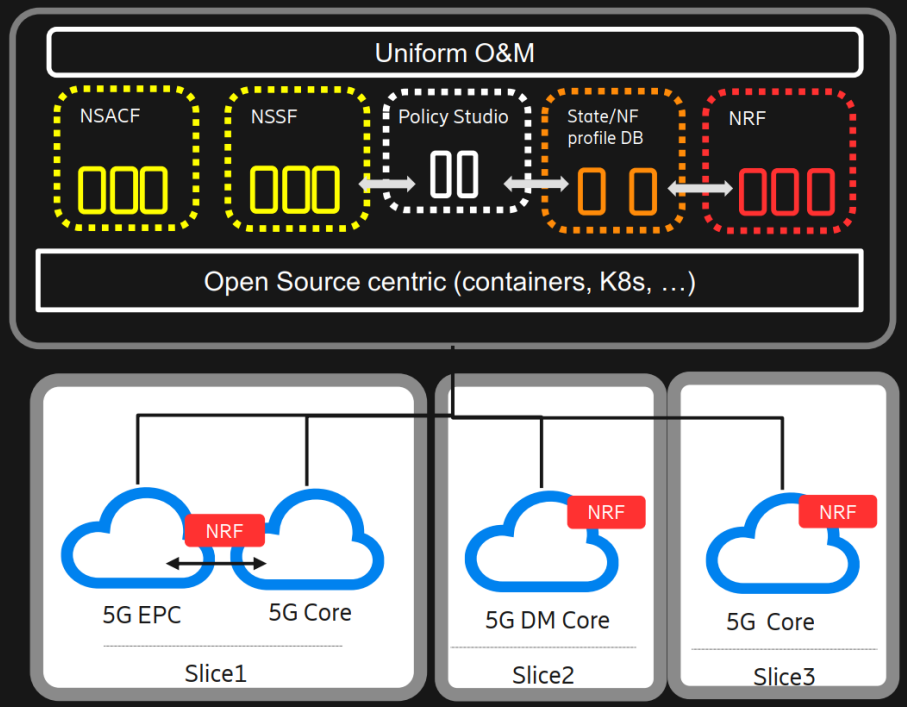
NOKIA

Cloud Core Resource Controller

Flexible deployment and grouping of NFs

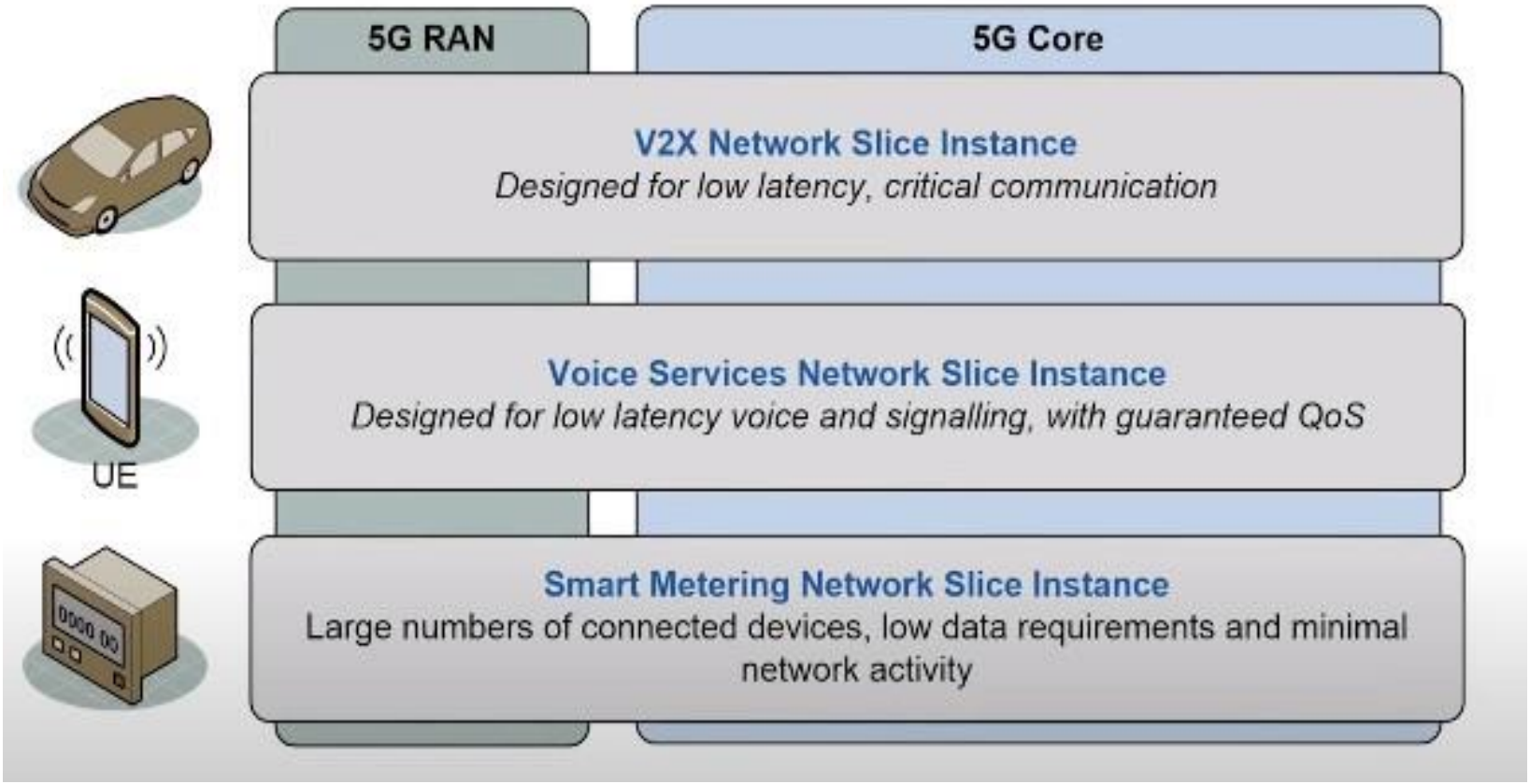
Cloud Core Resource Controller

NSSF | NRF



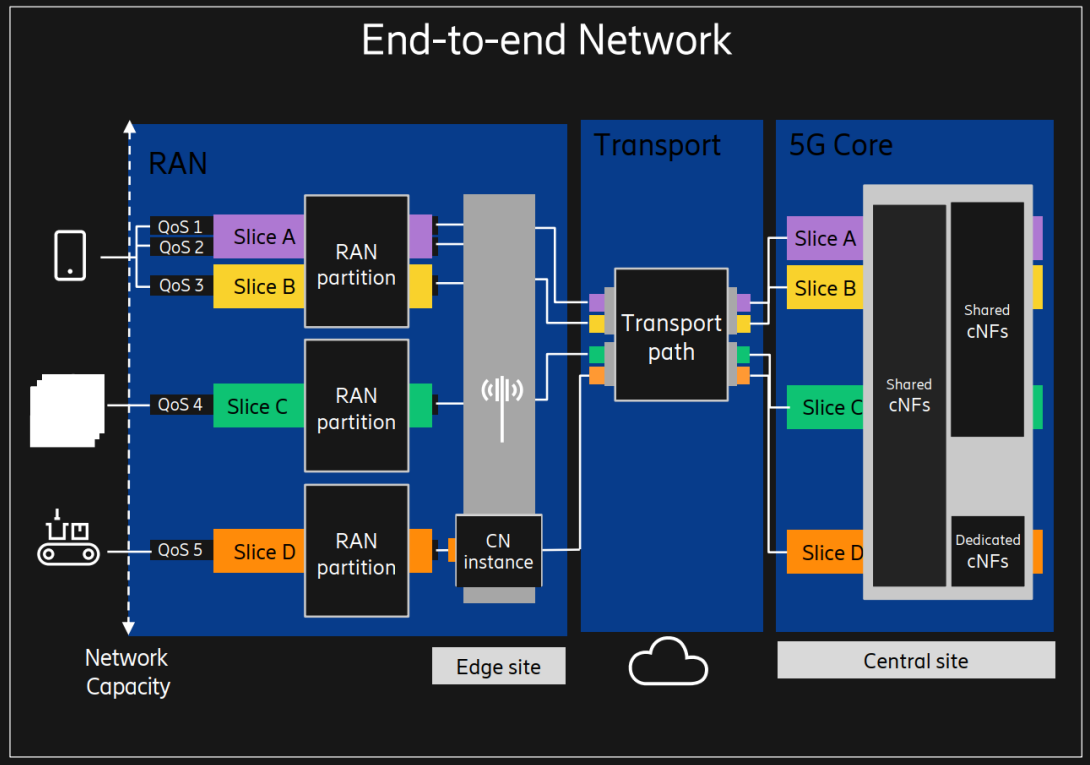
5G Dual Mode Cloud Core Resource Controller

- VNF Components:
  - NRF including embedded DNS
  - NSSF
  - NSACF
  - State/NF profile DB (M)
  - Policy Studio (M)
- Life Cycle Management and Workflows at VNF Component level
- O&M Unified at VNF Level
- Orchestration can activate/deactivate VNF Components for
  - 5G NSA
  - 5G SA
  - Full 5G NSA/SA
  - Dedicated NRF per slice
  - Shared NSSF/NRF for multiples slices
- Containers in VNFC can Scale-In/Scale-Out/Update/Upgrade independently



One device can connect to 8 network slices

5G Network Slicing concepts and characteristic



WHY Network Slicing?

- Isolation of the traffic and resources
- Differentiated traffic handling
- QoS differentiation for different service
- SLA fulfillment

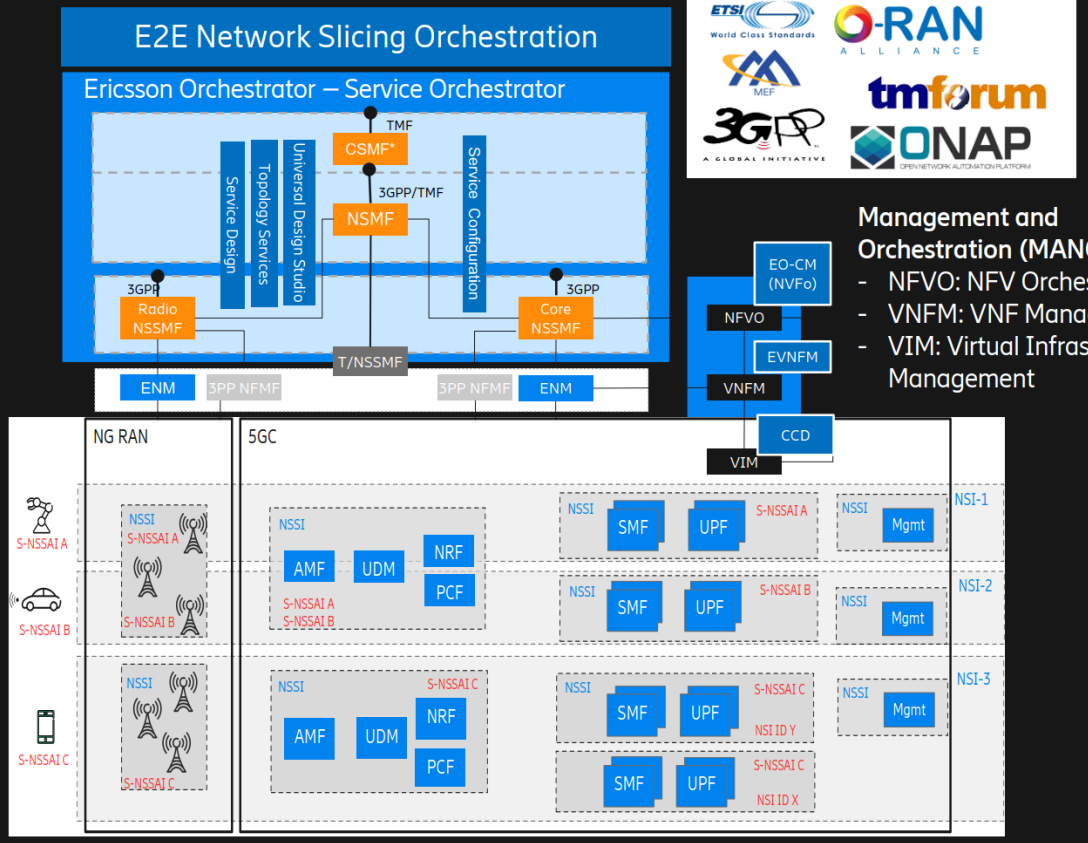
HOW is Network Slicing achieved?

- S-NSSAI – Single Network Slice Selection Assistance Information –uniquely identifies a Network Slice
- Can be created, changed and removed by management functions

E2E Network Slicing Orchestration - Standardization

Business values

- Key automation capabilities for **E2E 5G network slicing** for network field trials and for commercial operation
- Highly efficient operations with **TOP Usability** for Core and RAN slice orchestration (via 3GPP NSSMF) and for e2e Network slicing design and orchestration (via 3GPP NSMF and CSMF)
- Support for **hybrid networks** with both container-based and VM-based software
- Support for Core Networks and App. Orchestration across **multi-mode cloud stacks** (CSP private and public clouds) with smart workload placements
- Support **BSS integration**: TMF APIs exposure and Catalogue driven orchestration



Management and Orchestration (MANO):

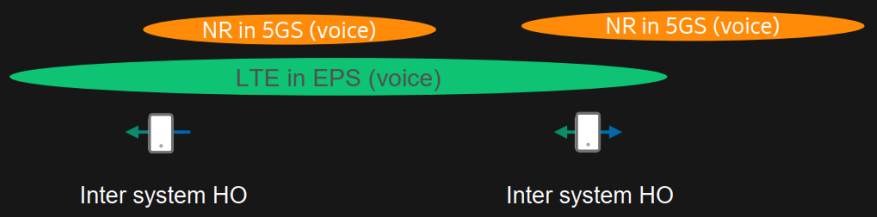
- NFVO: NFV Orchestration
- VNFM: VNF Manager
- VIM: Virtual Infrastructure Management

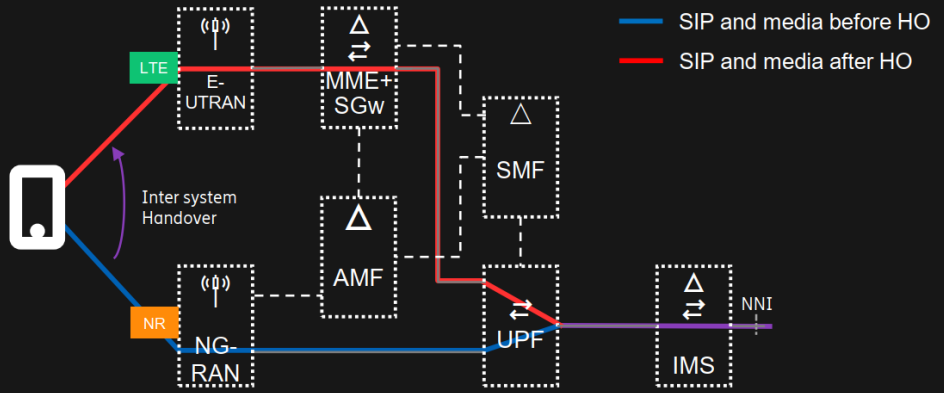
CSMF: Communication Service Management Function
NSMF: Network Slice Management Function
NSSMF: Network Slice Subnet Management Function
NFMF: Network Function Management Function

Voice over NR

- Voice over NR implies that voice calls can be made on NR.
- Typical coverage scenario
  - NR coverage controlled by a 5G Core that supports voice. The NR coverage can be embedded in, or partly outside, LTE coverage served by EPC
  - LTE coverage controlled by EPC supporting VoLTE

- The telephony service behavior
  - Calls can be made in NR coverage
  - Handover of IMS signaling and voice between 5GS and EPS (and of all other established PDU sessions) is performed e.g., when losing NR coverage or LTE coverage

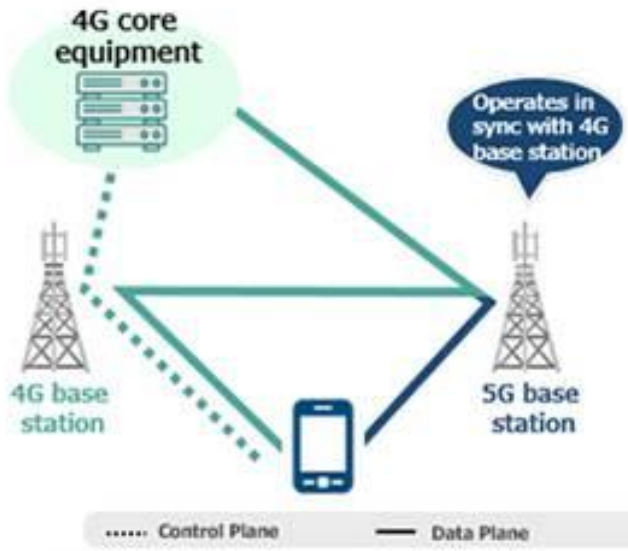




What is SA and NSA 5G

5G NSA

Ultra-high-speeds / high-capacity
achieved by utilizing 4G core equipment



Ultra-high-speed / high-capacity
Ultra-low-latency
Massive device connectivity

5G SA

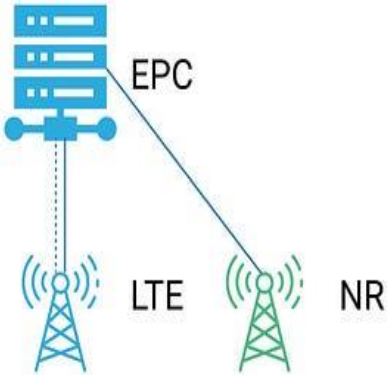
Ultra-low-latency /Massive device connectivity
also achieved by utilizing 5G core equipment

Ultra-high-speed / high-capacity
Ultra-low-latency
Massive device connectivity

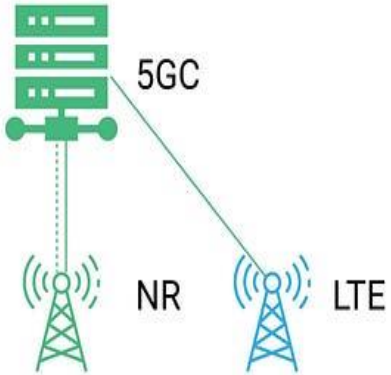
Standalone LTE under EPC (option 1)

Standalone NR under 5GC (option 2)

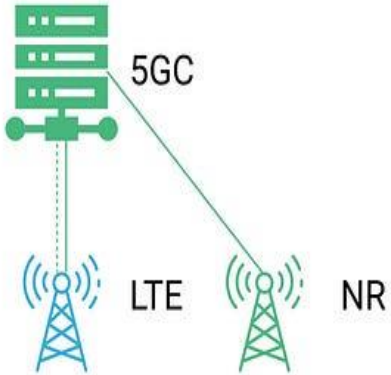
Standalone LTE under 5GC (option 5)



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



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

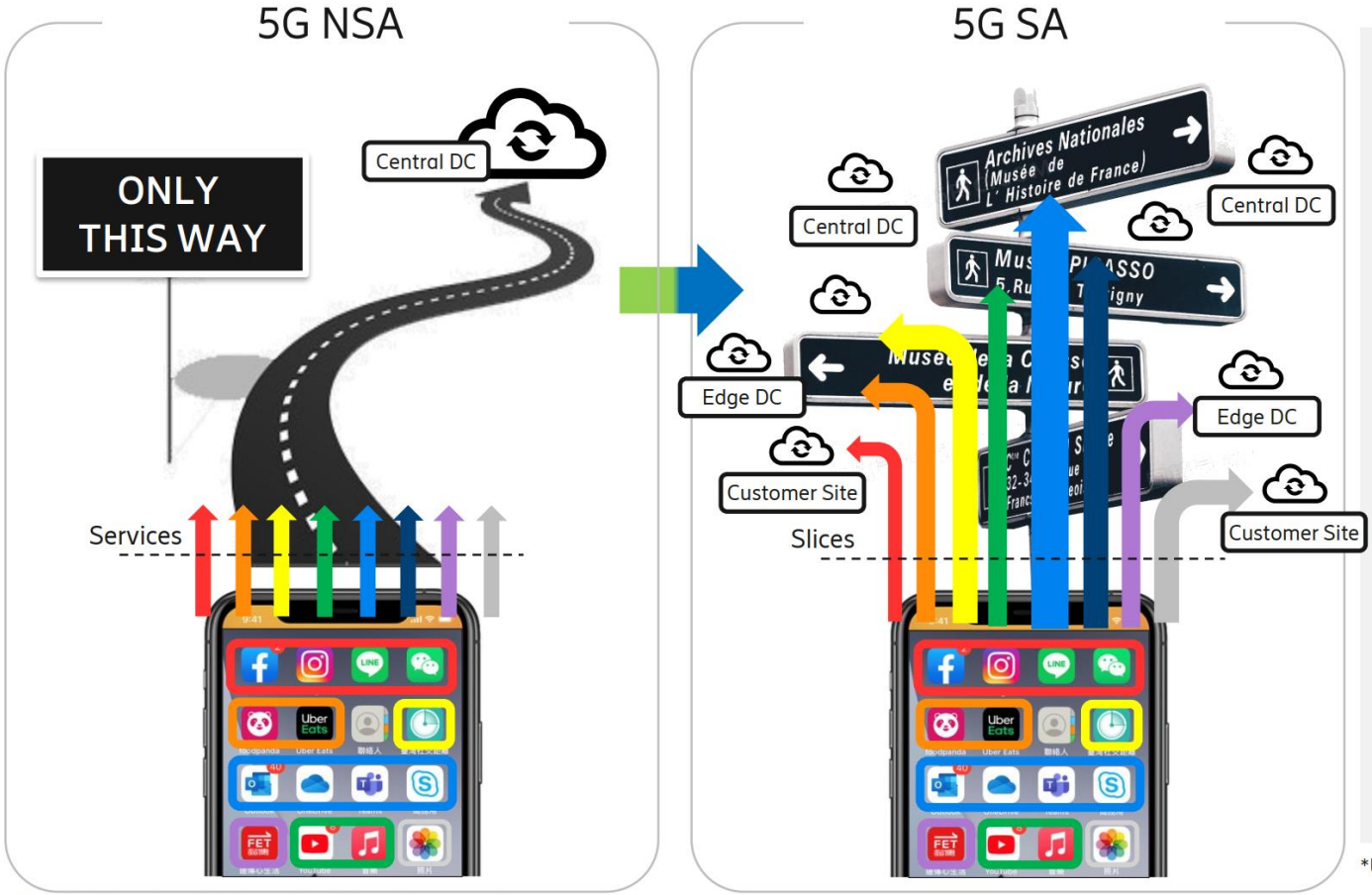


Non-standalone LTE and NR under 5GC (option 7)

5G NSA vs. 5G SA with Network Slice

Different Services connected to Different Networks

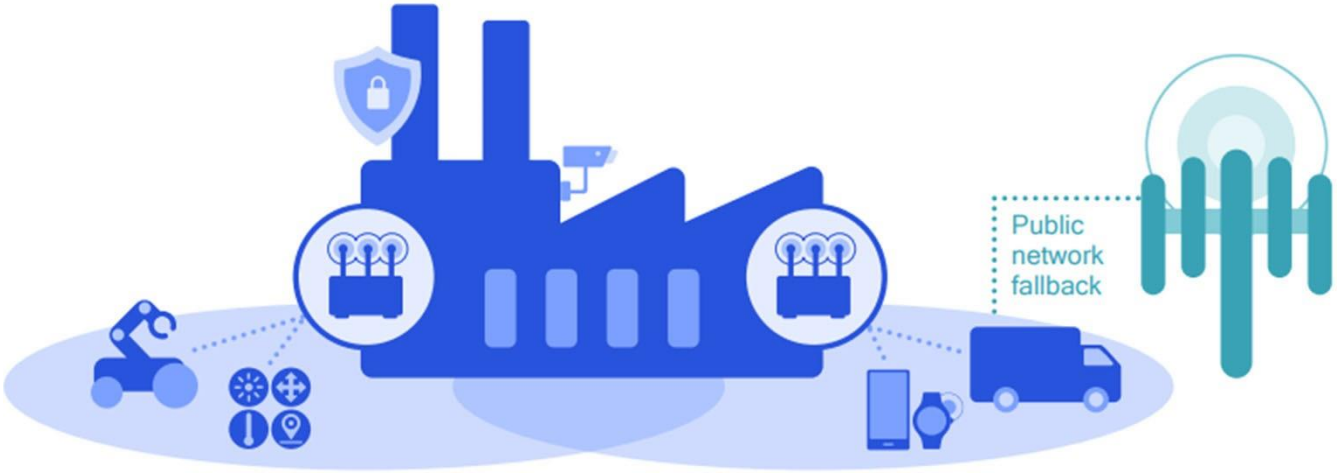
1
Network
↑
Different Services



8
Different Networks
↑
Different Service Profiles
+
Network Selection Policy (*URSP)
+
Applicable Charging Model

*URSP = UE Route Selection Policy

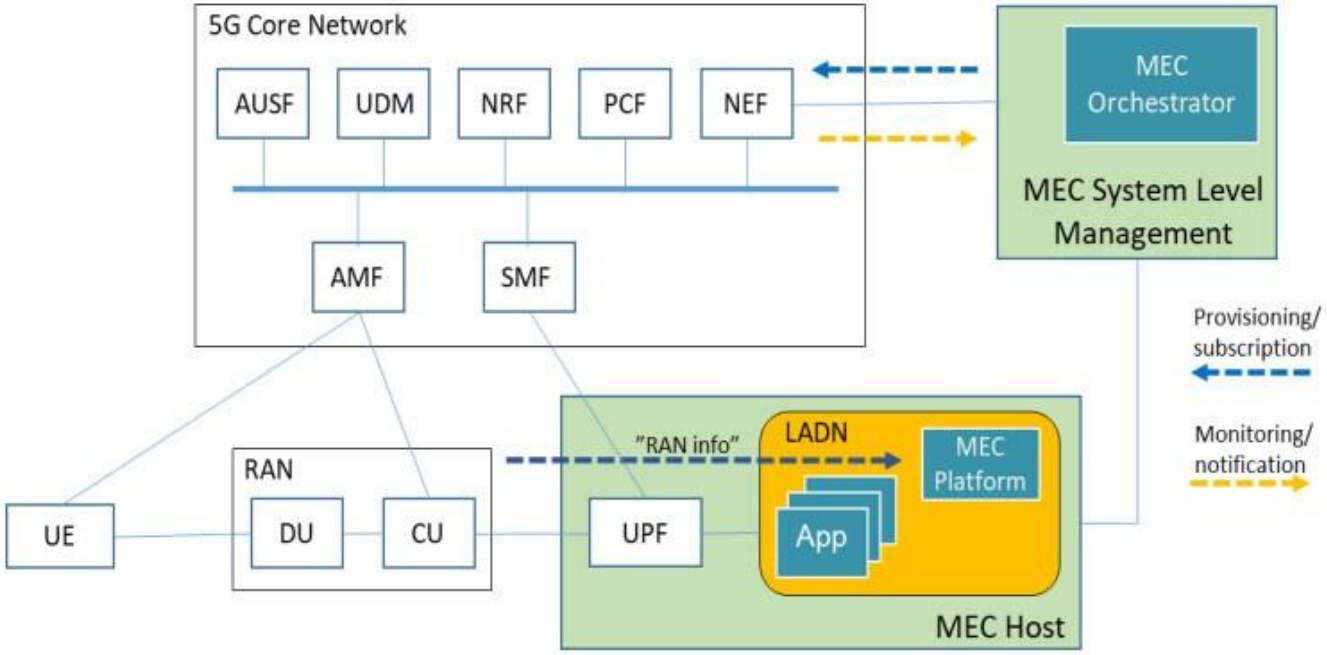
Private 5G Network for Enterprises



Dedicated
- Local Networ
- Dedicated Resources
- Self Managed

Secured
- 3GPP Security
- Data reside in premise

Optimised
- Tailored for required QoS



The separation of user place enables deployment of multi edge commuting.

Such edge services includes gaming, Virtual reality, cloud services ,third-party cloud service ,Healthcare services Fleet management, Industrial IoT etc

mmWave deployment

eMBB

FWA

Hot Spot

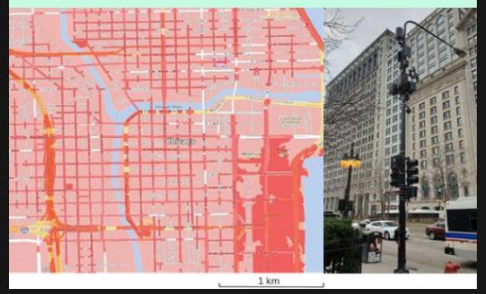
- All, ATT,
  - Performance and capacity
  - Indoor and outdoor

City macro sites

- TMO, Japan, AU
  - Leverage existing sites
  - Spotty coverage

Street sites

- Verizon, Telstra
  - Densify for best coverage
  - Urban + Suburban

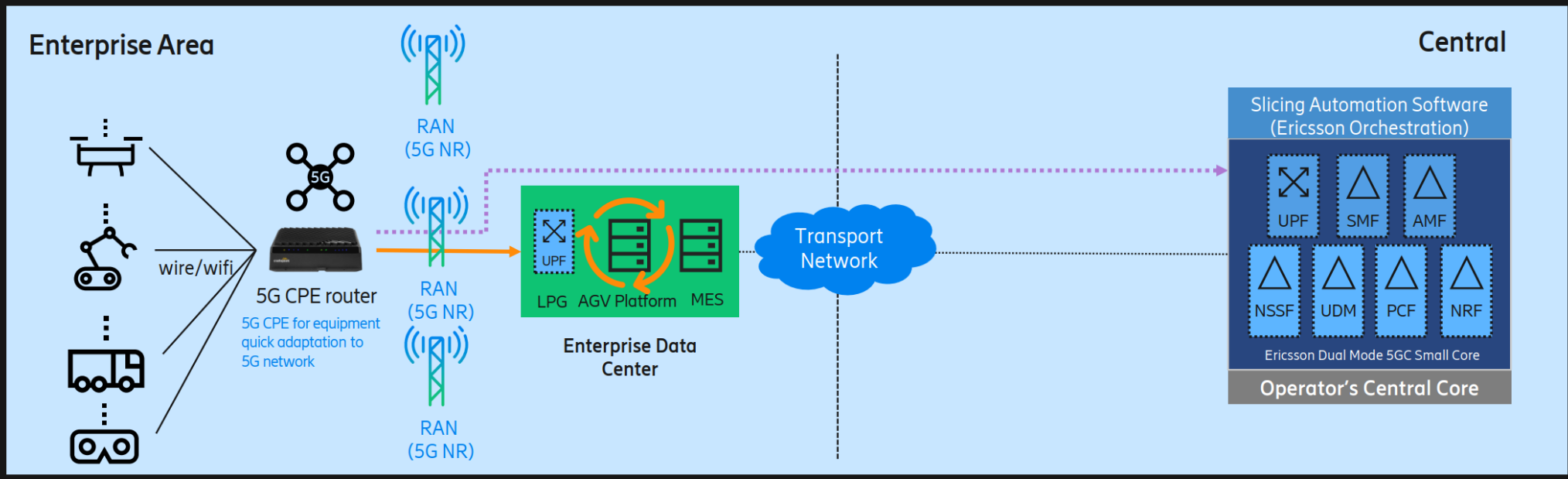


Macro tower

- Fastweb, USCC
  - Coverage targeting FWA customer

Use Cases : 5G Smart Manufacturing

- 5G network as main infrastructure to connect all factory's equipment. Optimize production processes through data linking and product tracking on the assembly line
- 5G AGV for transport the product within factory area. 5G can provide seamless mobility for AGV between indoor<->outdoor or between floor in the building
- On-premise LPG for data local-break out. Provide low-latency and highly secured network by 5G. No data out of the factory area



mmWave HW products for all deployments

AIR 1281

High Band 5G deployment on street and in open indoor, for speed and capacity

- Small formfactor radio for pole, wall and strand deployment
- Larger venues indoor deployment

High Band (mmWave) 800 MHz OBW
EIRP: 53-56 dBm
Volume: 7 liter, Weight: 8 kg

AIR 5322

Street Macro High Band Radio

- Small formfactor radio for roof top deployment

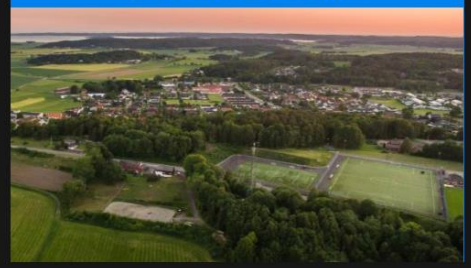
High Band (mmWave) 800 MHz OBW
EIRP: 59-62 dBm
Volume: 7 liter, Weight: 8 kg

Hot Spot

City macro sites

Street sites

Macro tower

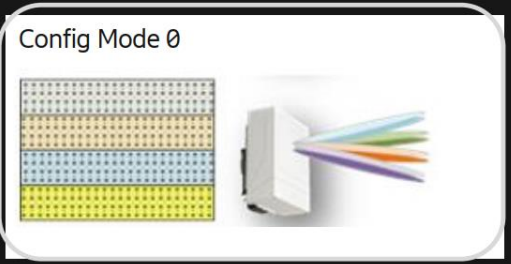


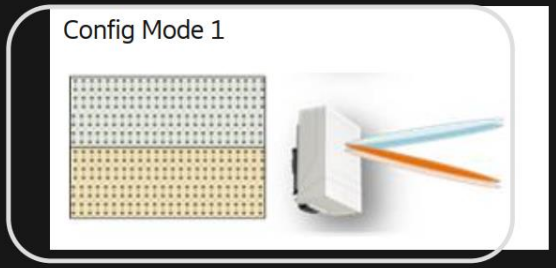
Antenna Configuration Modes
AIR5322

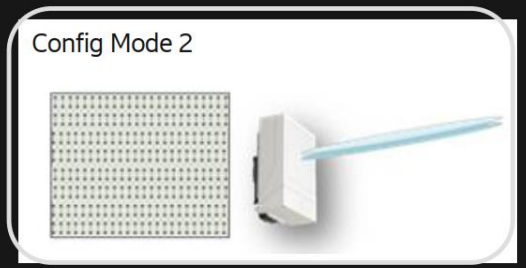
— AIR5322 supports 3 Configuration Modes.
- Mode 0 :4 blocks of 200MHz 8 CC (100MHz carrier)Two layers per carrier
- Mode 1: 2 blocks of 400MHz 8 CC (100MHz carrier)Two layers per carrier
- Mode 2: 1 blocks of 400MHz 4 CC (100MHz carrier)Two layers per carrier

— PAAM Split Mode, that allows up to 8 Carriers – 4 Per PAAM segment where each segment has maximum bandwidth of 400MHz

— By enabling DL carrier aggregation 8CC, the total bandwidth of 800 MHz of two PAAM segments can be utilized for downlink data transfer by one UE







mmWave SW evolution

First product in 2019

- Robust configurations
- Basic coverage and performance

Focus on 5G coverage and beam management robustness

- UL and DL physical channel improvements
- Enhanced beam management
- High speed UE up to 100km/h
- Extended range support (FWA)

Maximize user data rate and ease of deployment

- Peak rate evolution
- Enhanced RRM
- SA introduction with FR1-FR2 DC
- Fronthaul sharing
- Coverage shapes
- Indoor solution

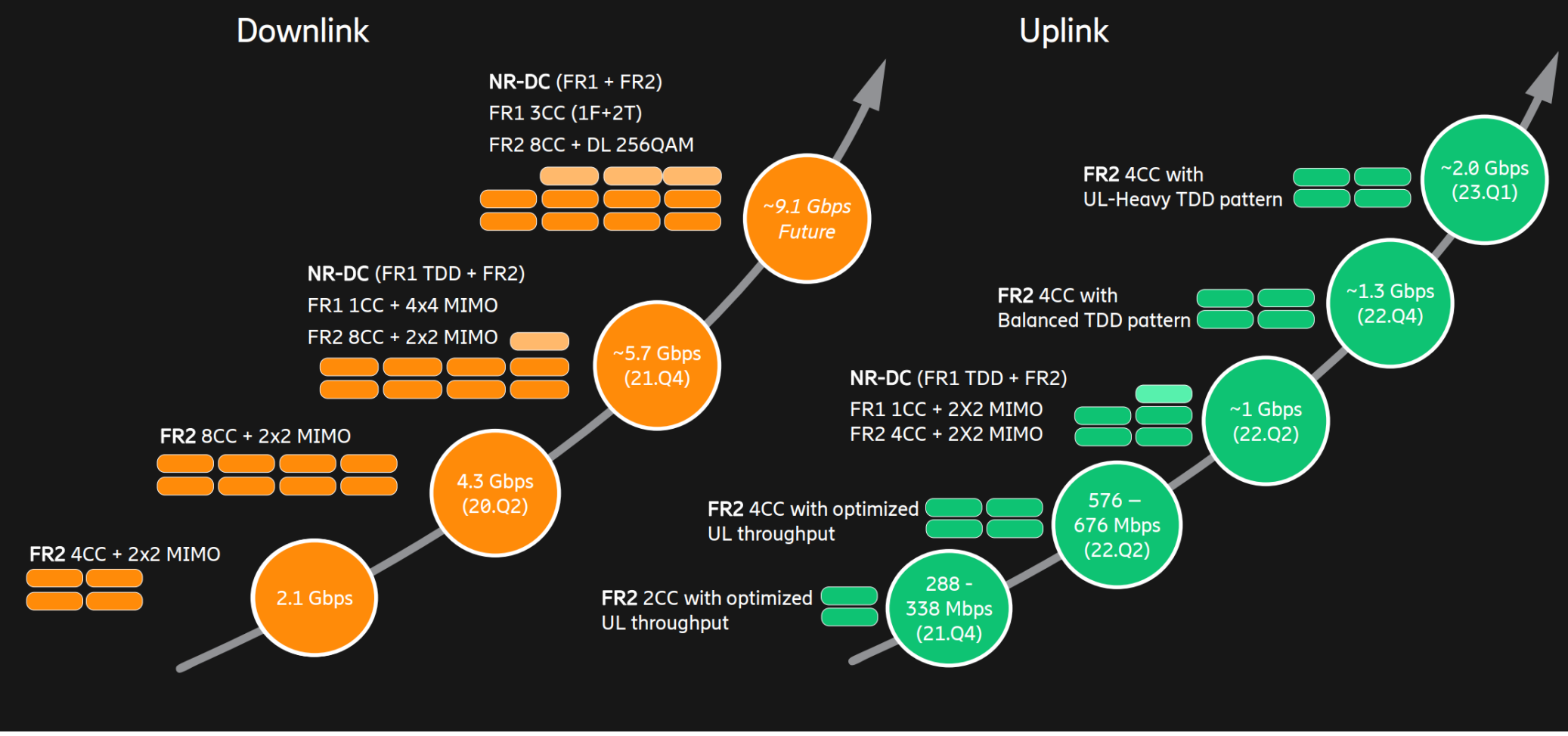
Improve performance (capacity, coverage) for high-load networks

- Capacity evolution
- Multi-user scheduling
- Multi-layer NW
- Traffic management

Enable new business & improve cost efficiency

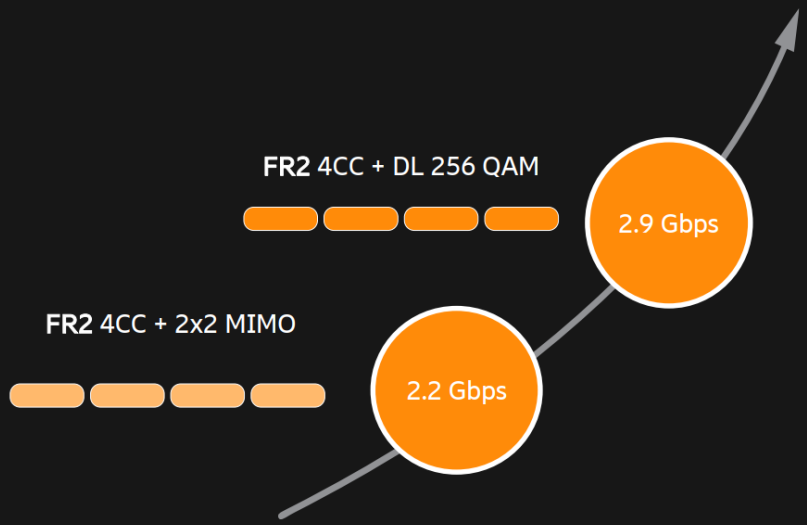
- Critical IoT
- QoS/Slicing framework
- TDD patterns for local deployment
- FR2 SA
- Energy efficiency
- UE power saving

Peak Rate Evolution

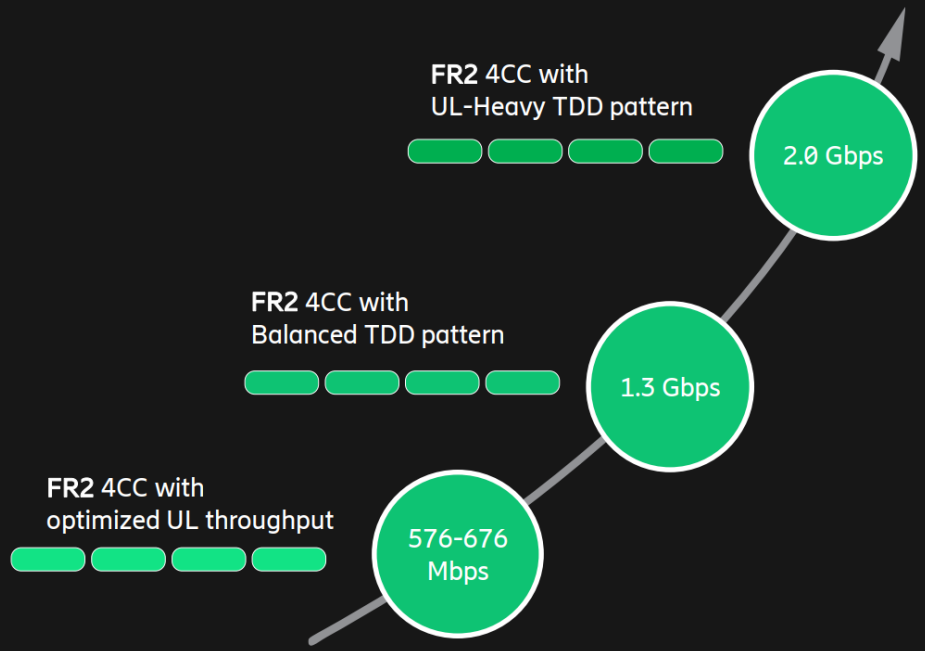


NT configuration
n258 : 26.4-26.8GHz

- 4x100MHz

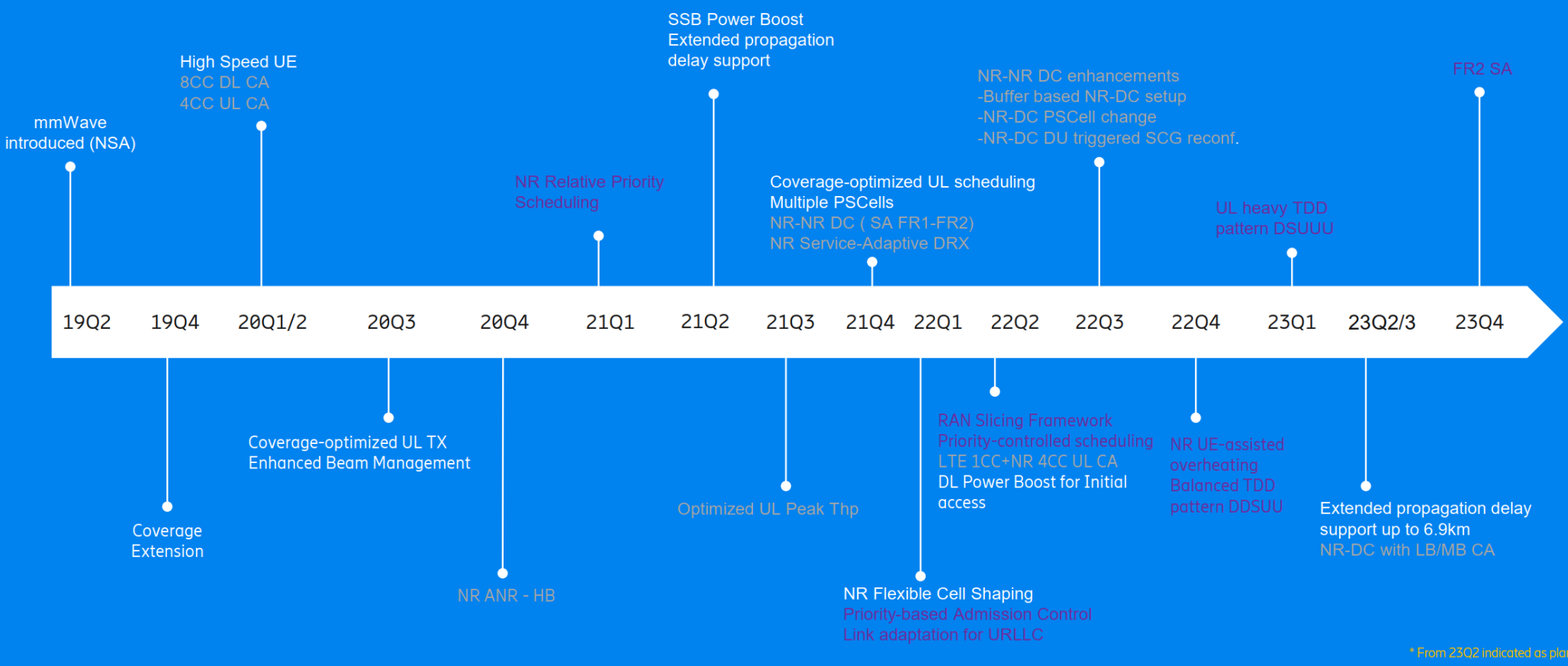


Downlink



Uplink

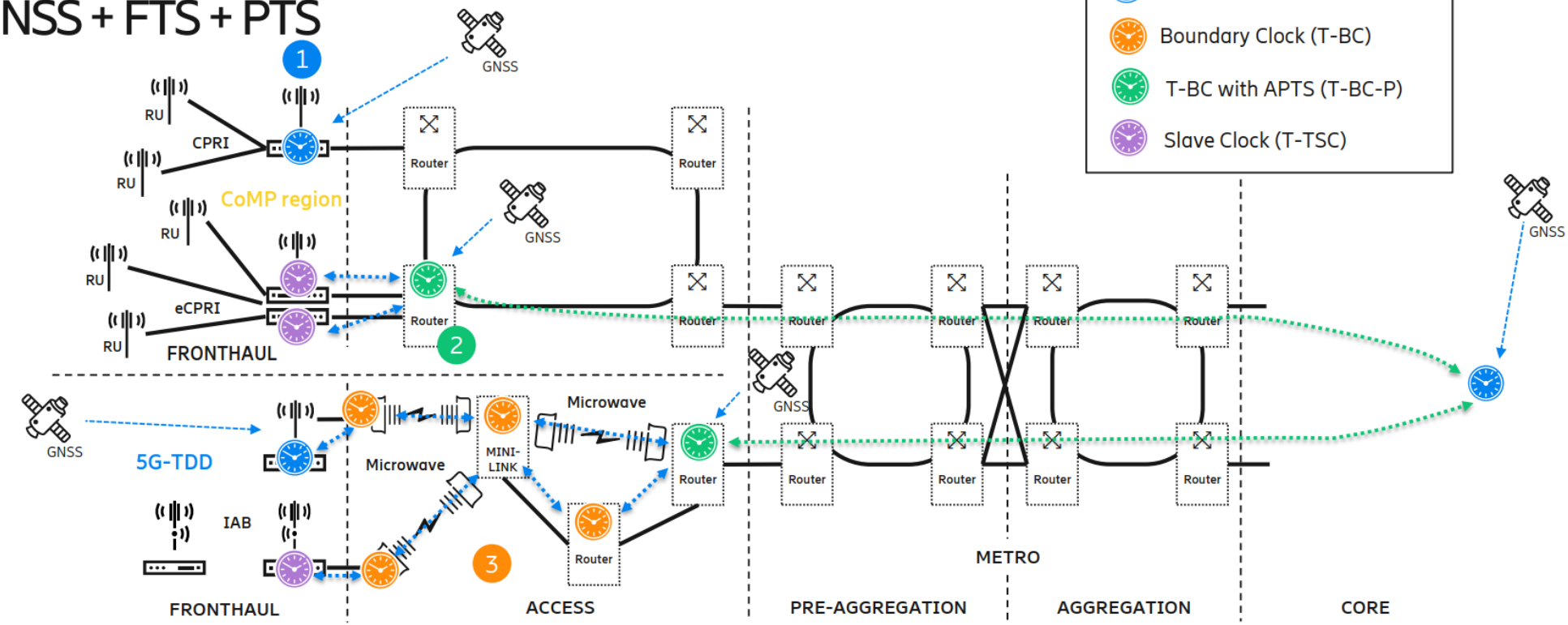
mmWave SW evolution



* From 23Q2 indicated as planned

End-to-end time sync distribution

GNSS + FTS + PTS



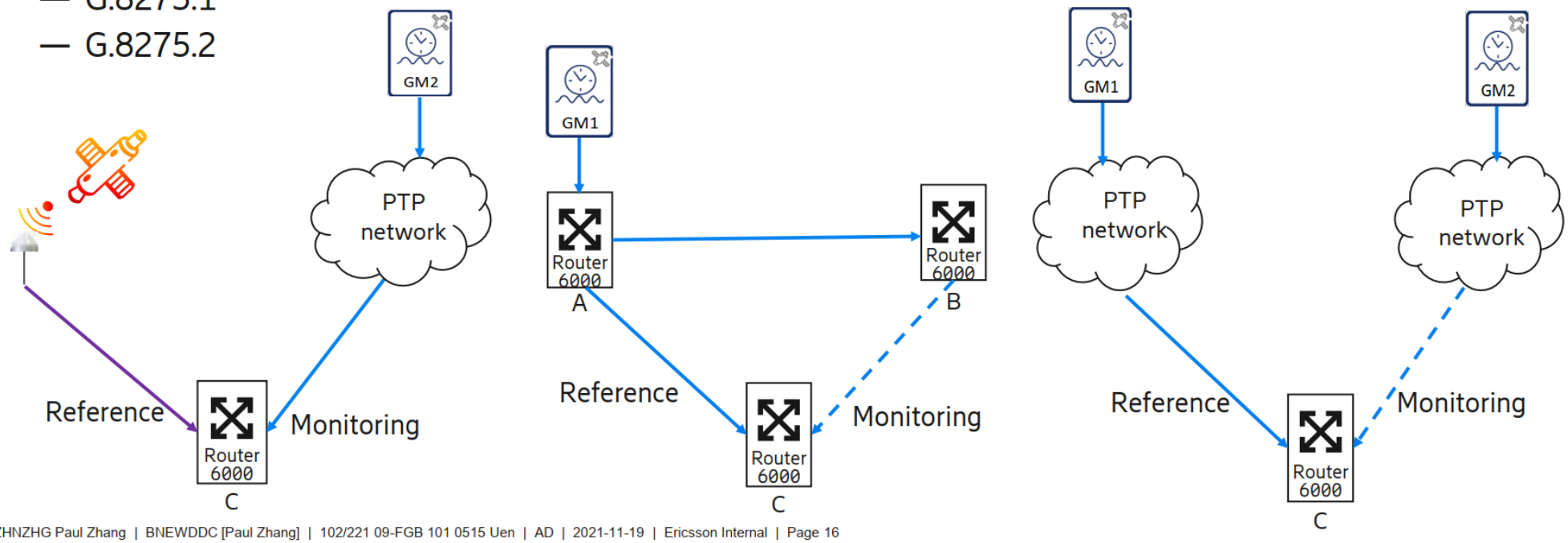
High accuracy Fronthaul for tight coordination
Standards: G.8271.1; G.8275.1; G.8273.2 (Class B/C);

Full timing support in access network for accuracy, redundancy and reliability
Standards: G.8271.1; G.8275.1; G.8273.2 (Class B/C);

Backup PTS connections over core network without PTP support
Standards: G.8275.2; G.8273.4; G.8271.2

PTP quality monitoring and measurement scenarios

- Reference clock source can be
  - GNSS which is mandatory to be primary clock source
  - G.8275.1
- Clock source under monitoring can be
  - G.8275.1
  - G.8275.2

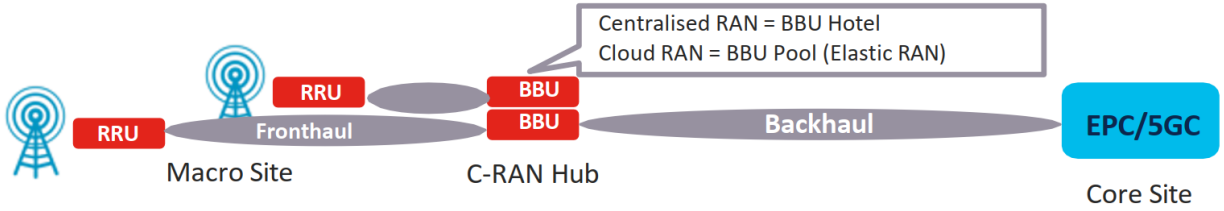


RAN Evolution and Definitions

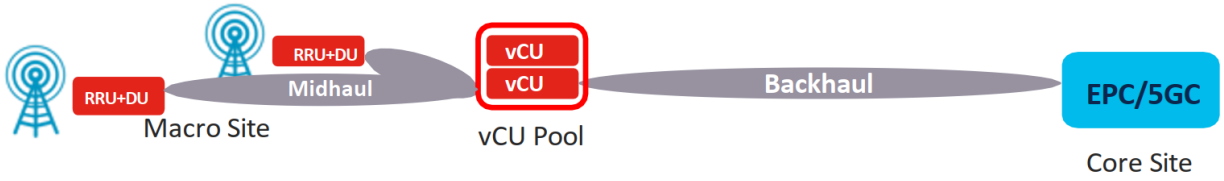
Glossary
= Remote Radio Unit
RU = Radio Unit
5GC = 5G Core
BBU – Baseband Unit
DU = Distributed Unit RRU
CU = Centralised Unit
EPC = Evolved Packet Core
MEC = Multi-access Edge Compute

DRAN – Distributed RAN

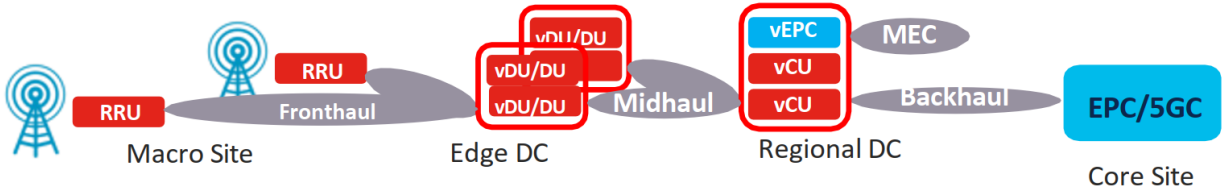
CRAN – Centralised RAN



CRAN – Centralised RAN



CRAN – Centralised RAN



RAN Evolution and Definitions

Glossary

= Remote Radio Unit
RU = Radio Unit
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EPC = Evolved Packet Core
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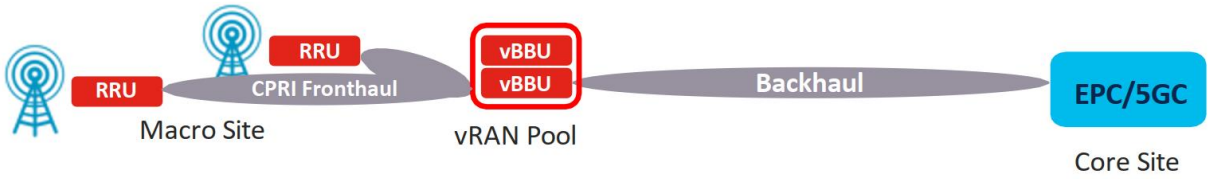
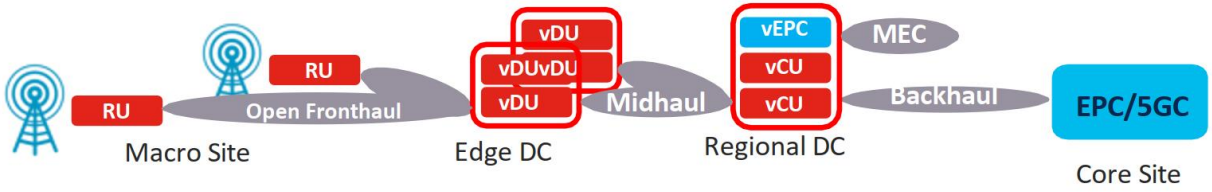
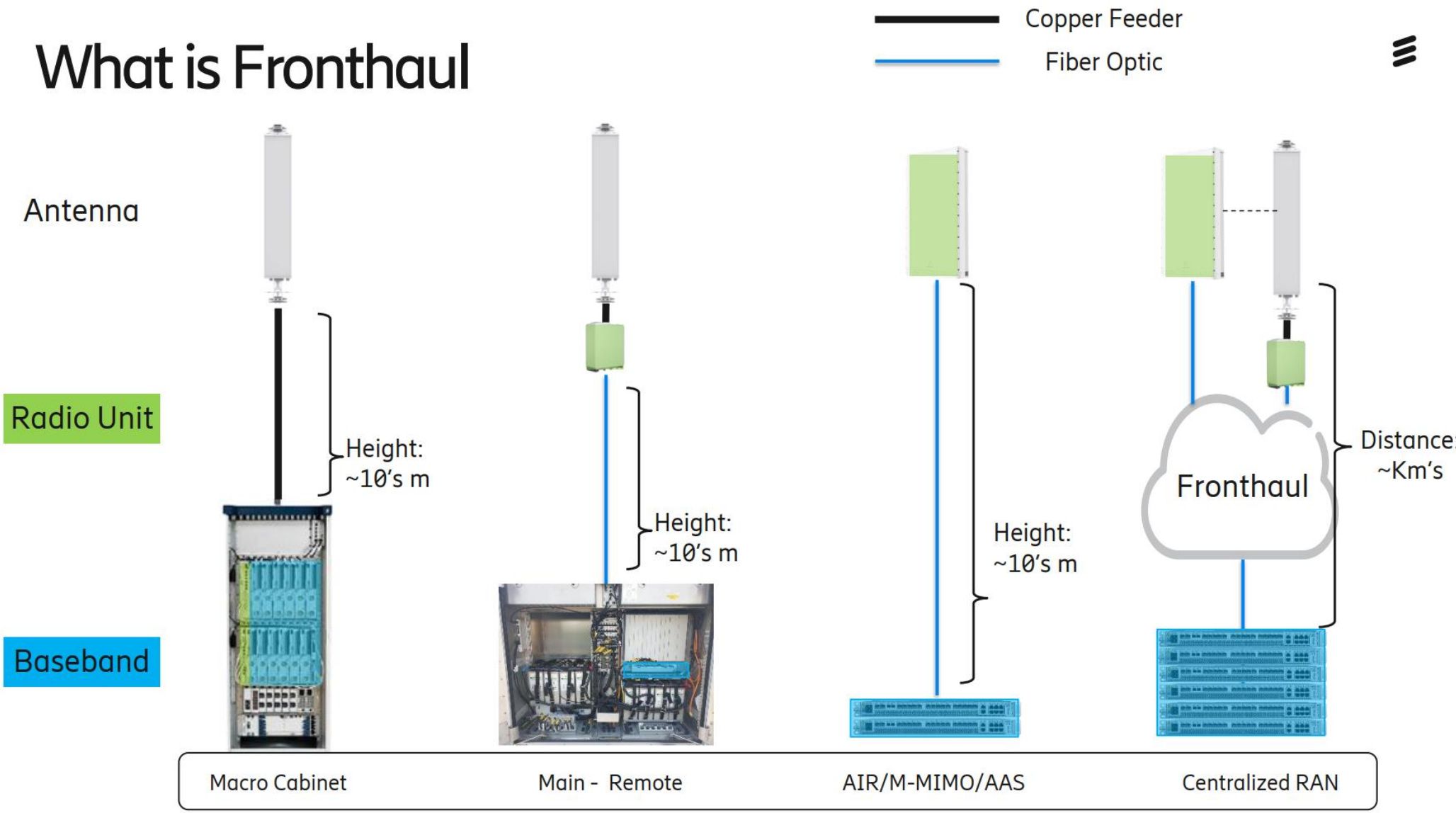
VRAN – Virtualised RAN



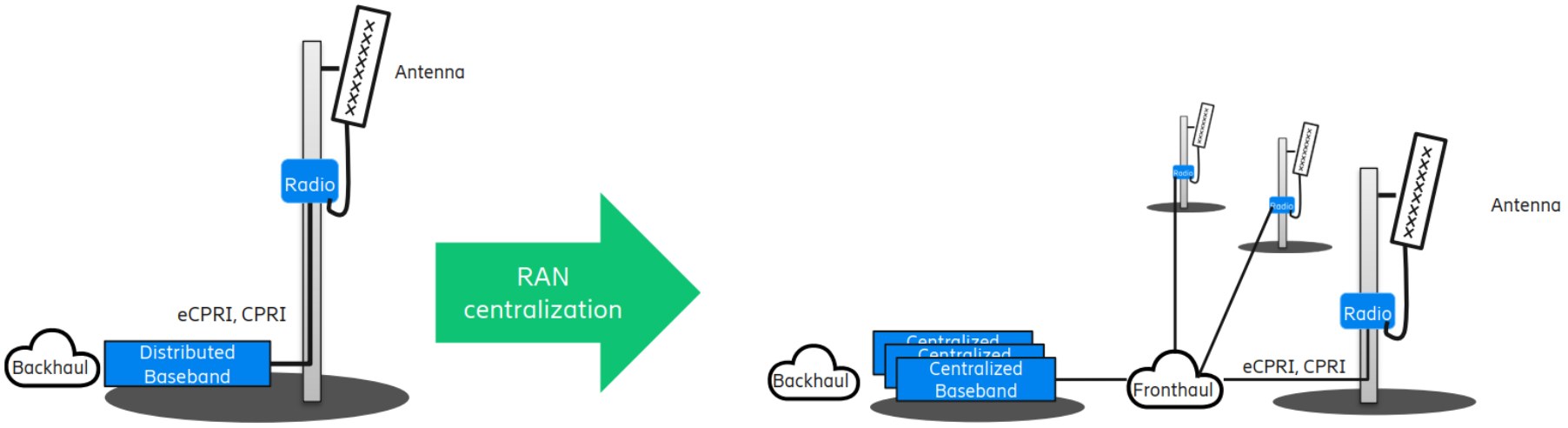
ORAN – Open vRAN



What is Fronthaul



From DRAN to CRAN



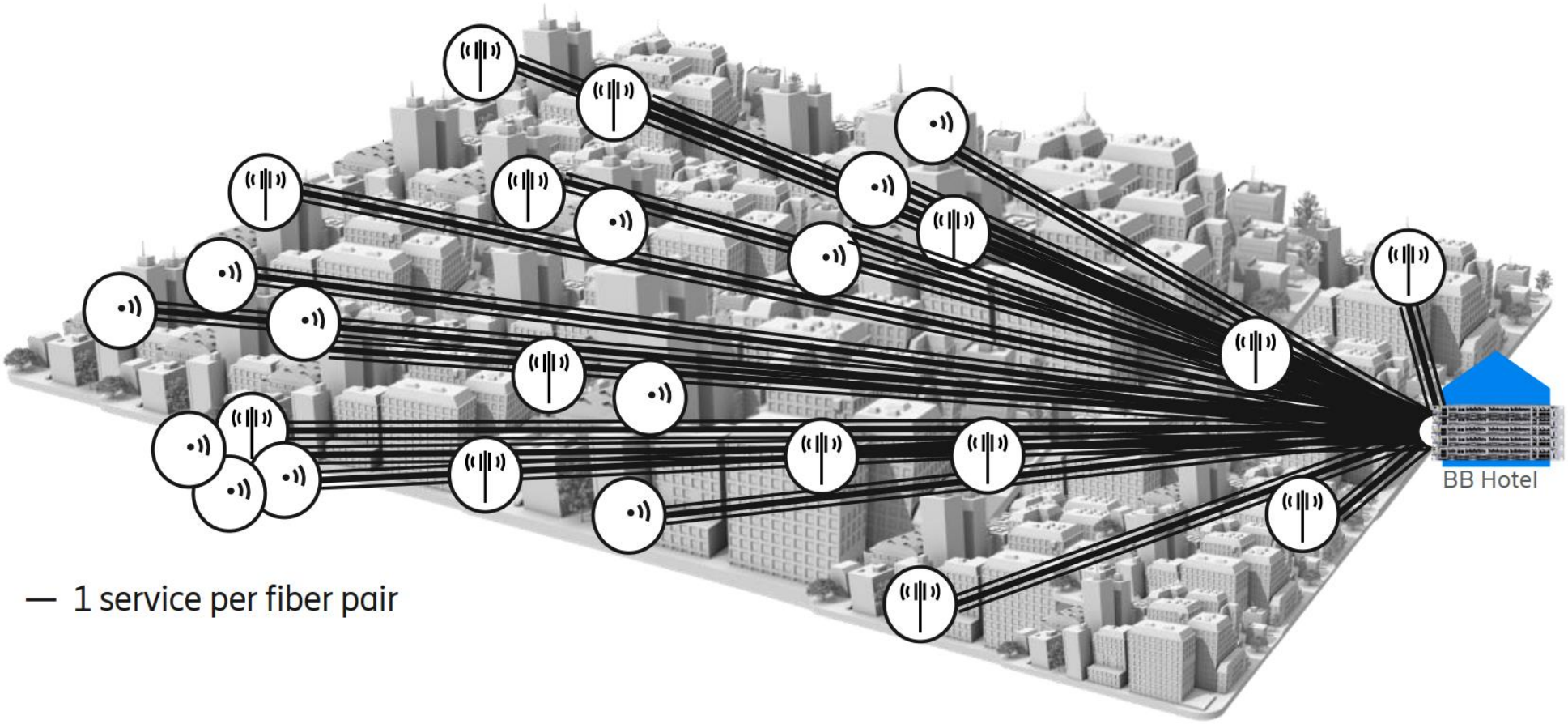
Distributed RAN site
- Antennas
- Radios
- Basebands
- Power
- Battery
- Air conditioner
- Site router
- GPS

Baseband hotel site
- Basebands
- Power
- Battery
- Fronthaul
- Air conditioner
- Site router
- GPS

Radio site
- Antennas
- Radios
- Fronthaul
- Power
- Battery

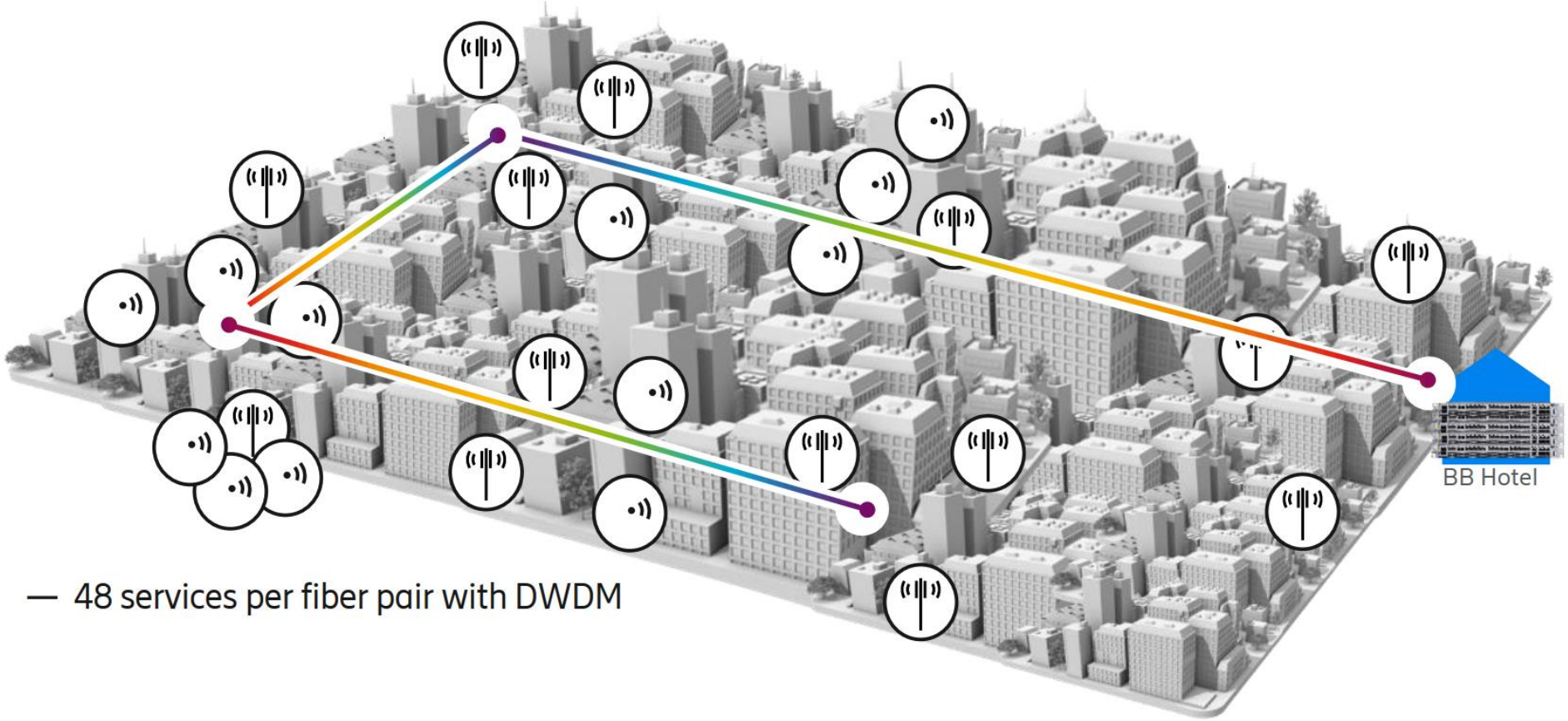
Centralized RAN requires a lot of fiber

Densification and Capacity



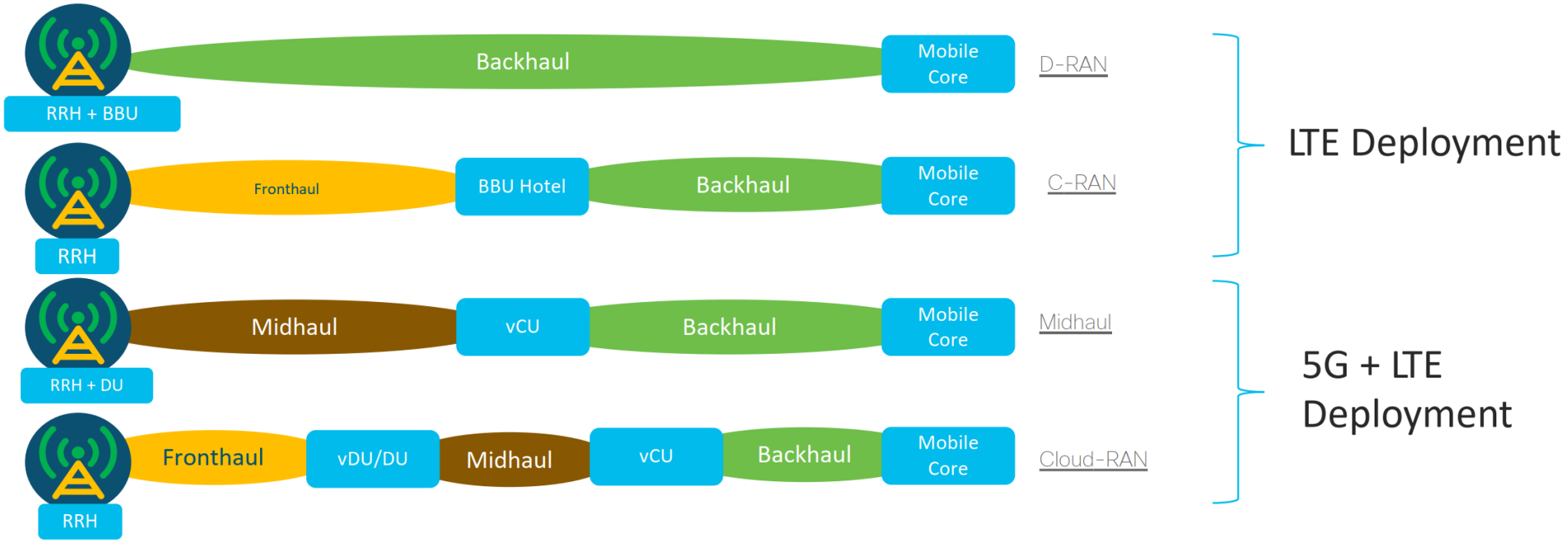
— 1 service per fiber pair

Fronthaul 6000 lowers the fiber requirement with DWDM technology



— 48 services per fiber pair with DWDM

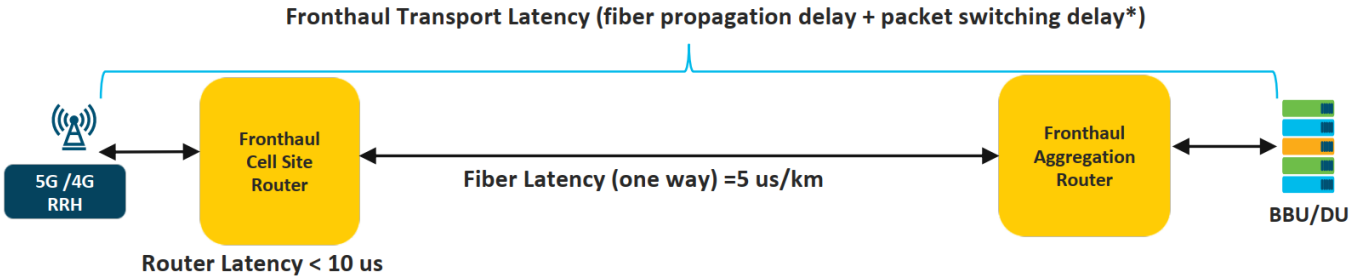
Mobile Network Deployment Models



NG Transport	1-Way Latency	BBU and RRH Typical Distance	Interface
Backhaul	Service dependent	10 km to 80 km	10G/25G/100G/200G
Midhaul	1-5ms	10 km to 25 km	10G/25G/100G
Fronthaul	75us/100 us (LTE) 150us (5G NR uRLLC)	<15 km <30 km	10G/25G

BBU: Baseband Unit (CU + DU)
RRH: Remote Radio Head
CU: Central Unit
DU: Distributed Unit

Transport Network Latency



Network	Split Options	Transport Latency One Way	Bandwidth
Backhaul (S1 / Nx)	None	Service Dependent	~User bandwidth
Midhaul (F1)	Option 2: PDCP-RLC	1- 5 milliseconds	~User bandwidth
Fronthaul	Option 8	75us/100 us (LTE)	Very High
Fronthaul	Option 7: PHY Hi- PHY Lo	150us (5G NR uRLLC)	High
Fronthaul	Option 7: PHY Hi- PHY Lo	500 us (5G NR eMBB)	High

Fronthaul Latency ?

- Sync Uplink HARQ loop (LTE)
- Async Uplink HARQ loop (5G NR)

Fronthaul Latency impact on distance

- LTE: 100us – Maximum distance **20KM (fiber propagation delay + packet switching delay)**
- 5G: 500us– Maximum distance **100KM (fiber propagation delay + packet switching delay)**

Source OCP Telcos Project: AT&T Fronthaul Gateway (FHG) requirements and Use Cases Revision 1

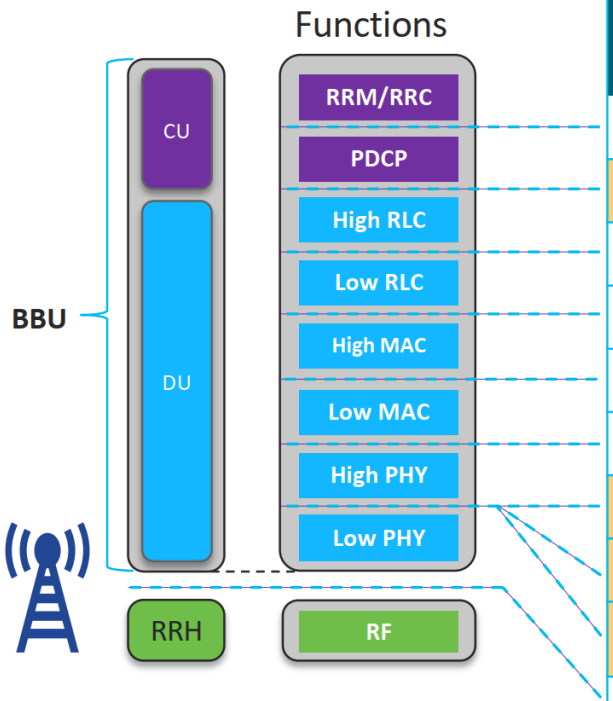
- Fronthaul uRLLC Round trip (RRT) must not exceed **125 micro seconds** (62.5 microseconds one way)
  - The maximum fiber distance between the RRU and BBU is 10km
  - This delay budget requirement applies to both CPRI and eCPRI traffic.

*The processing performed by the BBU (DU) or RRH is not included

CU Centralized Unit
DU Distributed Unit
BBU Baseband Unit
RRH Remote Radio Head

RAN Functional Split Consideration

Some 5G requirements — such as ultra-low latency and ultra-high throughput — require highly flexible RAN architecture and topology. This will be enabled by splitting RAN functions, including the separation of the user plane (UP) and the control plane (CP) in higher layers.

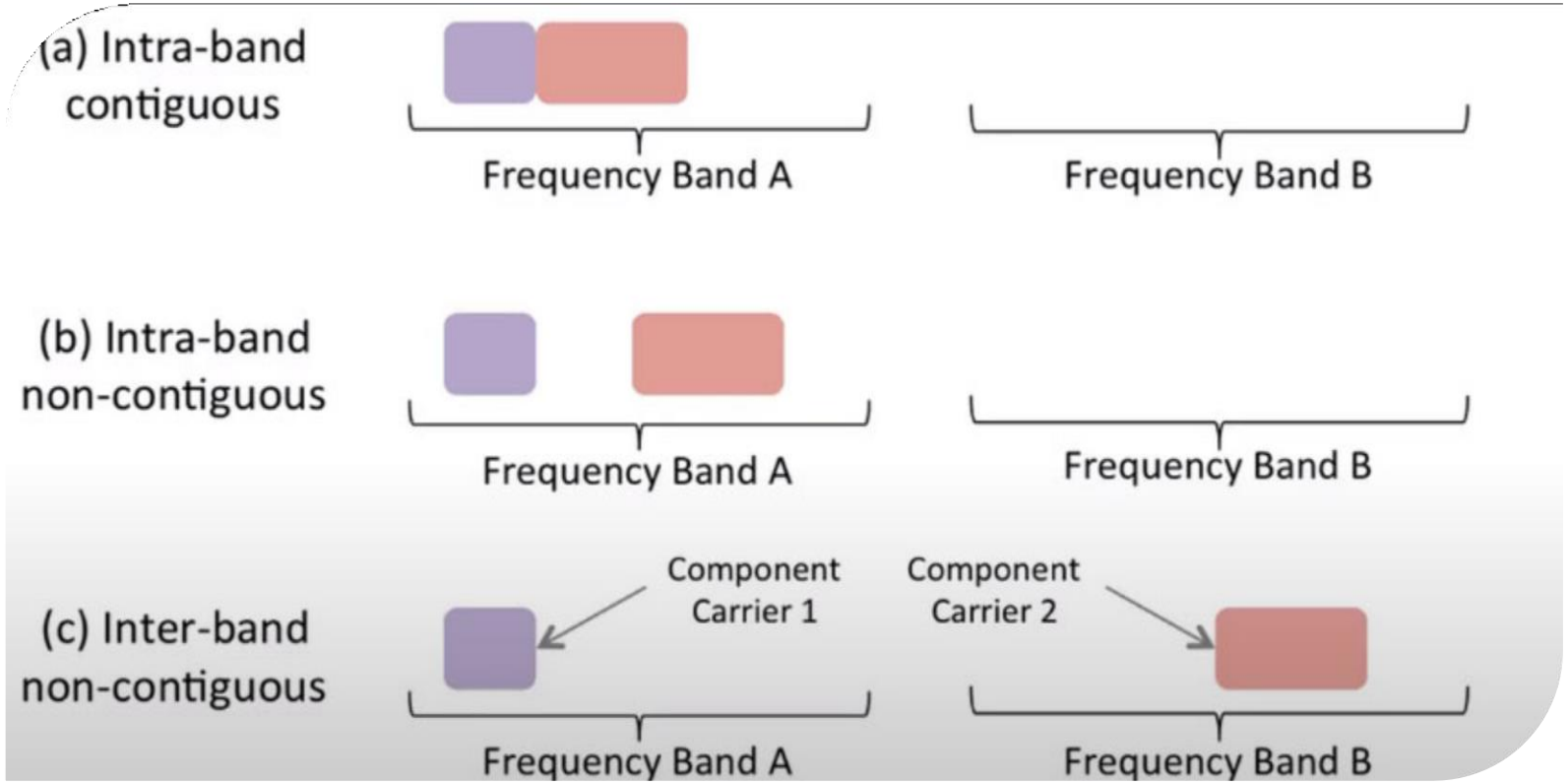


Split Option	Required Bandwidth		Max allowed 1-way Latency	Fronthaul Interfaces
	DL	UL		
Option 1	4Gbps	3Gbps	10ms	
Option 2	4016Mbps	3024Mbps	1ms~5ms	F1 (3GPP)
Option 3	Lower than option 2 for UL/DL		1.5ms~10ms	
Option 4	4000Mbps	3000Mbps	Approx. 100us	
Option 5	4000Mbps	3000Mbps	100's us	
Option 6	4133Mbps	5640Mbps	250us	
Option 7a	10.1~22.2Gbps	16.6~21.6Gbps	250us	eCPRI ORAN ROE (IEEE1914.3)
Option 7b	37.8~86.1Gbps	53.8~86.1Gbps	250us	
Option 7c	10.1~22.2Gbps	53.8~86.1Gbps	250us	
Option 8	157.3Gbps	157.3Gbps	250us	CPRI

Transport costs minimized with higher splits

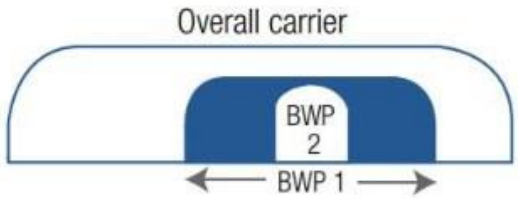
RF Gains improved with lower splits

Note: * Transmission link Requirements per TR 38.801 (100MHz, 256QAM,m 8x8 MIMO)

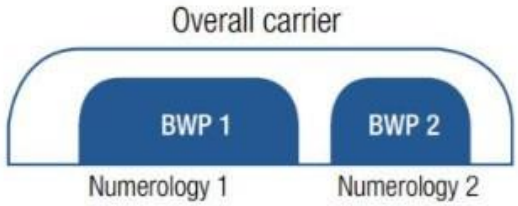


Up to 16 carriers in intra or intra band, contiguous or non contiguous can be aggregated to achieve high data rate

Bandwidth part



Inserts a reduced device energy consumption for each separate user through using smaller part of the overall carrier.



Overall carrier contains two non-contiguous bandwidth parts with different numerologies.

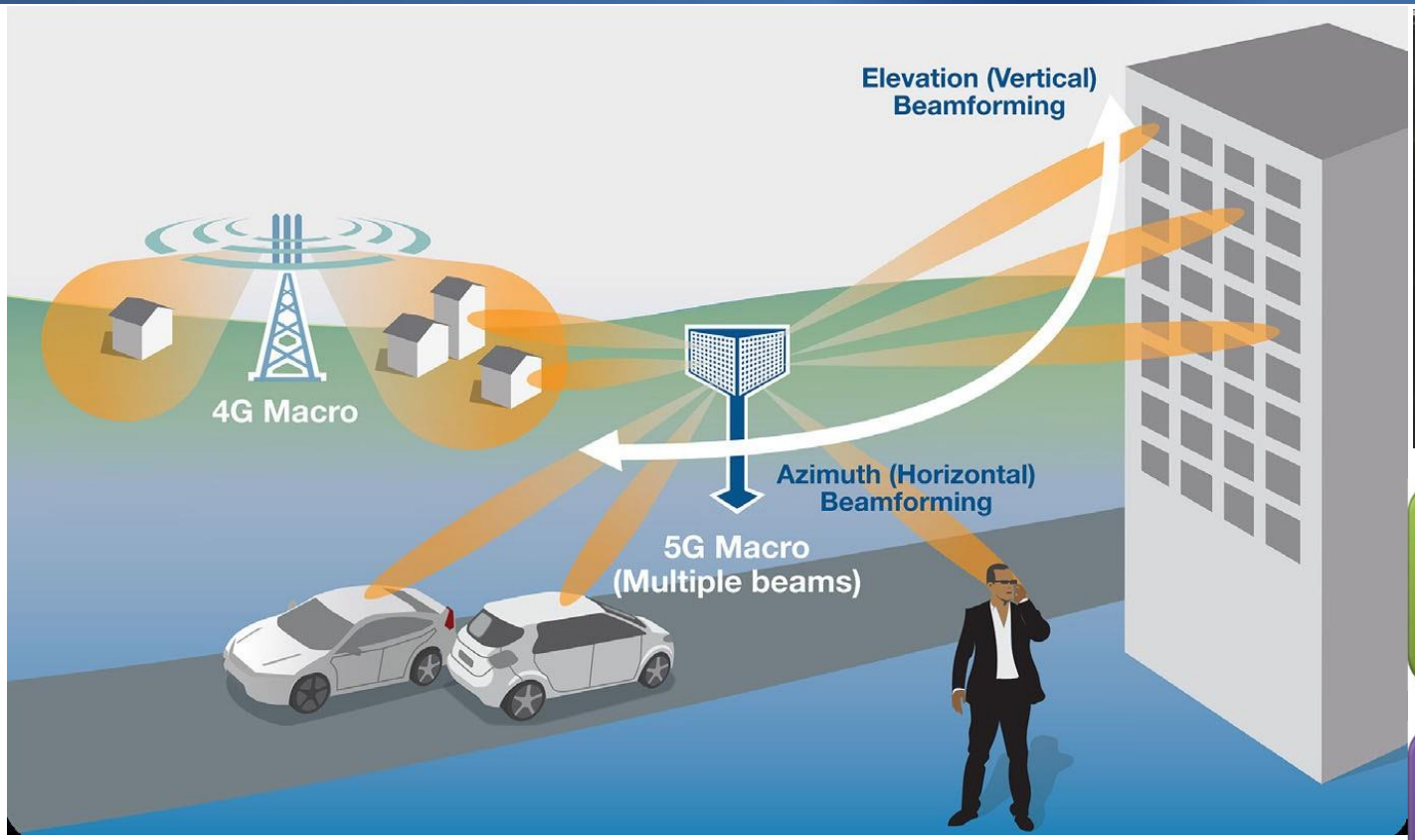
Non-contiguous spectrum that can have an unknown service inserted.

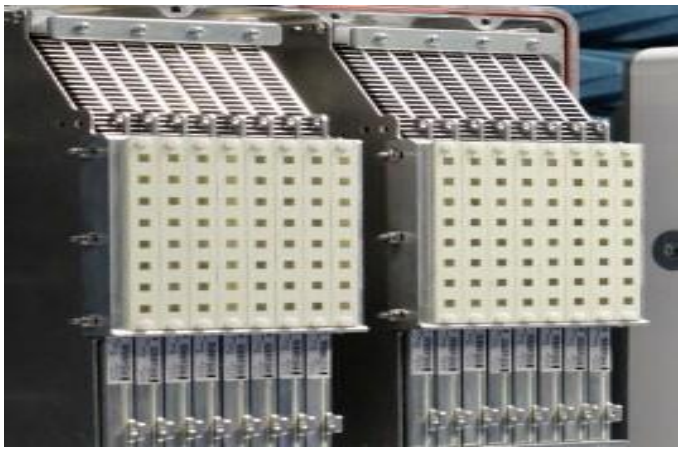
Open bandwidth to support something new or something not yet defined.

- Support reduced UE BW
- Supporting UE reduced Energy Consumption
- Support Different Numerology
- Support non contiguous spectrum
- Support Forward Compatibility

- Multiple element base station
- Greater capacity,
- Multiple users,
- Faster data

Massive MIMO and Beam Forming





Use of mm waves enables massive MIMO using small size antenna in large number in a single panel

Every antenna element can be controlled and hence beam can be formed and steered by changing the phase of signal.

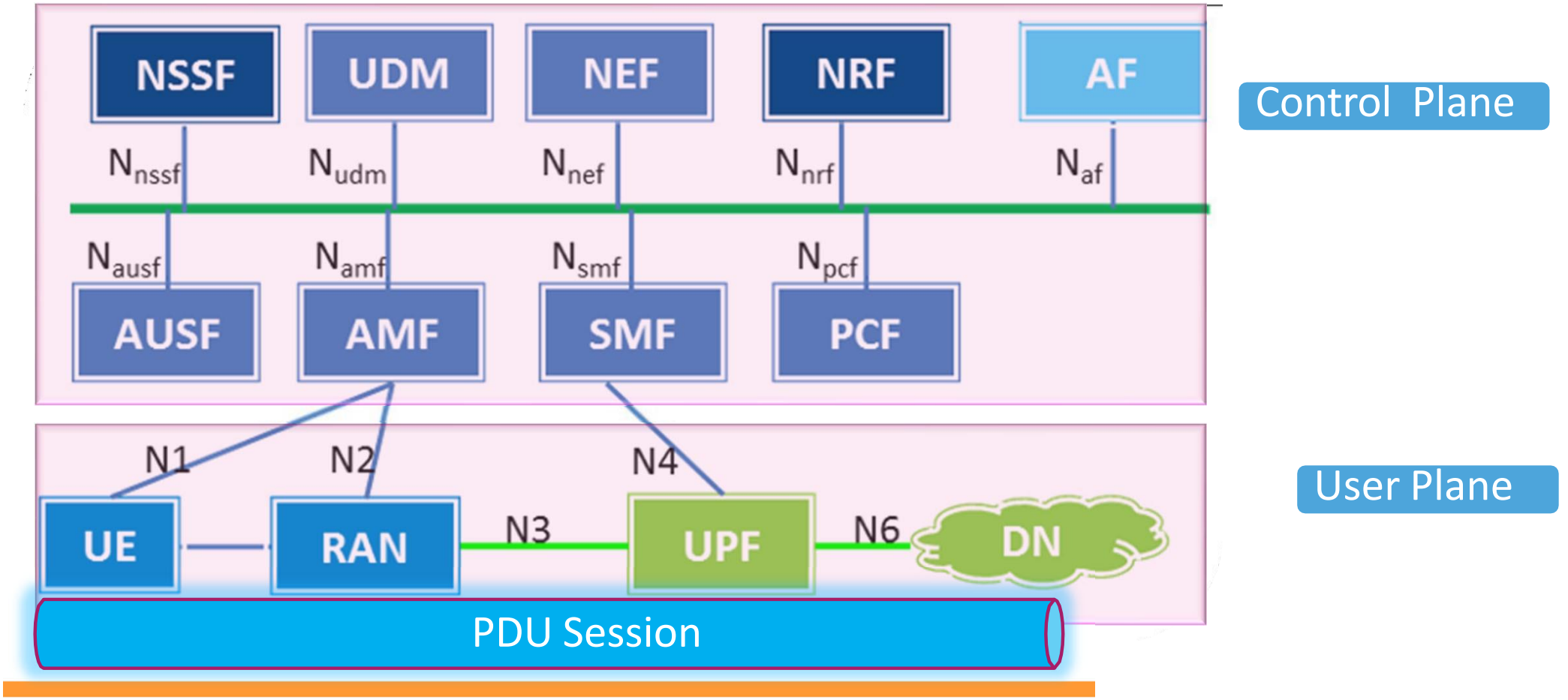
- Use of millimeter wave
- Need Dense Network of small cells
- Use of Street Furniture for Small Cell
- Requirement of fiber and radio backhaul.
- Enabling policy needed

Quality of Service in 5G

3GPP TS 23.501 V16.5.1 (2020-08)

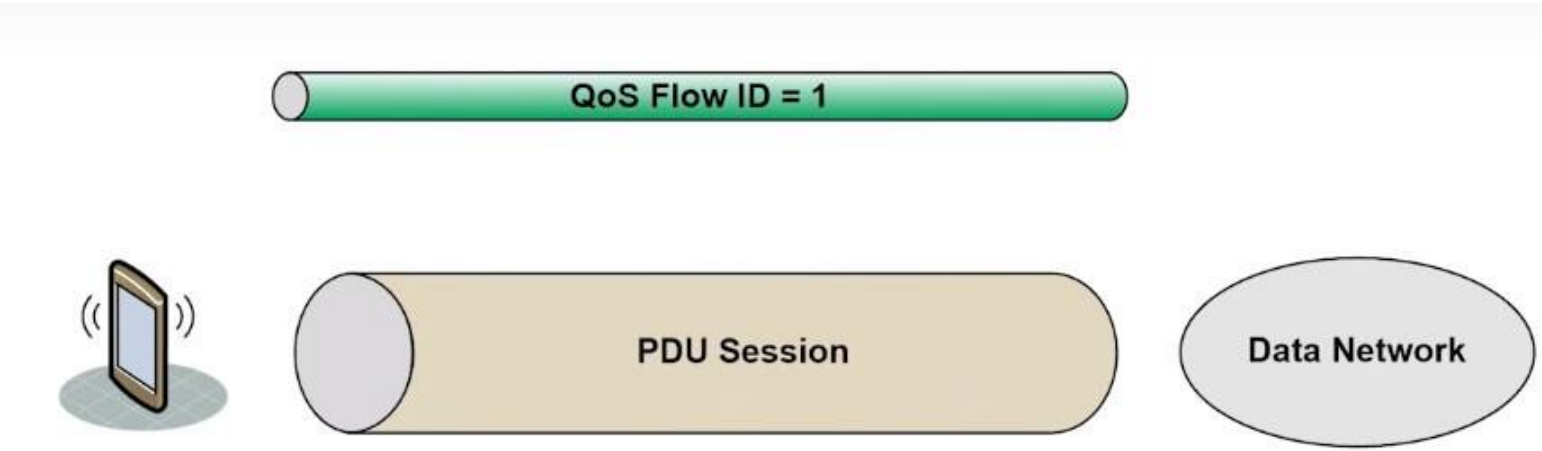
Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Services and System Aspects;
System architecture for the 5G System (5GS);
Stage 2
(Release 16)


NSSF
UDM
NEF
NRF
AF
Control Plane
N_{nssf}
N_{udm}
N_{nef}
N_{nrf}
N_{af}
N_{ausf}
N_{amf}
N_{smf}
N_{pcf}
AUSF
AMF
SMF
PCF
N1
N2
N4
User Plane
UE
RAN
N3
UPF
N6
DN
PDU Session

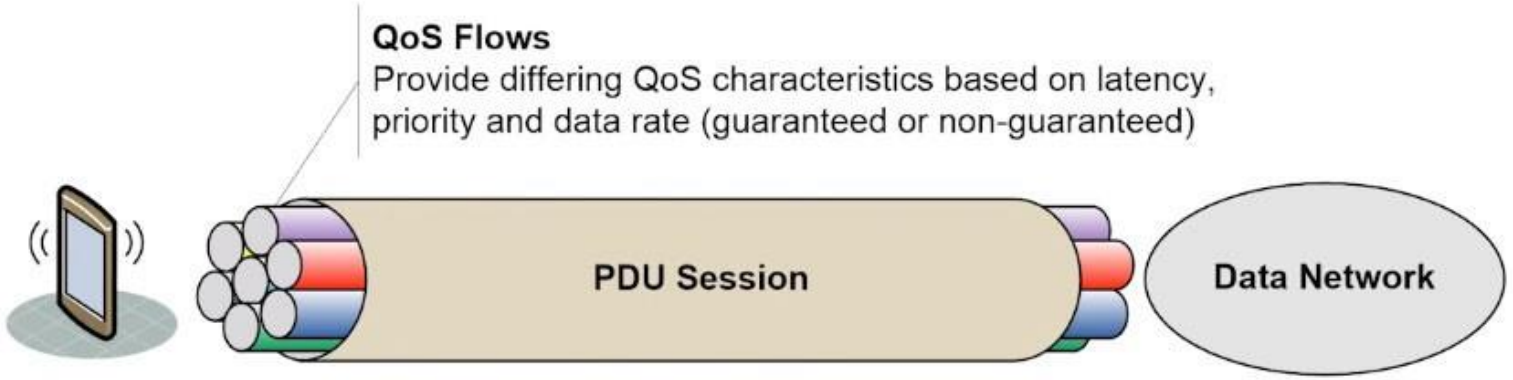
After Initial Registration, PDU Session is Created.

PDU Session is unique to UE



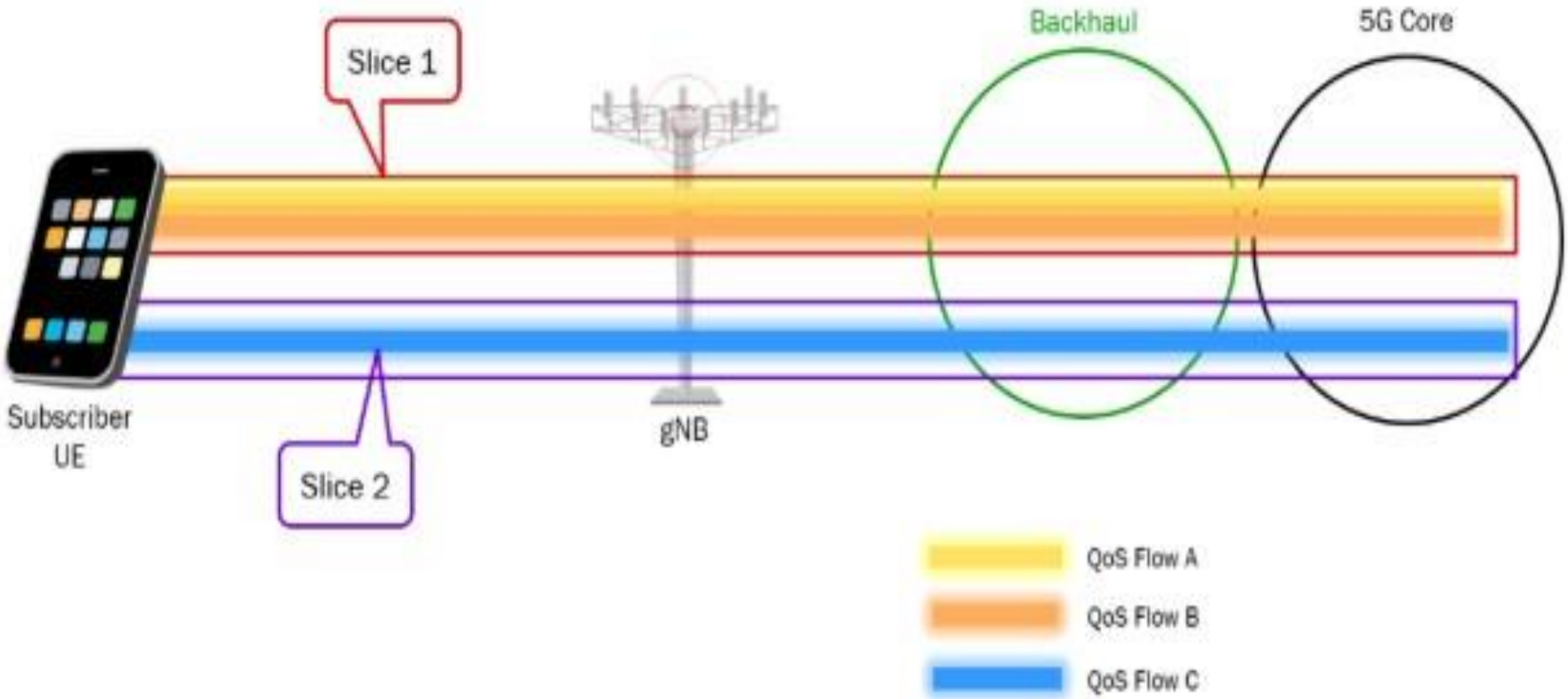
Within the PDU session, QoS is achieved by creating separate QoS Flows which are uniquely identified with a QoS Flow ID

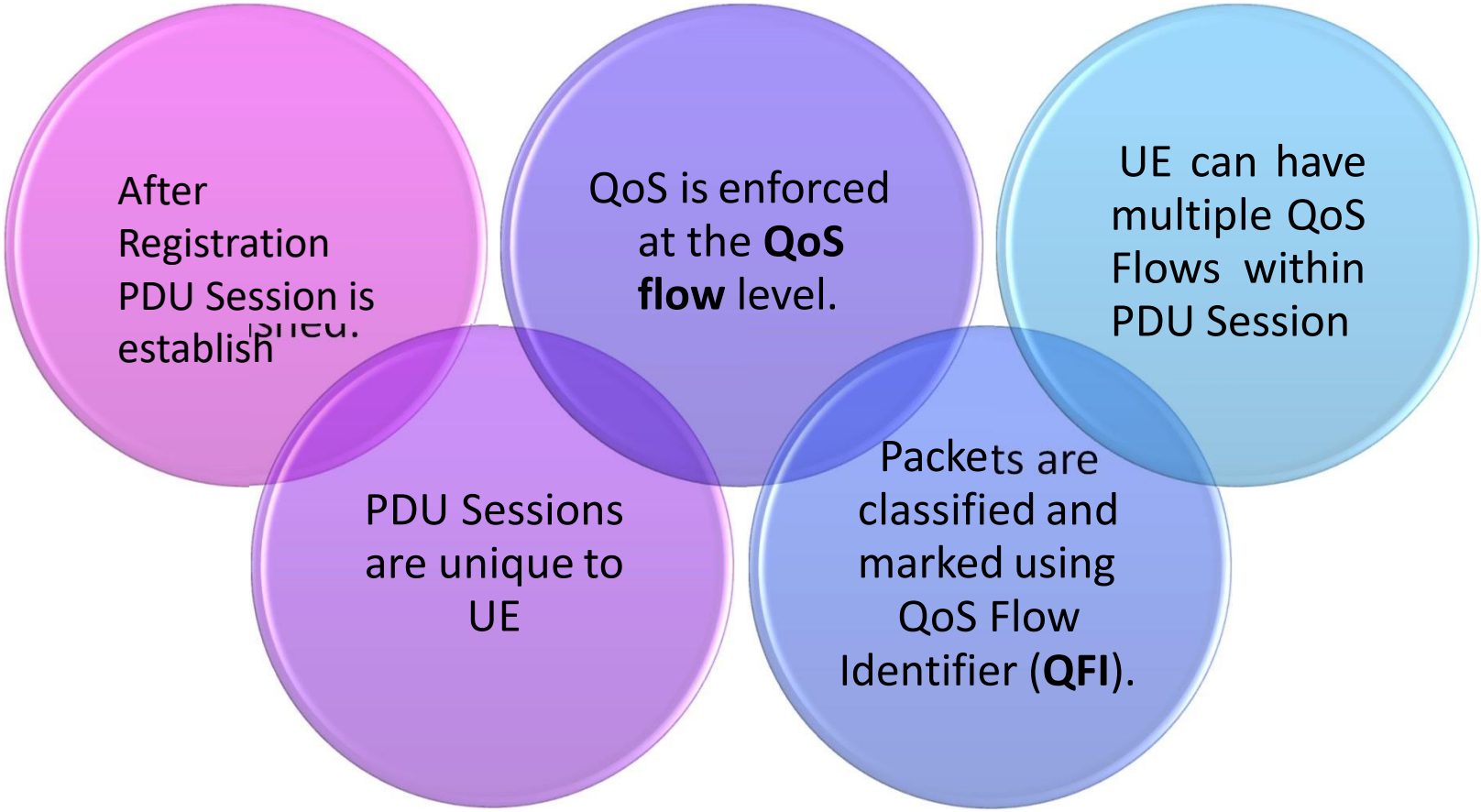
There will be a QoS Flow that has a default QoS profile which all traffic related to the subscriber can use

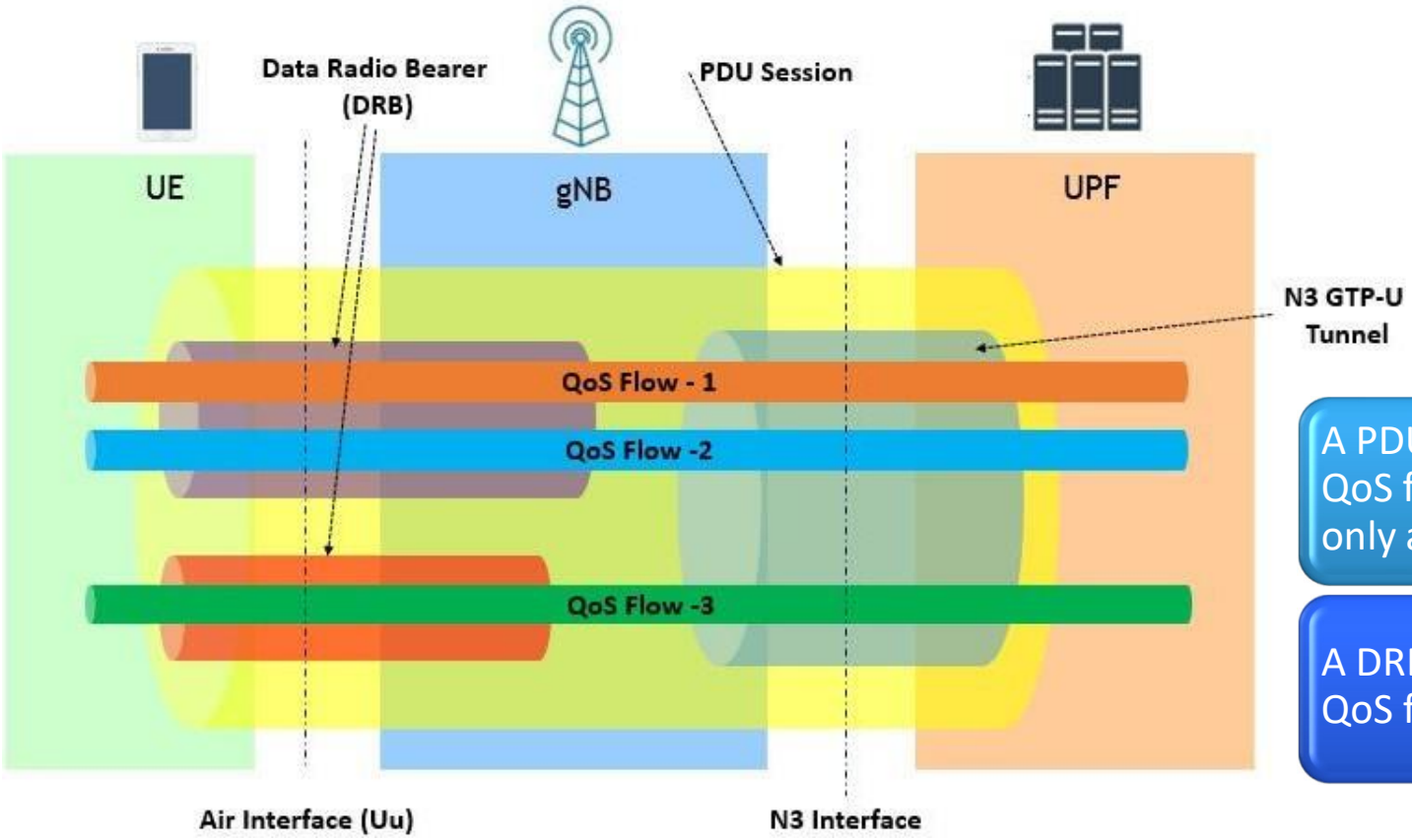


QoS Flows can be established and removed on the basis of the QoS requirements of the User Plane traffic

Network Slices and QoS Flows




After Registration PDU Session is established.
QoS is enforced at the **QoS flow** level.
UE can have multiple QoS Flows within PDU Session
PDU Sessions are unique to UE
Packets are classified and marked using QoS Flow Identifier (**QFI**).

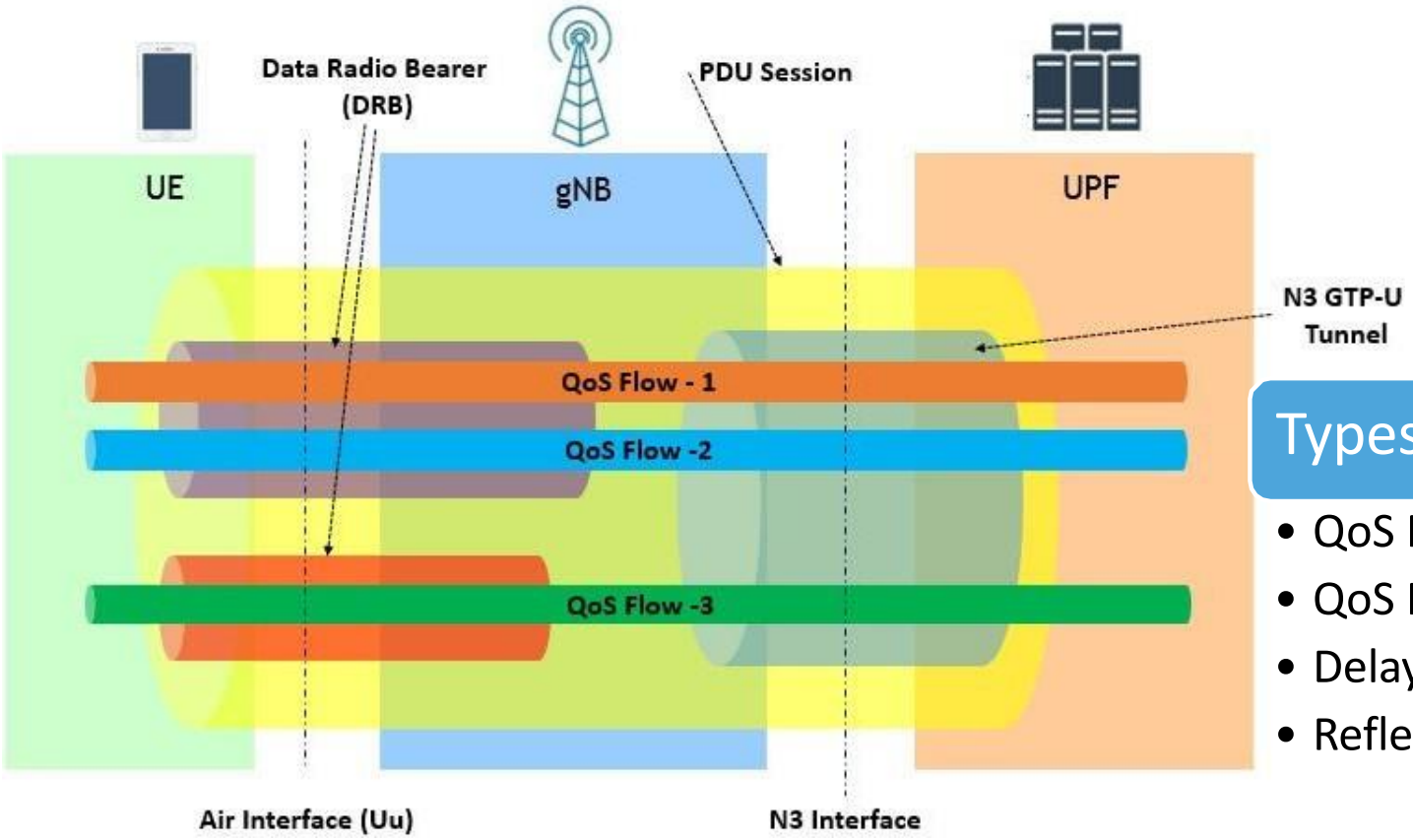


A PDU session may contain multiple QoS flows and several DRBs but only a single N3 GTP-U tunnel.

A DRB may transport one or more QoS flows.

Image Source : **GPRS Tunnelling protocol**

5G QoS Architecture



Types of QoS Flow

- QoS Flow with GBR
- QoS Flow with NGBR
- Delay Critical GBR
- Reflective QoS

Image Source : **GPRS Tunnelling protocol**

5G QoS

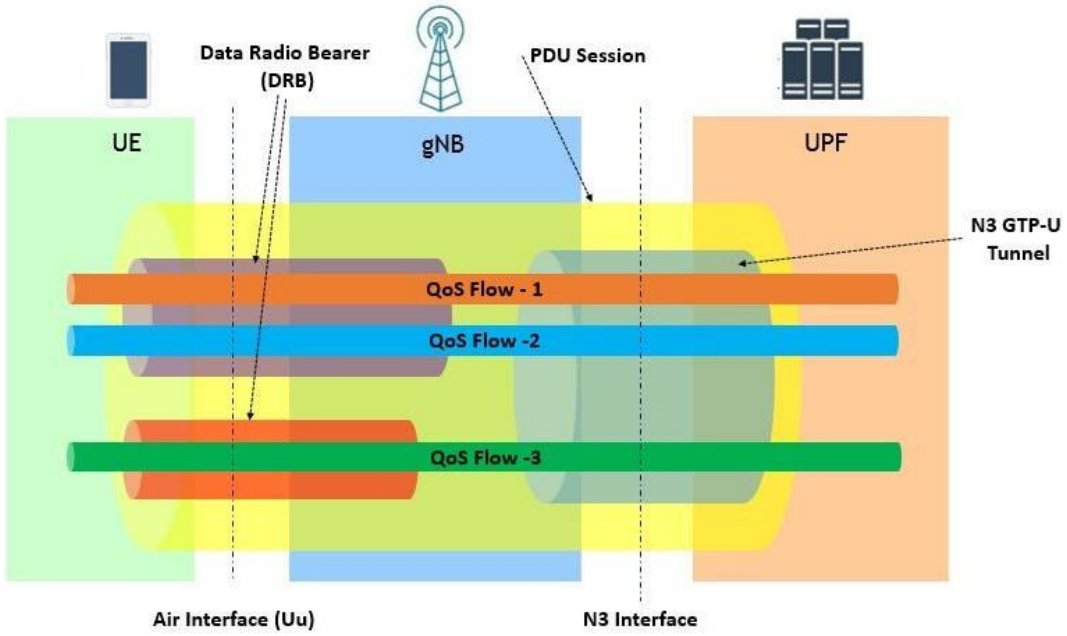
One or more **PDU Sessions** for each UEs

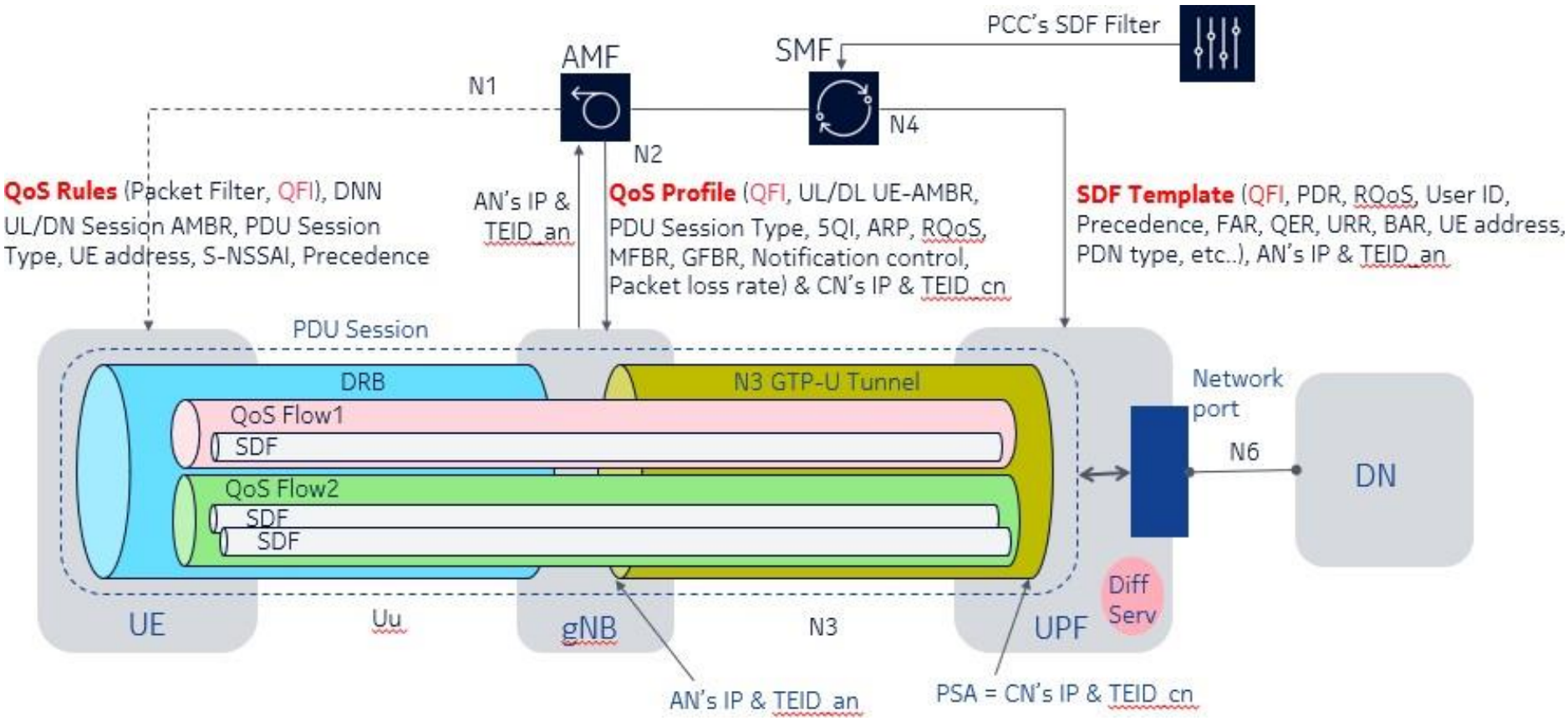
At least one Data Radio Bearers (**DRB**) together with the PDU Session

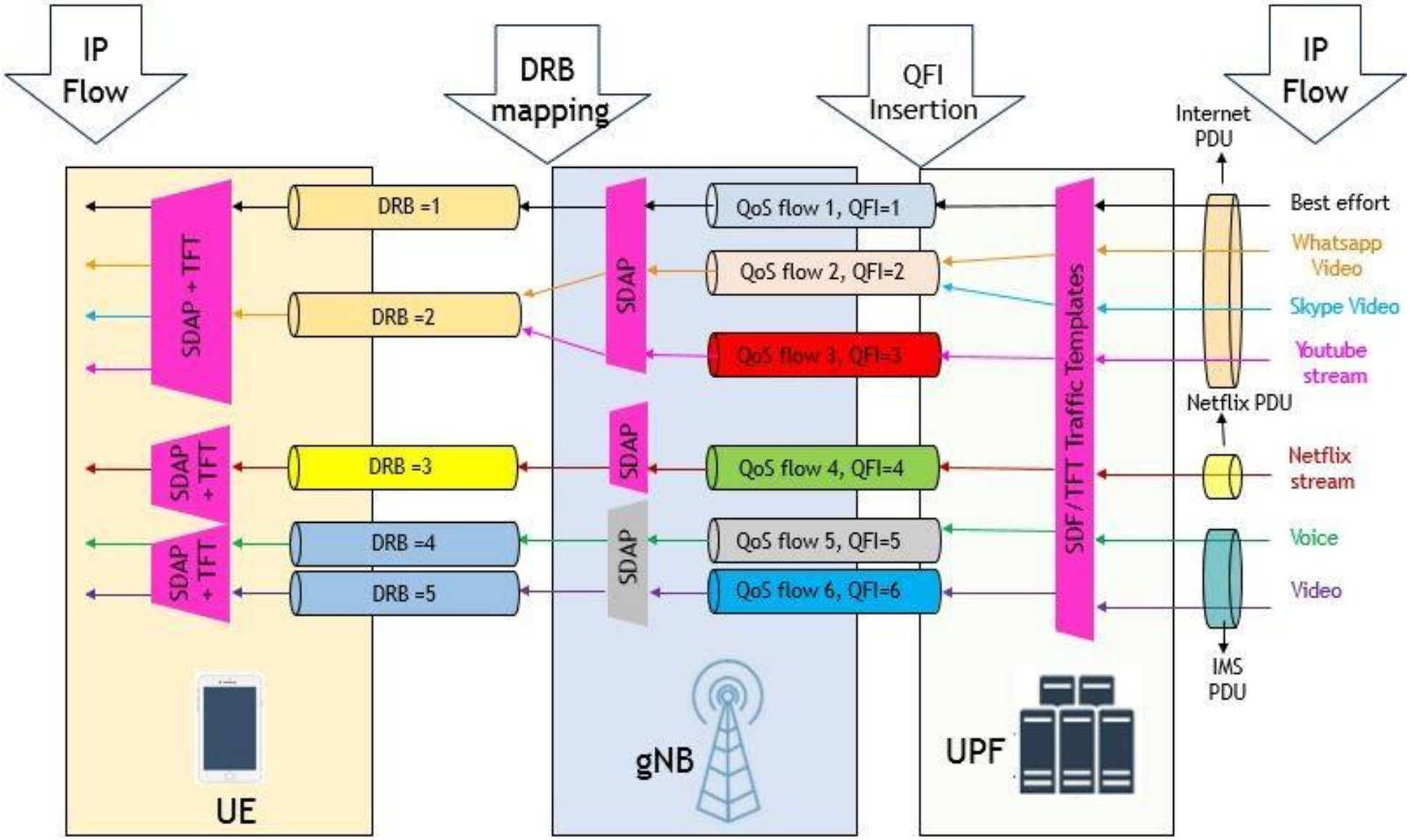
Additional DRB(s) for **QoS flow**(s) of that **PDU session** can be subsequently configured for each UEs

Mapping of packets belonging to different **PDU sessions** to different **DRBs**

Supports GBR, NGBR, Delay Critical GBR and Reflective QoS




PCC's SDF Filter
AMF
SMF
N1
N4
N2
QoS Rules (Packet Filter, QFI), DNN UL/DN Session AMBR, PDU Session Type, UE address, S-NSSAI, Precedence
AN's IP & TEID_an
QoS Profile (QFI, UL/DL UE-AMBR, PDU Session Type, 5QI, ARP, RQoS, MFBR, GFBR, Notification control, Packet loss rate) & CN's IP & TEID_cn
SDF Template (QFI, PDR, RQoS, User ID, Precedence, FAR, QER, URR, BAR, UE address, PDN type, etc..), AN's IP & TEID_an
PDU Session
DRB
N3 GTP-U Tunnel
QoS Flow1
SDF
QoS Flow2
SDF
SDF
Network port
N6
DN
Diff Serv
UE
Uu
gNB
N3
UPF
AN's IP & TEID_an
PSA = CN's IP & TEID_cn


IP Flow
DRB mapping
QFI Insertion
IP Flow
Internet PDU
Best effort
Whatsapp Video
Skype Video
Youtube stream
Netflix PDU
Netflix stream
Voice
Video
IMS PDU
SDAP + TFT
SDAP + TFT
SDAP + TFT
DRB =1
DRB =2
DRB =3
DRB =4
DRB =5
SDAP
SDAP
SDAP
QoS flow 1, QFI=1
QoS flow 2, QFI=2
QoS flow 3, QFI=3
QoS flow 4, QFI=4
QoS flow 5, QFI=5
QoS flow 6, QFI=6
SDF / TFT Traffic Templates
UE
gNB
UPF

- One to many relationship DRBs -GTP-U tunnel
- Each QoS flow is mapped to a single GTP-U tunnel
- gNB may map individual QoS flows to one or more DRBs
- One PDU session - multiple QoS flows - several DRBs -single GTP-U tunnel.
- A DRB may transport one or more QoS flows.
- The DL PDU session information frame includes the Reflective QoS Indicator (RQI)