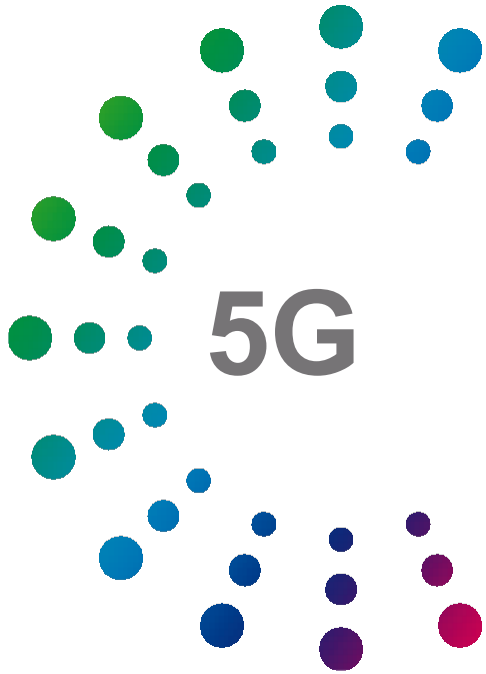


3GPP™

A GLOBAL INITIATIVE

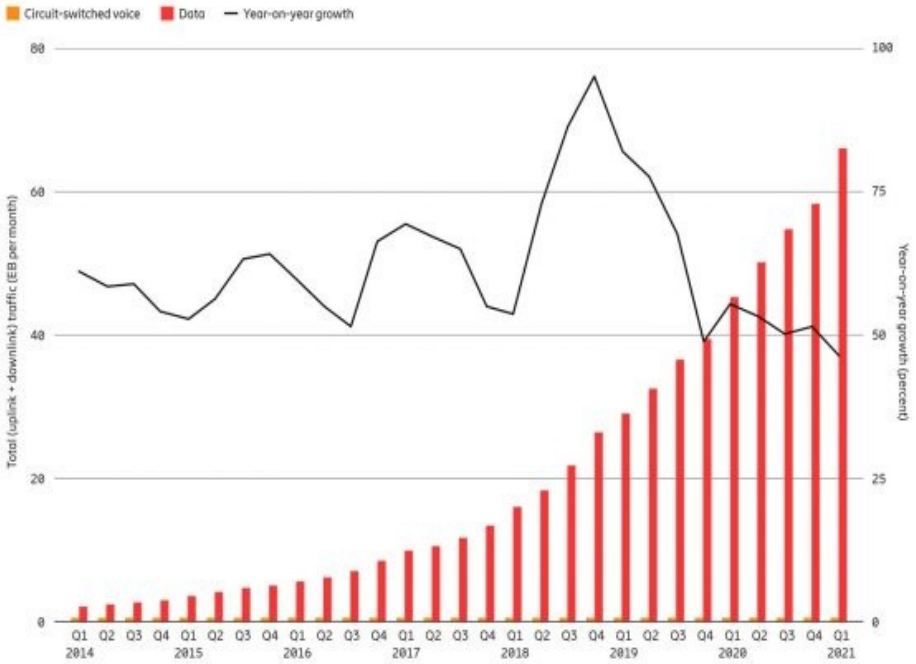
AGENDA

- Introduction
- The Market trend
- 5G Requirements
- 5G Architecture
- 5G New Radio
- 5G Core
- Conclusion

The Market trend

- The data growth
  - Q3 2019, mobile data traffic grew 68 percent year-on-year.
    - › increase of mobile subscriptions
    - › average data volume per subscription

Figure 12: Global mobile network data traffic and year-on-year growth (EB per month)



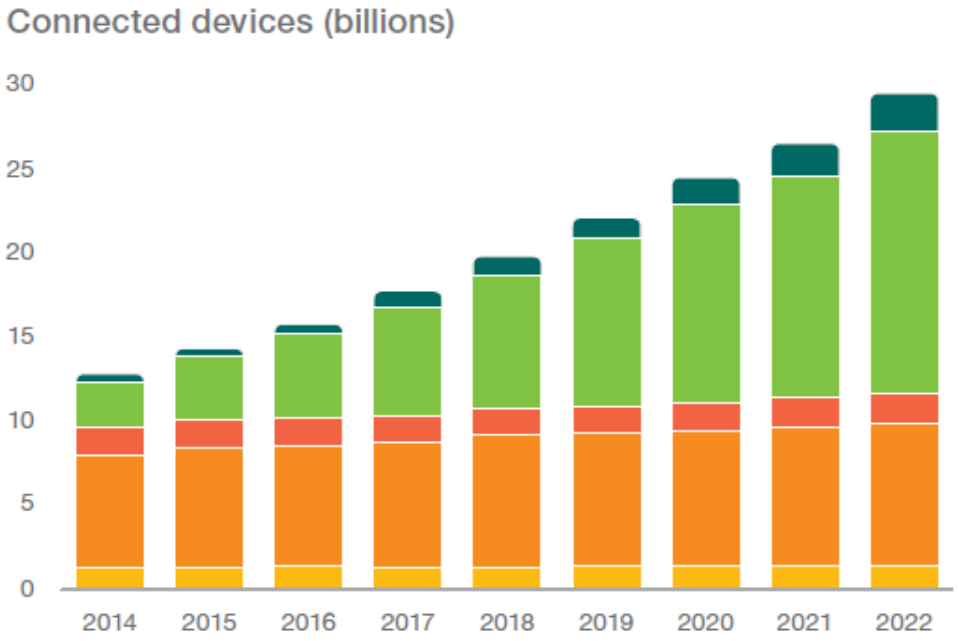
Note: Mobile network data traffic also includes traffic generated by fixed wireless access (FWA) services.

[1] Traffic does not include DVB-H, Wi-Fi or Mobile WiMAX. VoIP is included.

Source: Ericsson Mobility Report November 2021

The Internet of Thinks - IoT

- M2M – Machine to machine communication the next growth segment
  - 29 billion connected devices[1] are forecast by 2022,of which around 18 billion will be related to IoT.
  - 1.5 billion IoT devices with cellular connections by 2022



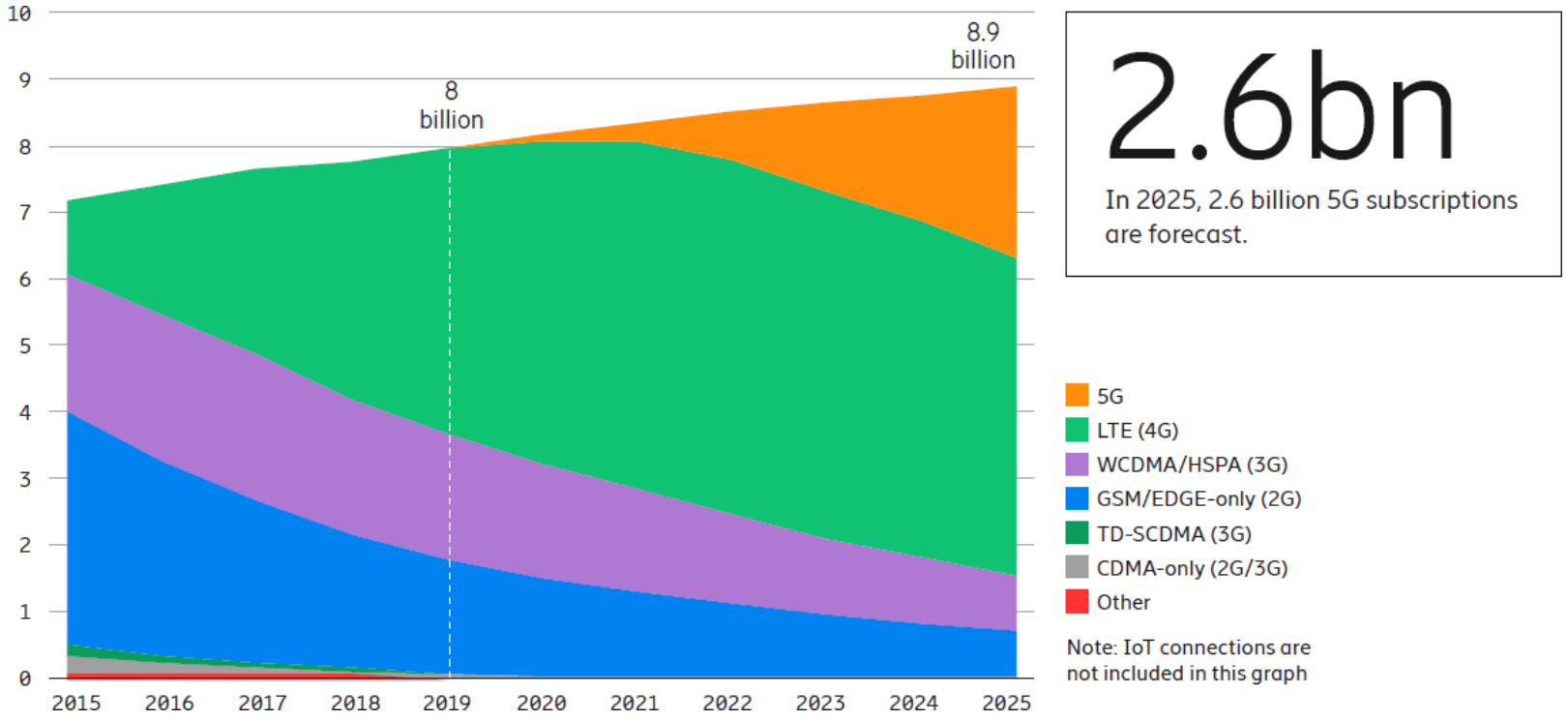
	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

- Short-range segment: devices connected by unlicensed radio with a typical range of up to around 100 meters,such as Wi-Fi, Bluetooth and ZigBee. This category also includes devices connected over fixed line local area connections.
- Wide-area category : devices using cellular connections (3GPP-based), as well asunlicensed low-power technologies, such as Sigfox, LoRa

Source: Ericsson Mobility Report November 2019

The Technology evolution

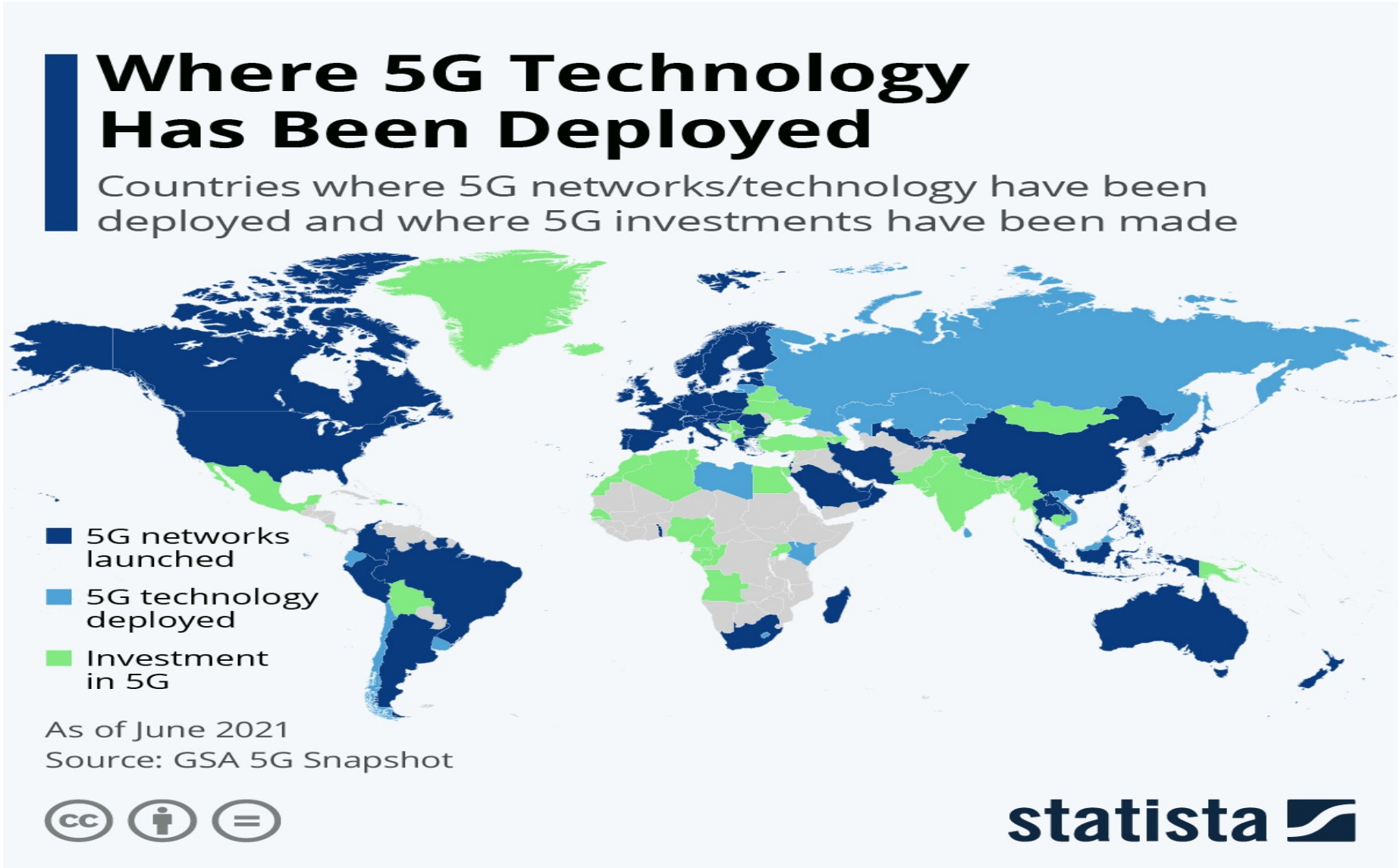
- In 2025 2.6 billion 5G subscriptions
  - 29% of mobile subscriptions



Source: Ericsson Mobility Report November 2019

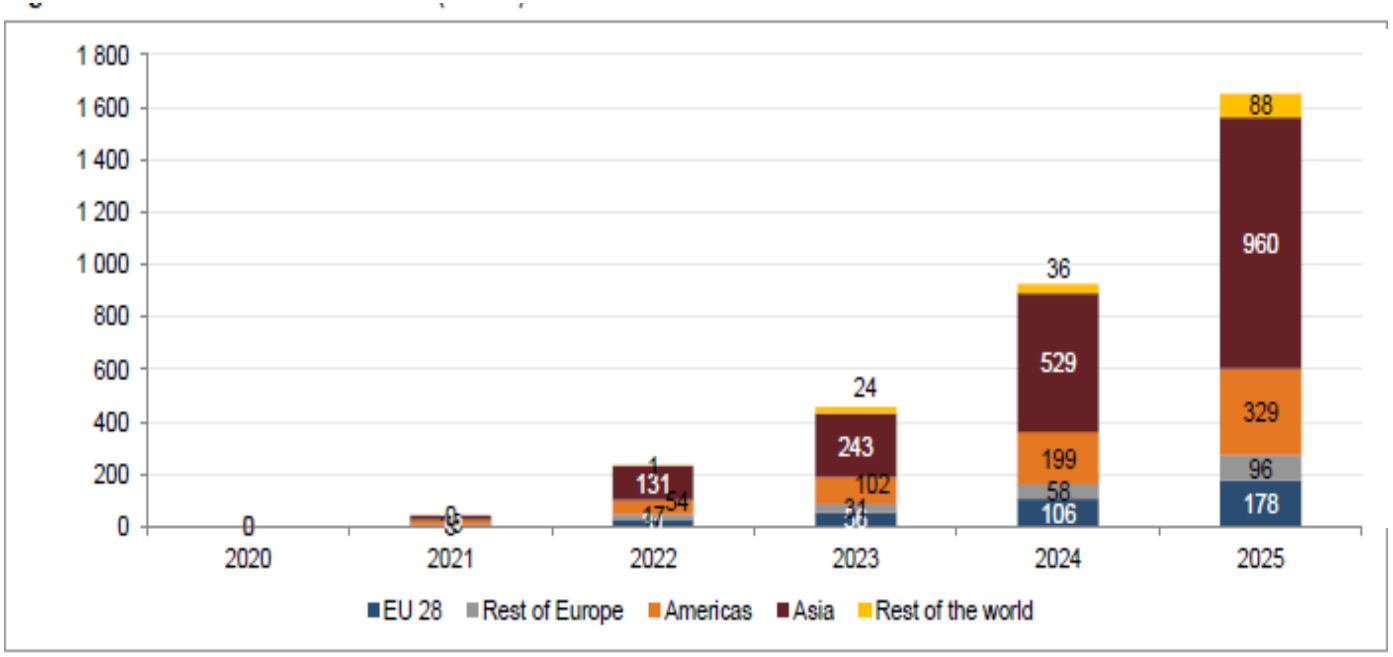
5G -Worldwide

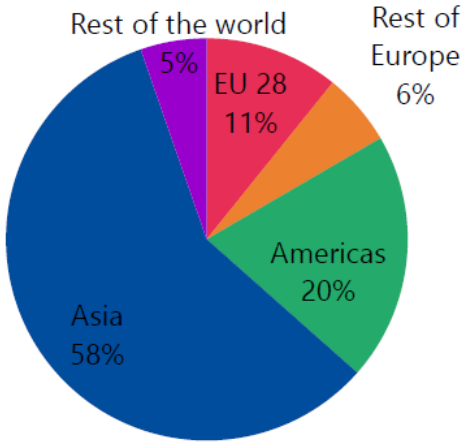
- 5G Launches and deployment: **Status of most advanced operator 5G investments, by country**



5G -Worldwide

- 5G Market
  - 2018 -5G launched in 2018 in Asia and the USA
  - 2020 -5G launched in Europe the migration from 4G to 5G is expected to be fast :
  - 2025 -1,7 billion mark will be passed (source DATE)
    - › Asia will account for more than half (58%, 950 million) of the subscriptions in 2025.
    - › With 274 million 5G subscriptions, Europe is expected to account for 17% of total 5G subscriptions in 2025 (and EU-28 for 11%).

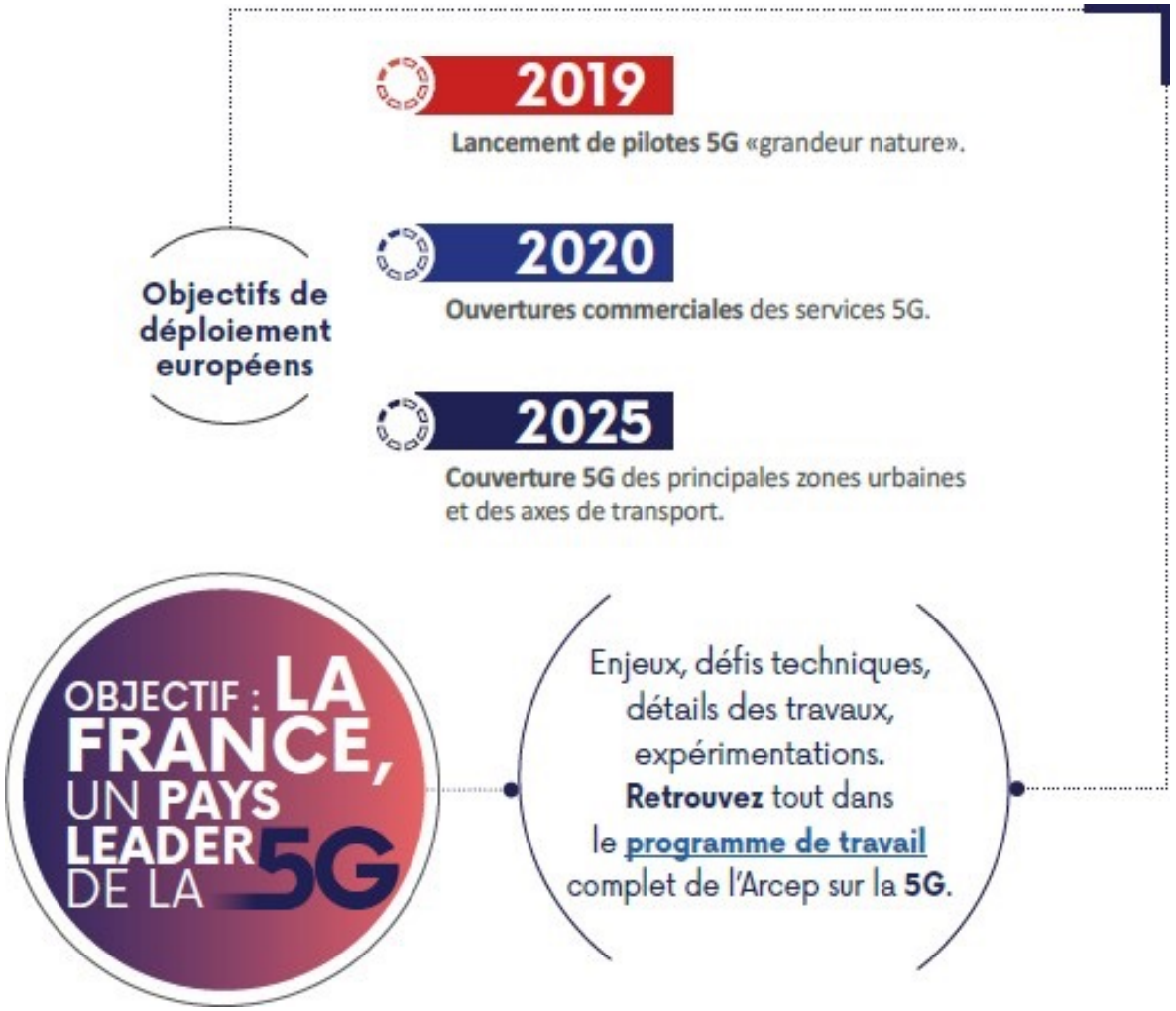




Source: IDATE

5G - France

- 5G Roll-out



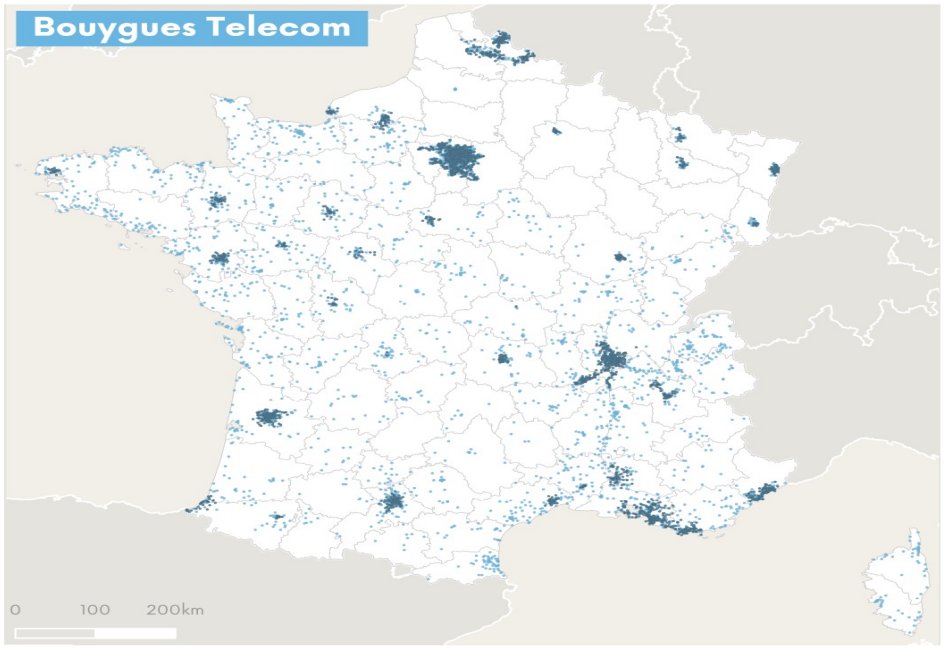
Source: ARCEP

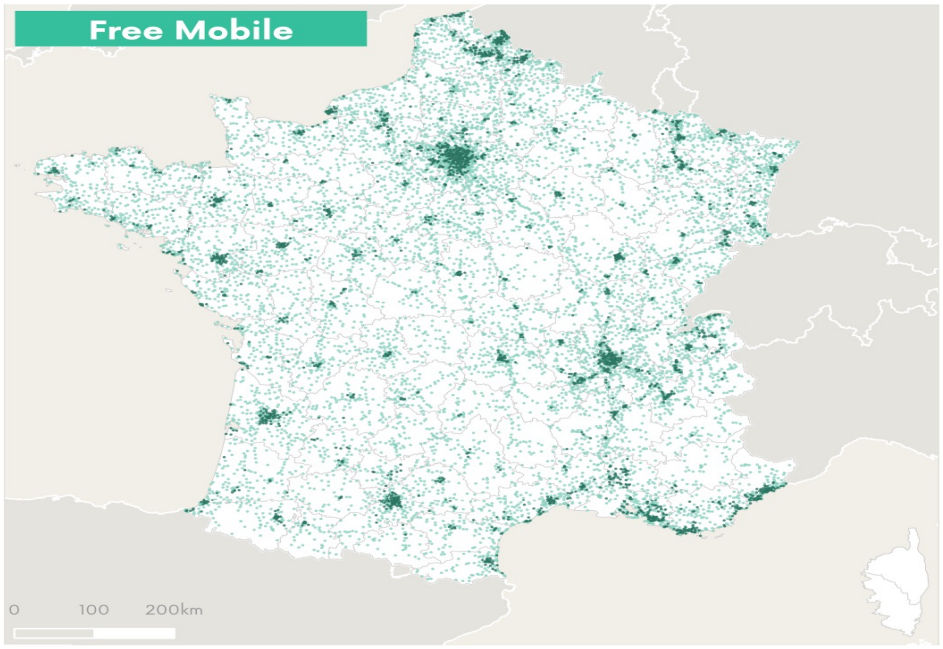
5G - France

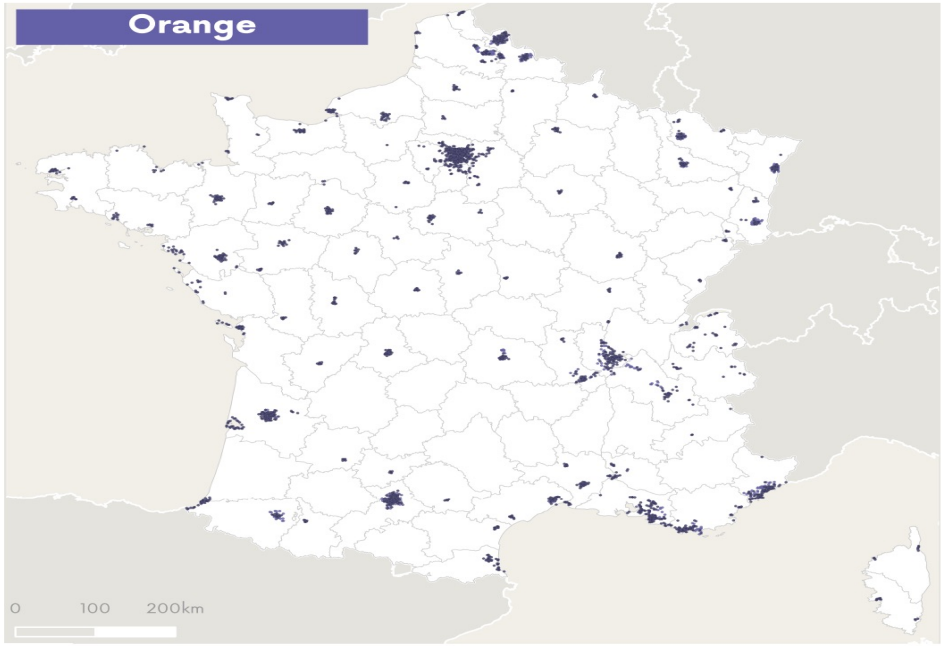
	Bouygues Telecom	Free Mobile	Orange	SFR
Nombre de sites 5G	**6730**	**13470**	**3035**	**4984**
Progression des sites depuis le 30/09/2021	+1727	+1470	+562	+1824
dont sites équipés en bandes :				
700 & 800 MHz	0	13470	0	0
1800 & 2100 MHz	6468	0	471	2156
3500 MHz	2689	2384	2698	2828

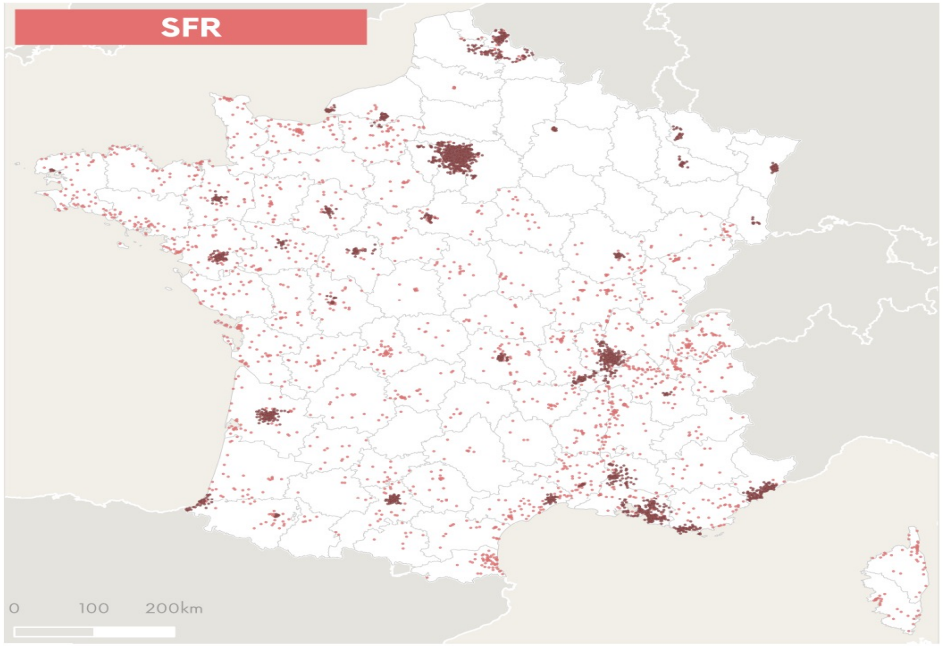
LEGENDE Plus haute bande de fréquences 5G du site :

Bouygues Telecom	700 & 800 MHz	1800 & 2100 MHz	3500 MHz
Free Mobile	700 & 800 MHz	1800 & 2100 MHz	3500 MHz
Orange	700 & 800 MHz	1800 & 2100 MHz	3500 MHz
SFR	700 & 800 MHz	1800 & 2100 MHz	3500 MHz







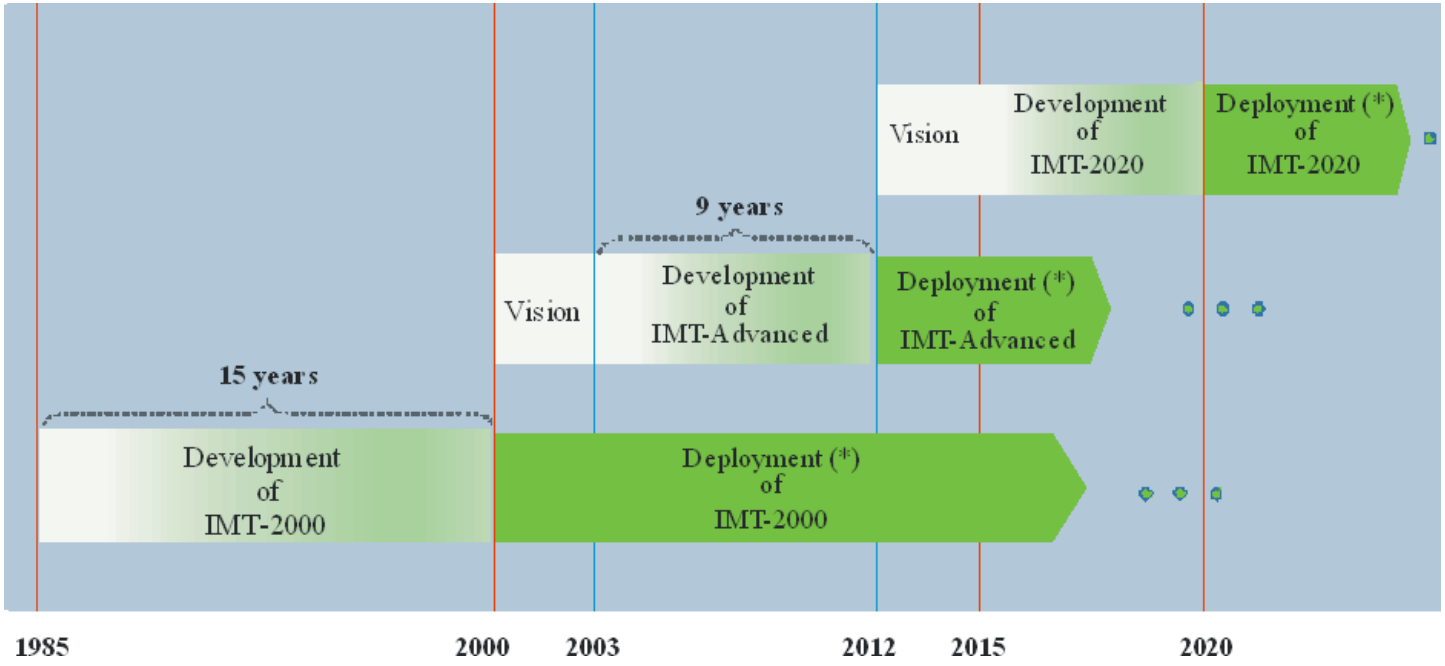


AGENDA

- Introduction
- The market aspect
- The new usage
  - The mobile usage
  - The Internet of Things
- The technology evolution
  - 5G
  - Network Function Virtualization
- Conclusion

ITU

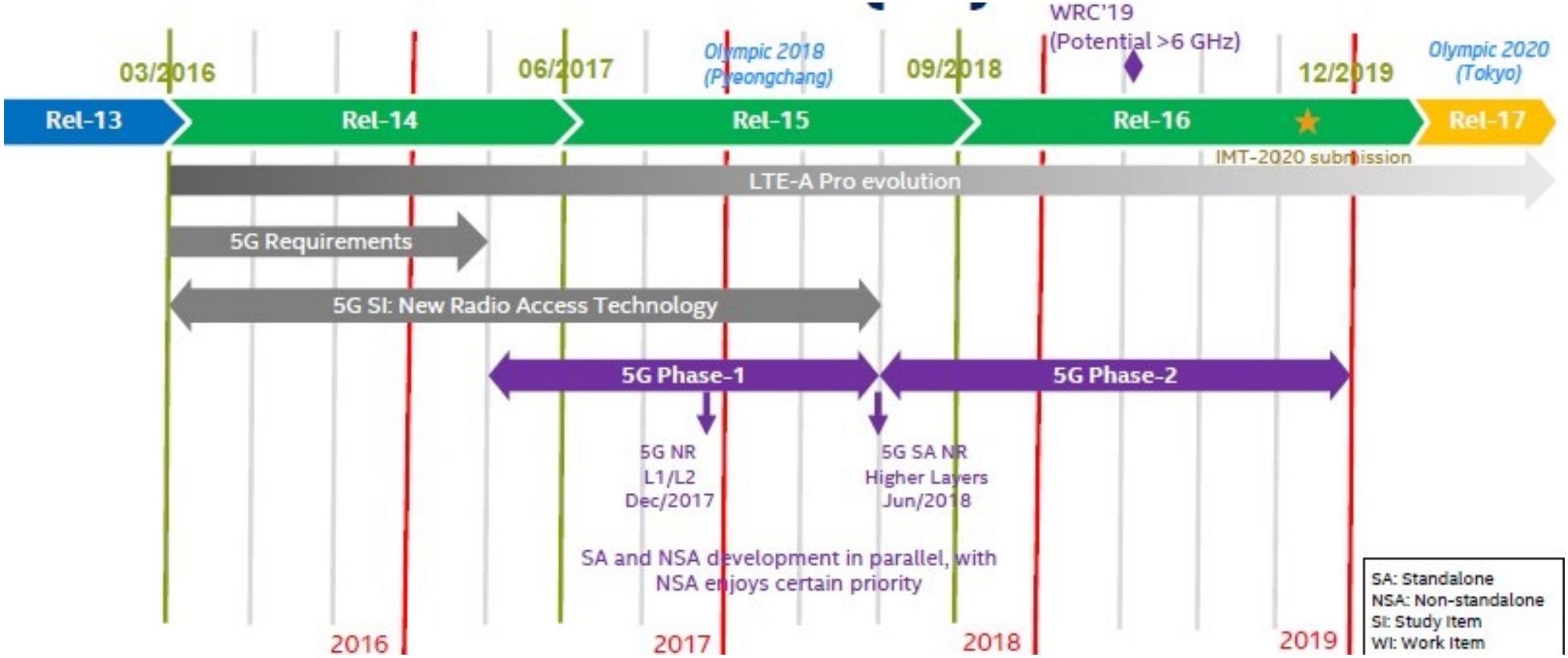
- The International Telecommunication Union (ITU)
  - Defines the standardization for International Mobile Telecommunication – IMT
    - The base line for the mobile systems generation
    - IMT-2000 for 3G
    - IMT-Advanced for 4G
    - IMT-2020 for 5G
      - In June 2015 ITU has established the overall roadmap for the development of 5G mobile
      - Development is expected within 5 years (compared to 9 years for IMT advanced and 15 years for IMT 2000)



Source: Recommendation ITU-R M.2083-0

3GPP

- The 3GPP
  - Defines the technical solution to achieve the objective of the ITU

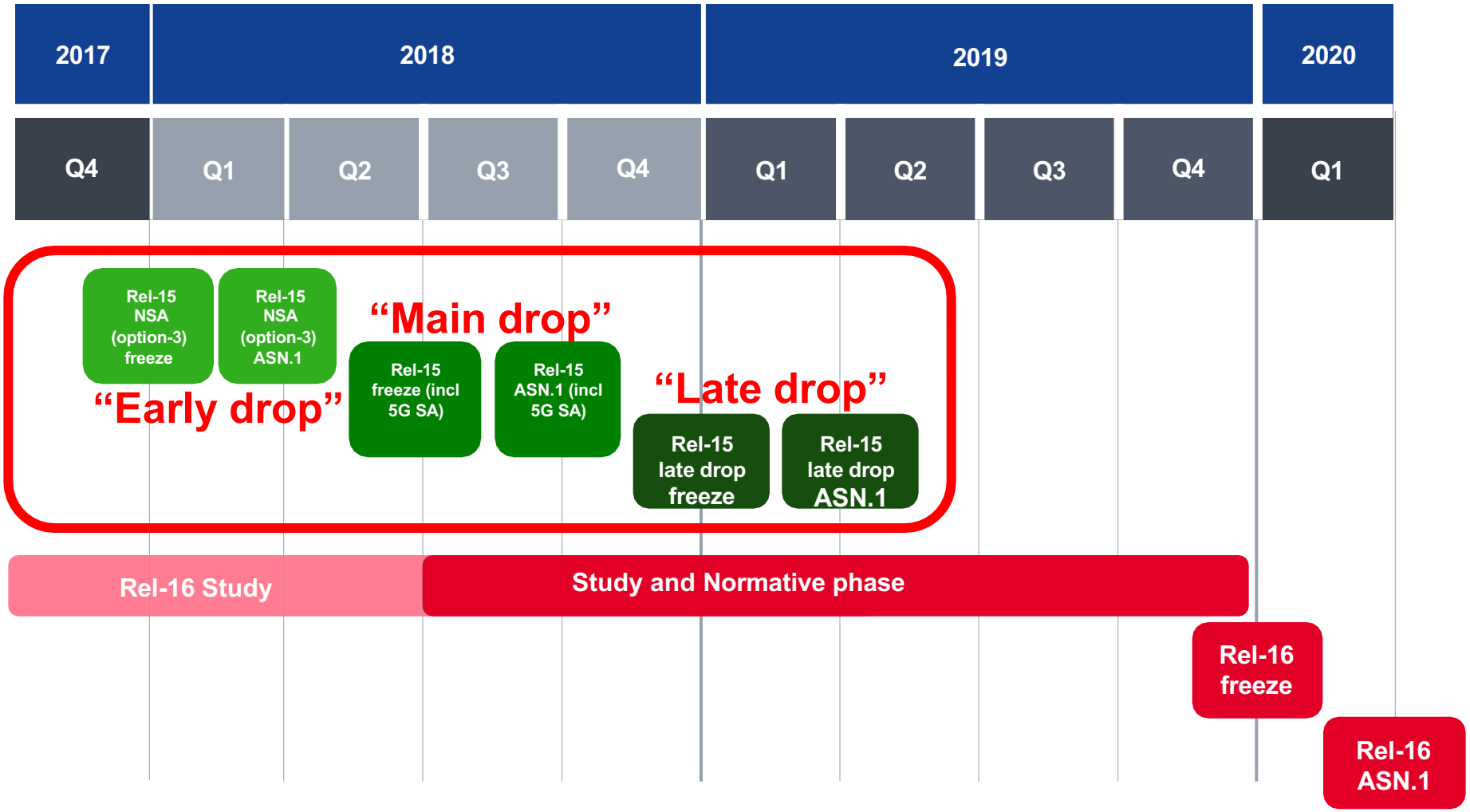


Source: Intel-5G-tecnology-mm-wave-frquencies

5G Preparation

- The 5G mobile communication
  - To prepare the network for the explosion of data bases services and Machine Type Communication (MTC)
  - Commercial availability: by 2020
  - Several forums ongoing: METIS in Europe
    - NGNM, ATIS 5G in the US, Japan, China, Korea

Timeline



ASN = Abstract Syntax Notation One

Source: 3GPP

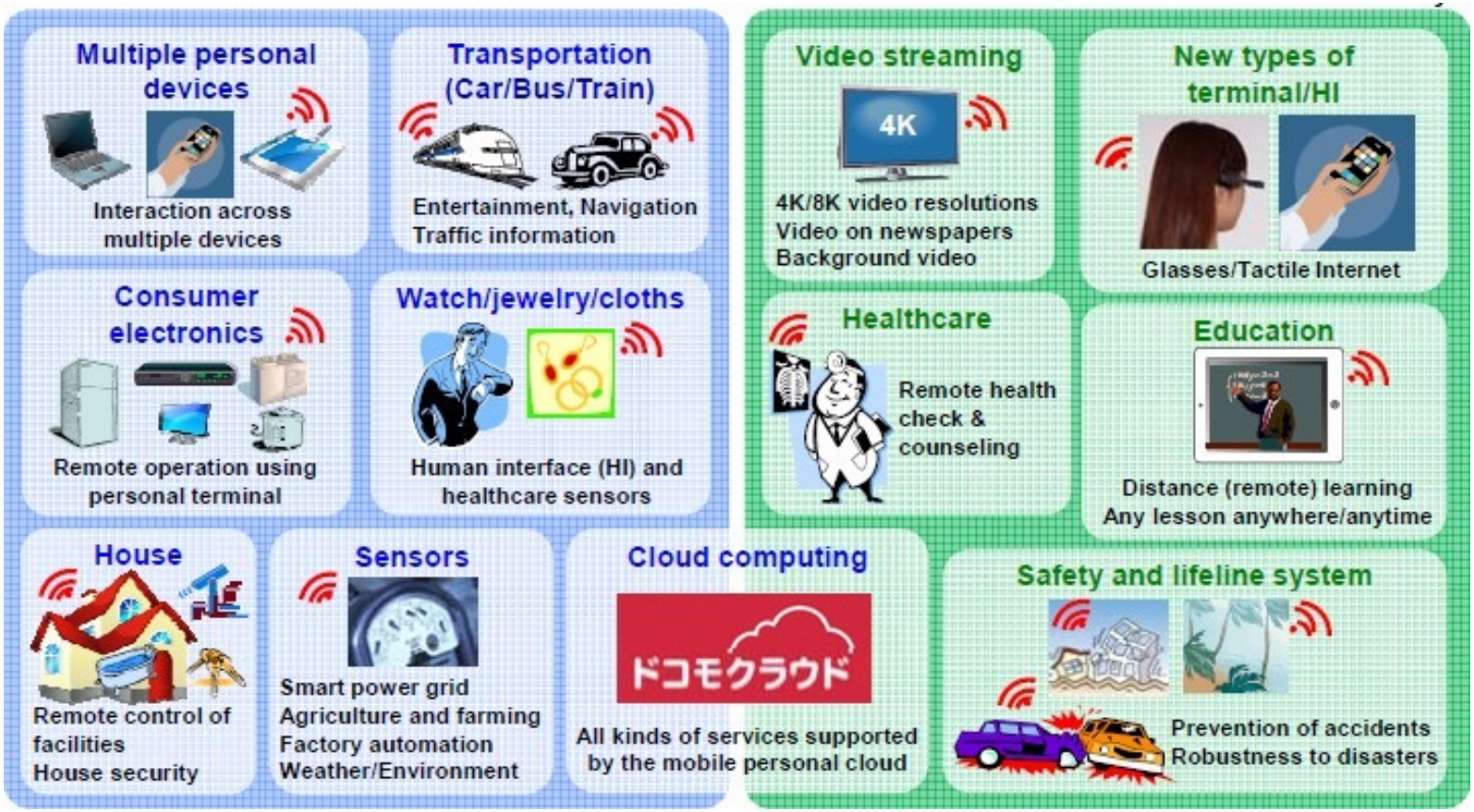
“drops”

- **“Early drop”** for Non-Standalone 5G
  - Addresses the most urgent deployment needs for eMBB
    - Uses LTE anchor with 5G NR in Dual Connectivity configuration
  - Accelerated specification to ensure a single global ecosystem
- **“Main drop”** for Standalone 5G
  - Contains full standalone 5G support with 5G Core
- **“Late drop” for accelerated migration**
  - Contains specs for all potential migration options

Source: 3GPP

The 5G Usage

- The Usage of IMT2020/5G
  - From massive nember of devices, to high performance application



Source: Docomo WP

The 5G Usage

1 ENHANCED MOBILE BROADBAND

- Très haut débit Mobile (>1Gbit/s)
- Vidéos live en très haute définition (UHD)
- Vidéos immersives en 3D et à 360°
- Accès mobile au cloud
- Jeux en ligne massivement multi-joueurs

2 ULTRA-RELIABLE AND LOW LATENCY COMMUNICATIONS

- Réalité virtuelle et augmentée
- Automatisation industrielle
- Véhicules autonomes
- Applications critiques et temps réel
- Chirurgie à distance
- Services de secours
- Vidéo pour bulle tactique & forces spéciales
- Gestion du trafic des drônes

3 MASSIVE MACHINE TYPE COMMUNICATIONS

- Smart Cities
- Smart Home / Building
- Smart Grid
- Capteurs IoT & contrôle à distance
- Robots agricoles
- Essaims de drônes

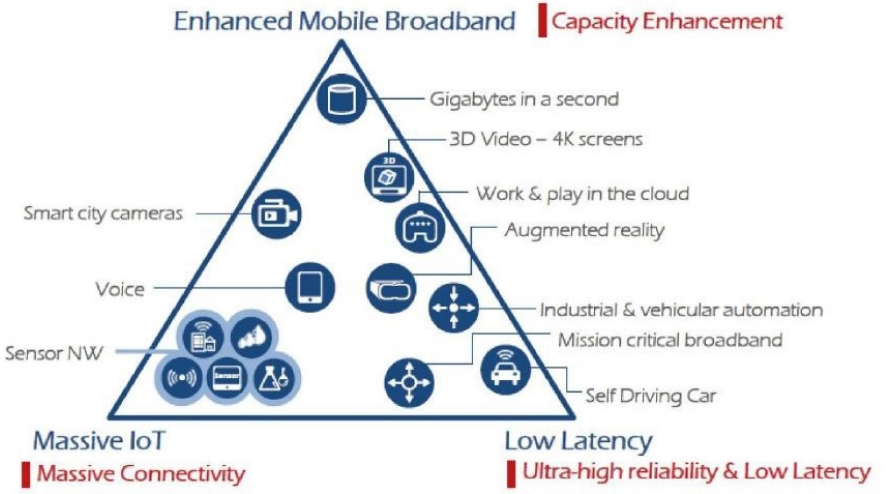
The 5G Usage

- The Usage of IMT2020/5G: 3 main types of communication

1. Massive machine communication: mMTC
   - Massive IoT: Wire area coverage, large number of devices, low cost device, low-energy operation, security

2. Critical Machine Type Communication: cMTC
   - Critical IoT: monitoring and control; in real time ➔ e2e latency requirements (at msec level) reliability and security
   - Also referred as ultra-reliable low-latency communication (URLLC)

3. Extreme mobile broadband: eMBB
   - eMBB: high data rate and low latency communications



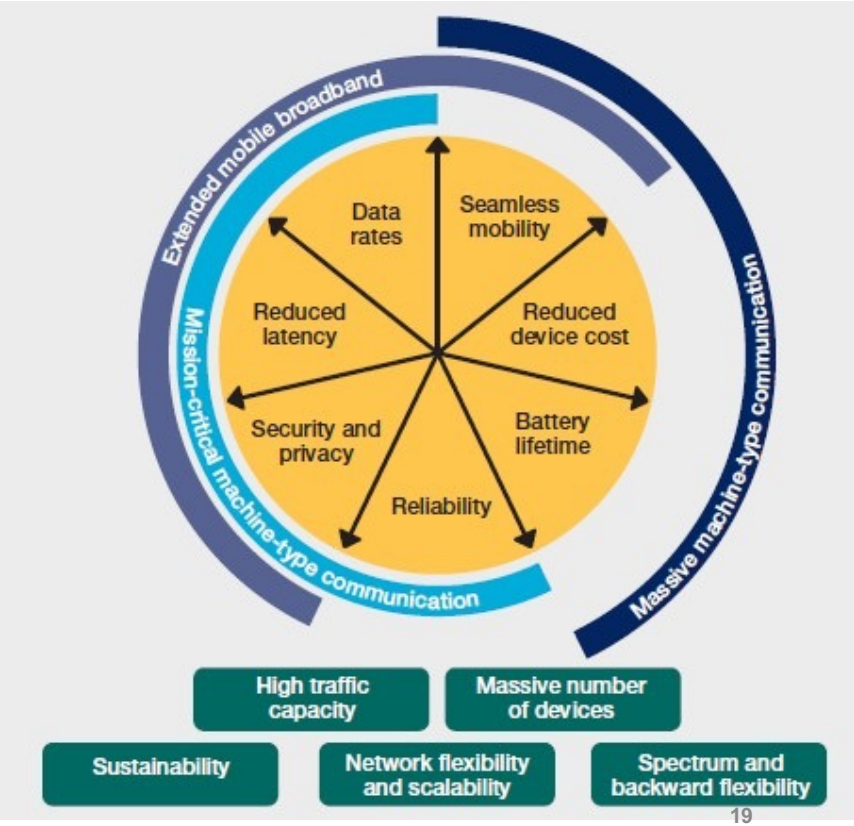
(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

Source: Docomo WP

The 5G requirements

- The 5G requirements: a large diversity
  - 10 to 100 times higher user rate [1 – 10 Gpps]
  - 5 times reduced end to end latency [1 millisecond]
  - 10 to 100 times higher number of connected devices [Connection density]
  - 1000 times higher user data volume per area [Connection density]
  - 10 times longer battery life for low power devices [Energy reduction]

- A large consensus over all the actors that the next network work will have to support:
  - high data rates,
  - low latency,
  - a massive number of connected devices and of different types,
  - low energy consumption,
  - and high reliability.



The 5G requirements

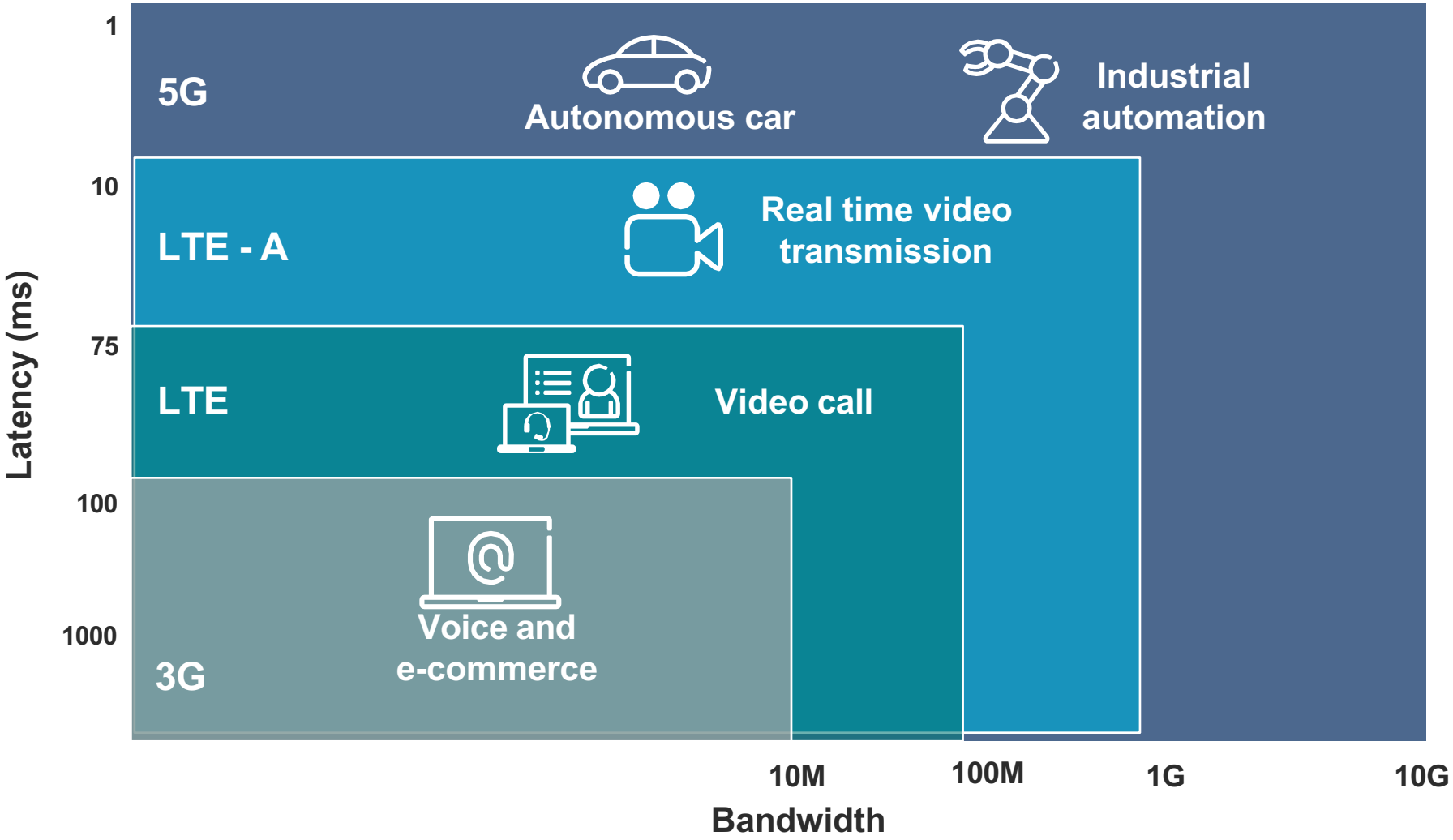
- 4G and 5G comparison

Performances/Generation	4G	5G
1. Peak data rate (Gbit/s)	1	20
2. User experience data rate (Mbit/s)	10	100
3. Spectrum efficiency	1x	3x
4. Speed (km/h)	350	500
5. Latency (ms)	10	1
6. Connection density (number of objects/km^2)	10^5	10^6
7. Network energy efficiency	1x	100x
8. Area traffic capacity (Mbit/s/m^2)	0.1	10

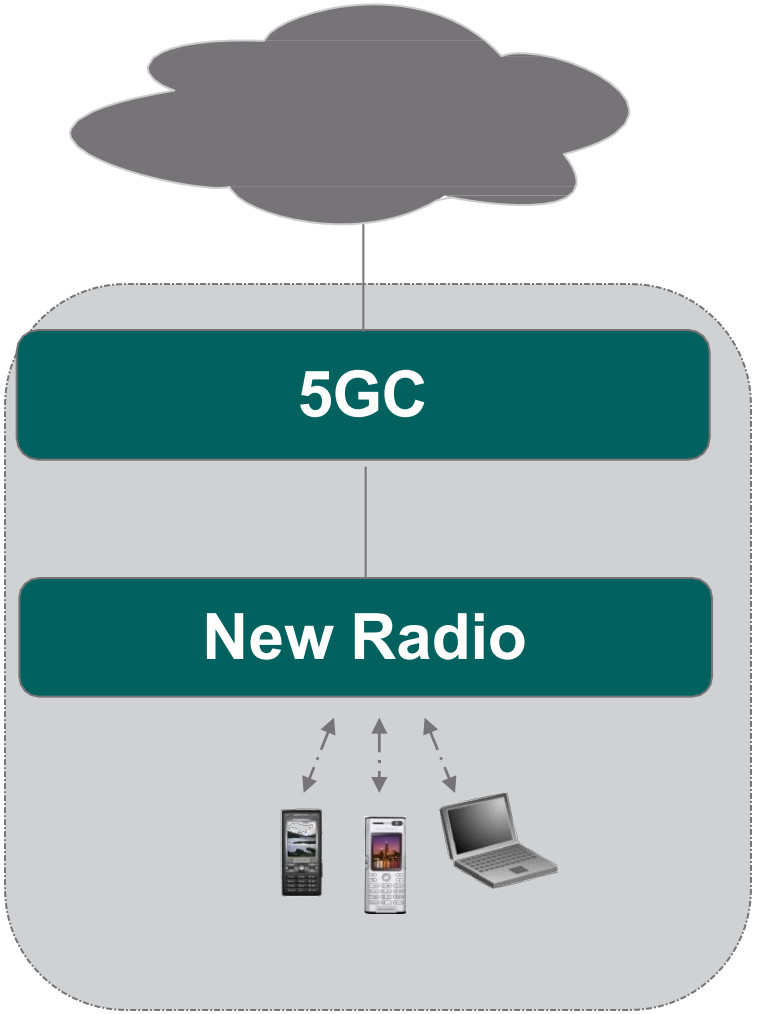
Source: ARCEP

The 5G requirements

- The 5G requirements: the use cases



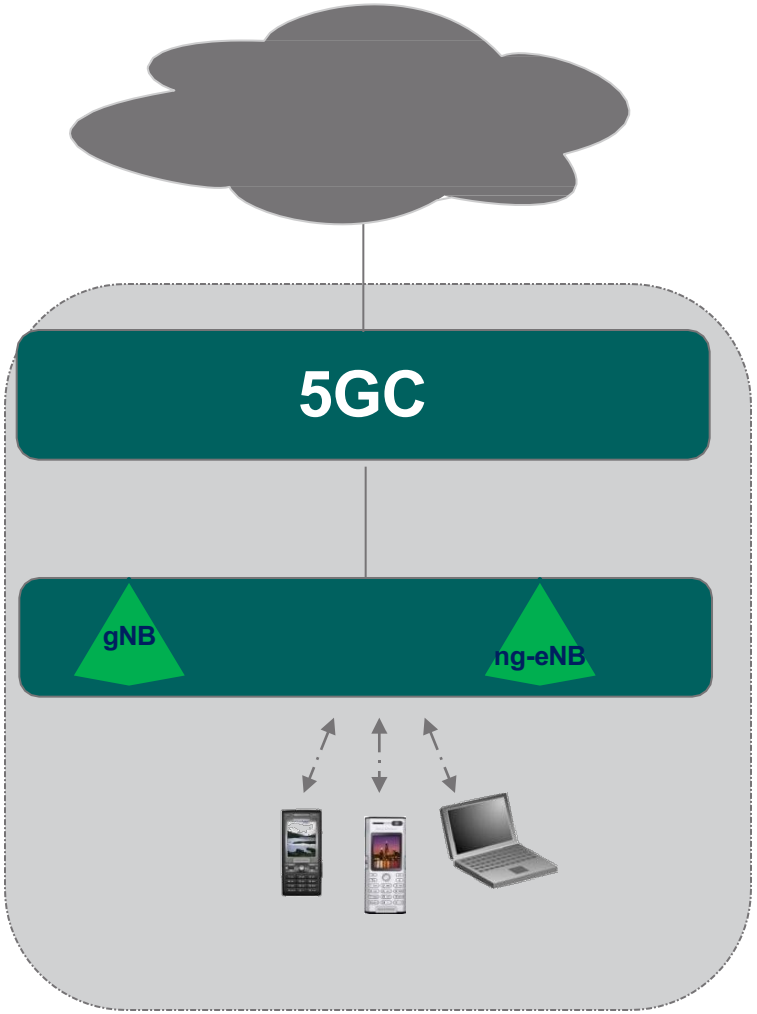
5G Architecture



5G Core

New Radio

5G Architecture



5G Core

New RAN

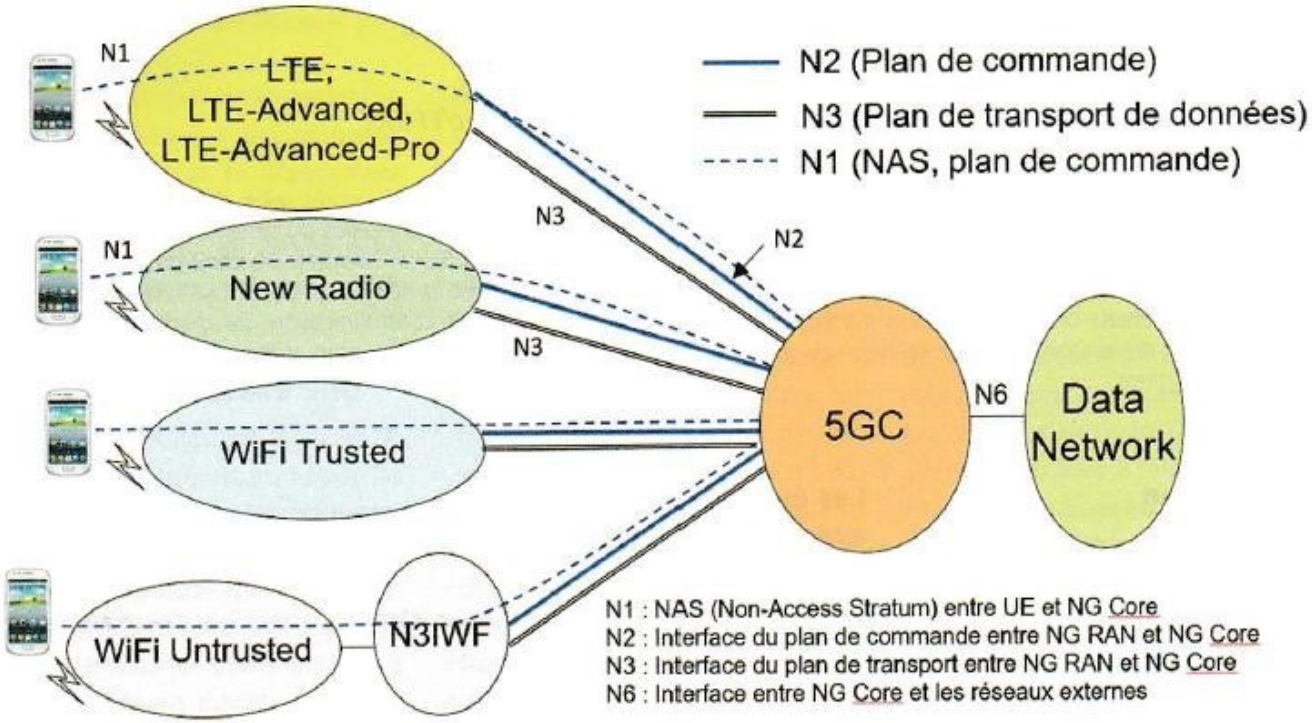
- The New RAN (Radio Access Network) for 5G provides both NR and E-UTRA (“LTE”) radio access
- A NG-RAN node is either
- gNB – (“5G base station”, providing NR access) or
- ng-eNB (“enhanced 4G base station”, providing E-UTRA access)

5G Architecture

5G Core

3 access types

1. New radio
   - 5G Ran
2. LTE, LTE-Advanced,
   LTE _Advanced pro
   eNB updated to support
   N2&N3 ref point➔ ng-eNB
3. WIFI access
   - Trusted
   - Untrusted



5G Core

Does not support

- 2G (GERAN), 3G (UTRAN)
- Circuit domain ➔ no Circuit Voice

Support

- Voice is VoIP

Source: EFORT

5G Architecture

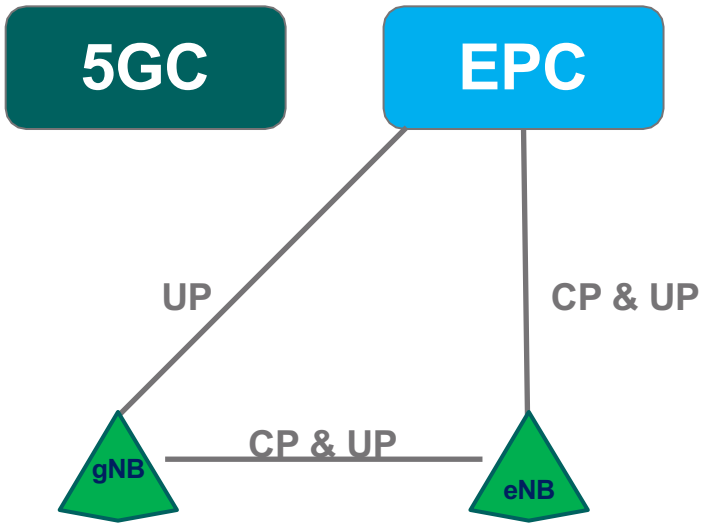
- Enabler for 5G

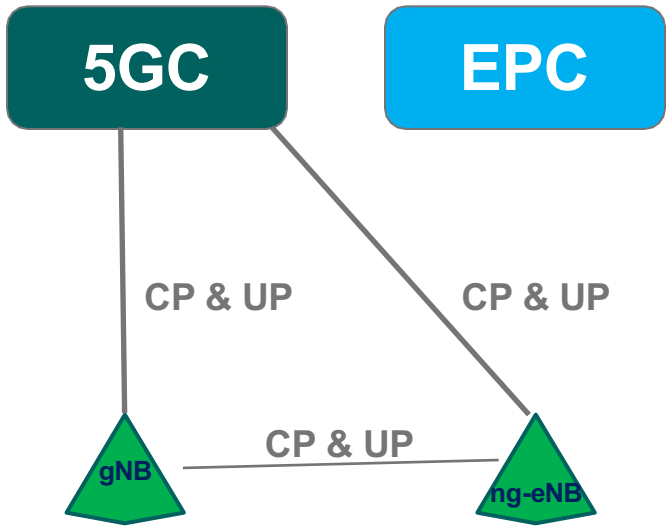
  - Virtualisation
    - The capability to run network functions “on the shelf” standard servers
      - The server resources can be shared by different application
  - Cloud
    - Scale the virtualization
      - 2 families
        - Saas : Software as a service
        - Paas and IaaS: platform as a service, Infrastructure as a service
  - Slicing
    - The capability to run different virtual network on the same physical network
  - Edge Computing
    - Applications can be hosted at “Edge-side”
      ->Low Latency compared with centralized manner

5G Architecture

5G Roll out : 2 scenario

- **Non –Standalone (NSA)**
  - No 5GC needed
  - Provides new radio resources
    - Data & customer increase
    - 4G Tx adapted to NR
- **Standalone (SA)**
  - 5GC
  - New 5G services
  - 4G eNB upgraded to ng-eNB to be connected to 5GC



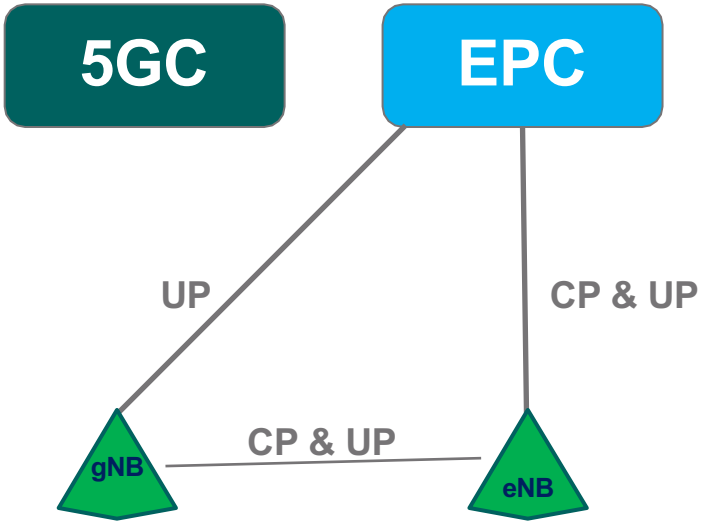


5G Architecture

- Non Standalone (NSA) Network

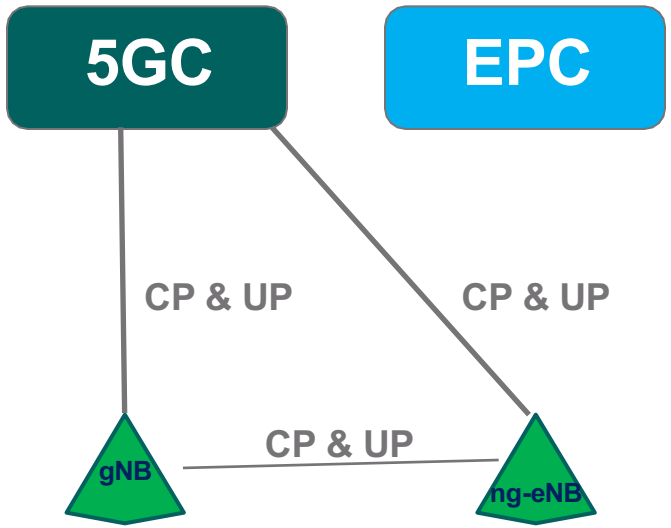
  – The first wave of networks and devices will be classed as Non-Standalone (NSA):
    › the 5G networks will be supported by existing 4G infrastructure.

  – 5G-enabled smartphones will connect to 5G frequencies for data-throughput improvements but will still use 4G for non-data duties such as talking to the cell towers and servers.



5G Architecture

- Standalone (SA) Network
  - The 5G Standalone (SA) network and device standard is still under review and is expected to be signed-off by 3GPP this year.
  - SA network and device will allow the development of new cellular use cases such as ultra-reliable low latency communications (URLLC).
  - Once the SA standard is approved this year, the migration from 5G NSA to SA by operators should be invisible to the user.



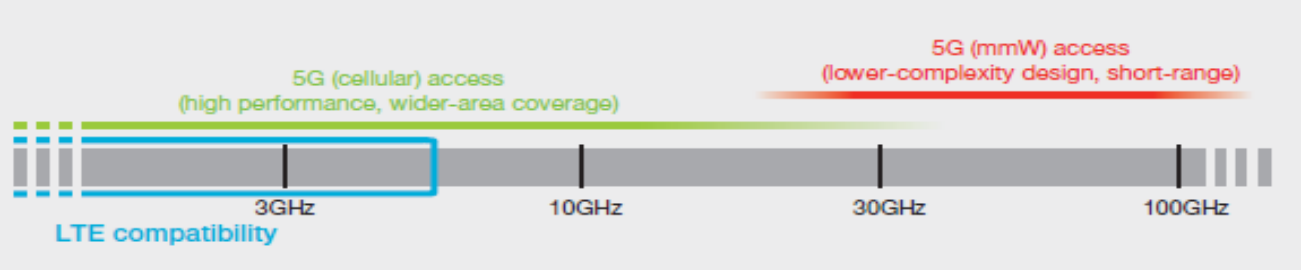
5G Architecture

- Non Standalone (NSA) Network
  - The initial roll-out of 5G cellular infrastructure will focus on enhanced mobile broadband (eMBB) to provide increased data-bandwidth and connection reliability via two new radio frequency ranges:
    - **Frequency Range 1** overlaps and extends 4G LTE frequencies, operating from 450 MHz to 6,000 MHz. Bands are numbered from 1 to 255 and this is commonly referred to as New Radio (NR) or sub-6GHz.
    - **Frequency Range 2** operates at a much higher 24,250 MHz (~24GHz) to 52,600 MHz (~52GHz). Bands are numbered from 257 to 511 and this is commonly referred to as millimeter wave (mmWave), even though strictly speaking the 'millimeter' frequency length starts at 30 GHz.
  - Available frequency zones in these ranges differ between countries.

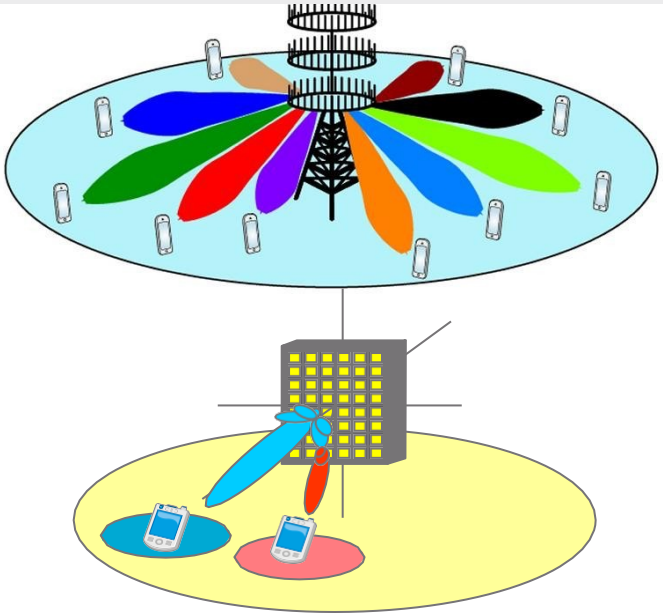
5G New Radio

5G NEW RADIO

- Milimeter Waves

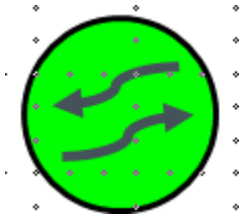


- Massive MIMO



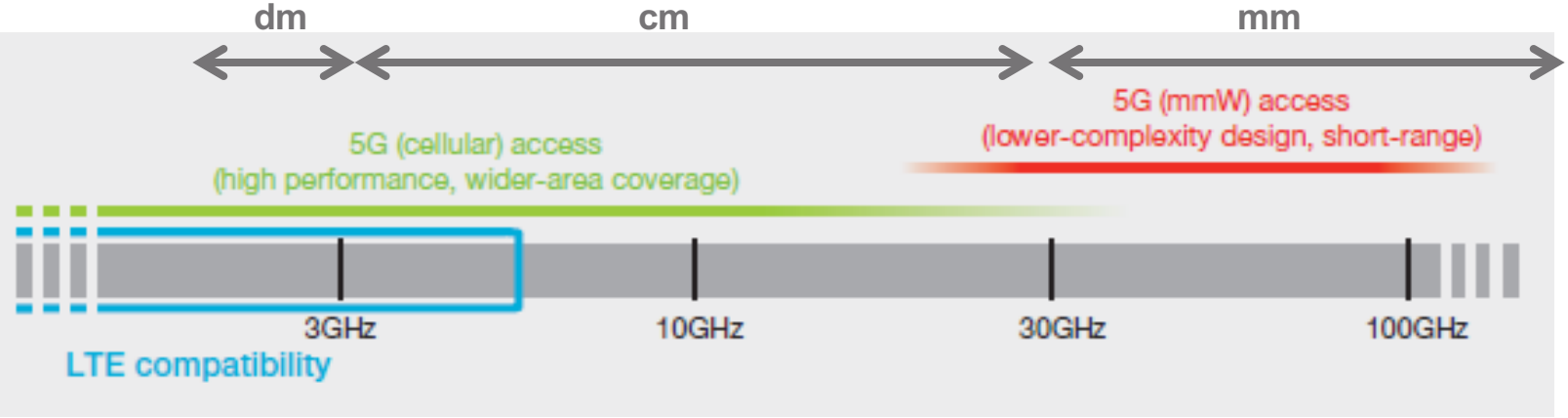
- Beamforming

- Full duplex



5G NEW RADIO

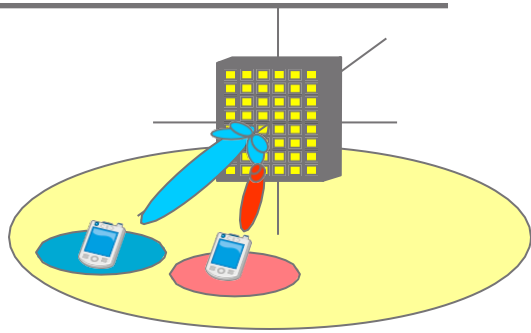
- The 5G spectrum: below 1 GHz to 100 GHz
  - To adress the traffic increase additional spectrum is required
  - this is the role of the 2015 WRC that will discuss the allocation below 6,5 Ghz
  - Additional spectrom from 10 GHz to 100 GHz is also considered and a candidate for the next WRC, the WRC-19: the mimimeter wave (mmW)



  - The radio channel will have different propagation characteristics depending on the frequency band
  - Different radio interface will be required
    - › OFDMA based acces up to ~10 GHz
    - › For higher frequency a new access design will be required to adress short-range communication and ultra-dense coverage

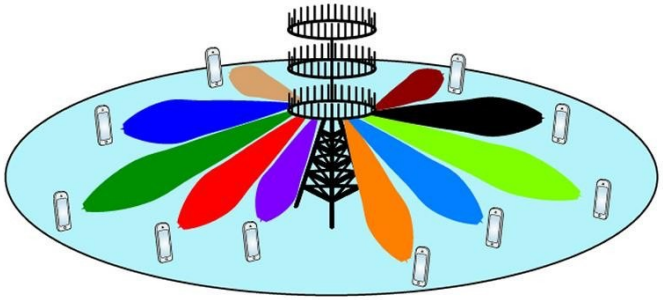
MIMO

- Massive MIMO
  - Use a large number of antennas: eg 128 antennas
    - 2 mains use
      - Beamforming to focus the transmission towards narrow beans
      - Extented spatial multiplexing refered as massive-MIMO
        - A factor 5x to 10x of the spectral efficiency is expected (the number of bits/hertz)



Beamforming for coverage

M-MIMO for capacity



- Photo: 160 antennas over 60x120 cm
- Network-MIMO tecnics that use the cooperation of antennas from different sites
  - Research is on-going

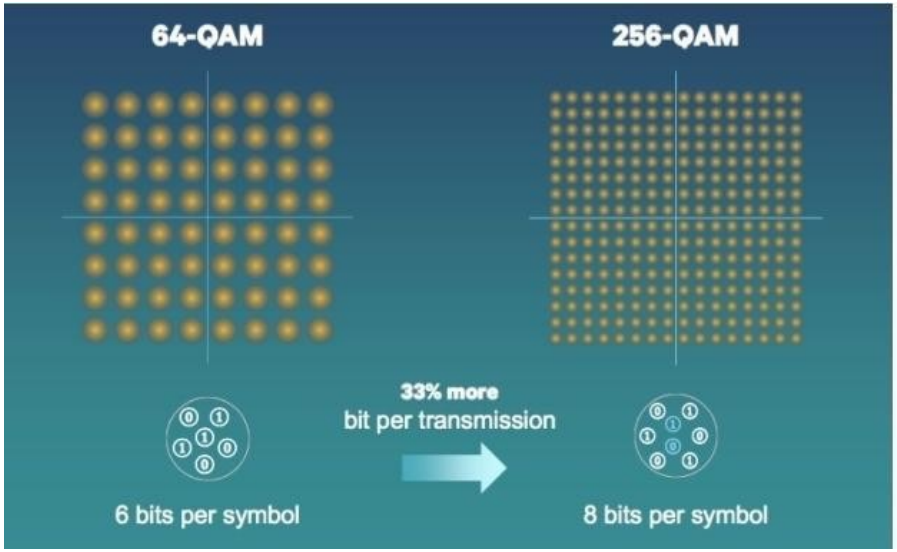
Source: Photo Lund University

MIMO

- Massive MIMO
  - Use with Time Division Duplexing - TDD -
    - Uplink and dowling channels are using the same frequency band and share the time
      - The UL and DL physical channel have the same caracteristics
      - Precoding of the DL can be done by the base station based on the channel estimation of the UL
      - Make use of a ”pilot”
  - Use with Frequency Division Duplexing - FDD –
    - Upling and dowlinh channels are using different frequency band
      - Channel estimation has to be done on both uplink channel and downling channel
      - Result must be send from the Terminal to the Base Station
      - Limit the MIMO to
        - Low mobility
        - Low frequency
  - Massive MIMO is limited to TDD (at the time being)

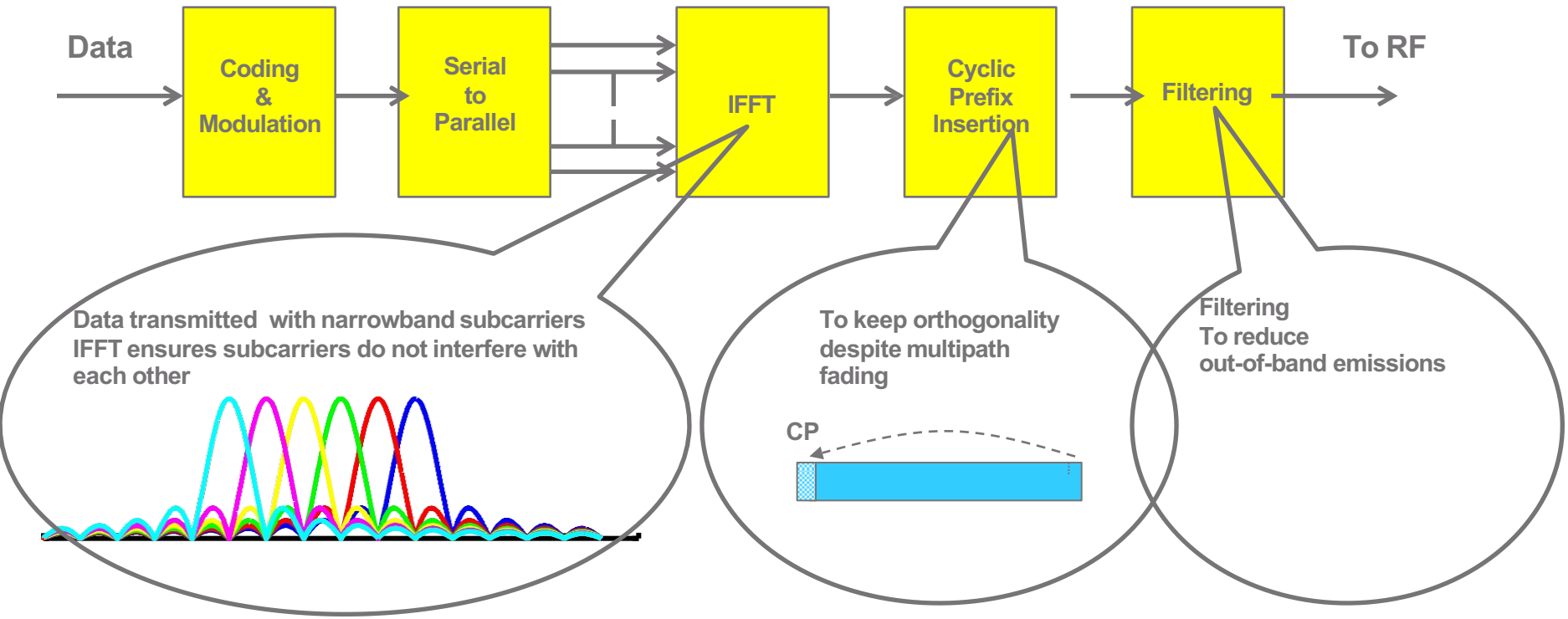
5G NEW RADIO

- Modulation
  - › Existing orthogonal access technics OFDMA with a larger set of modulation and coding shemes such as QAM256 (8bits/symbol)

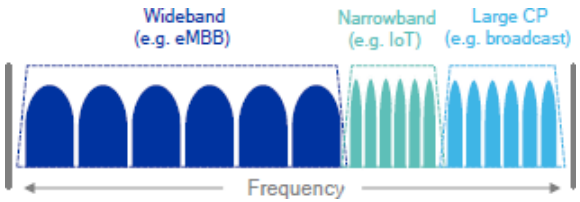


5G NEW RADIO

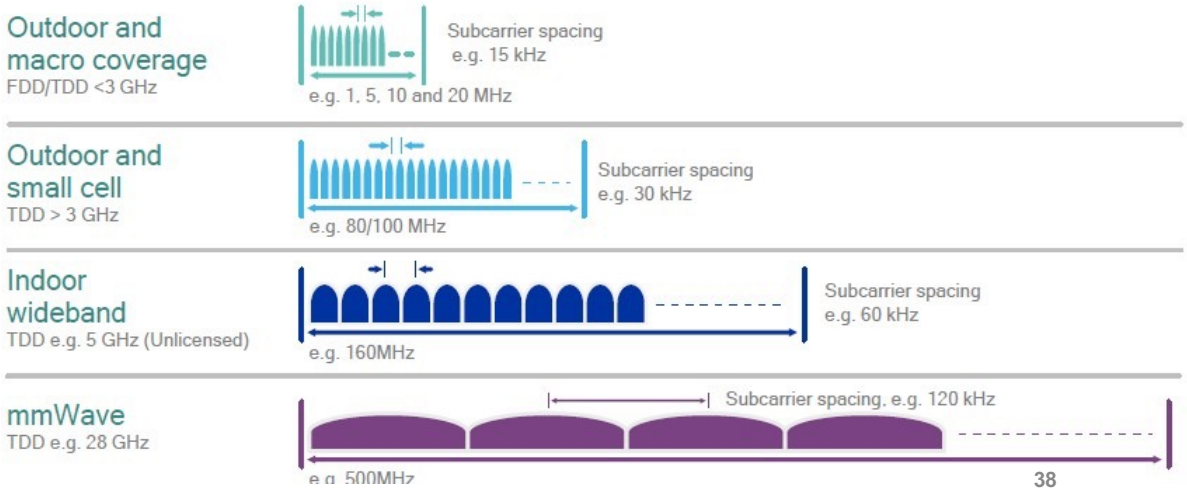
- Re-use of Orthogonal Frequency Division Multiplexing



5G NEW RADIO



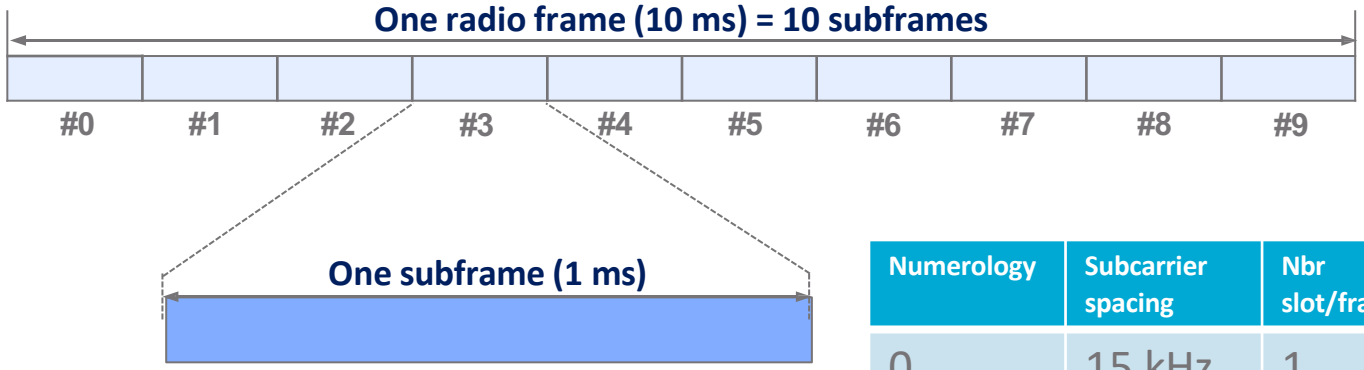
- Why OFDM:
  - Spectral efficiency, adapted to MIMO
  - Low complexity receiver
  - Frequency localisazion with windowing technics,iIn order to efficiently support multiplexing of 5G services, both in-band and out-of-band emissions must be kept to a minimum
  - Low-Power consumption with SC OFDM for uplink
  - Can co-exist with optimized waveforms and multiple access for wide area IoT
- Scalable numerology:
  - Fixed 15KHz SCS (subcarrier spacing)in LTE → Flexible SCS in NR
  - To efficiently address diverse spectrum, deployments and services



Source: Qualcom WP

5G NEW RADIO

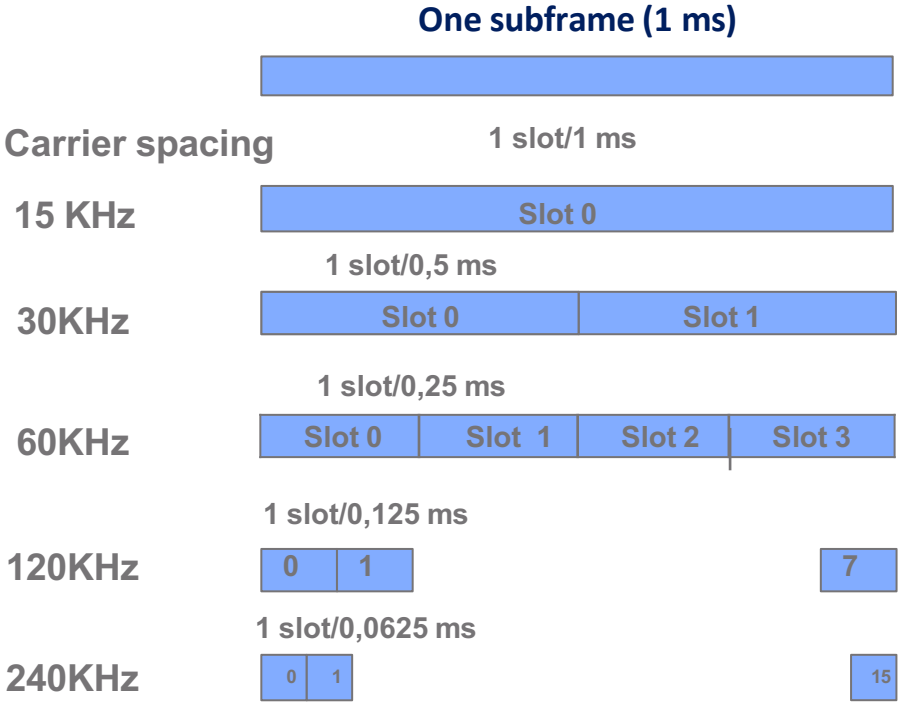
- Radio frame structure in the time domain
  - Downlink and uplink transmissions are organized into radio frames
    - Radio frame duration : 10ms
  - A radio frame is divided in 10 subframes
    - Subframes duration: 1 ms
  - The number of slot in a subframe depends of the subcarrier spacing



Numerology	Subcarrier spacing	Nbr slot/frame
0	15 kHz	1
1	30 kHz	2
2	60 kHz	4
3	120 kHz	8
4	240 kHz	16

5G NEW RADIO

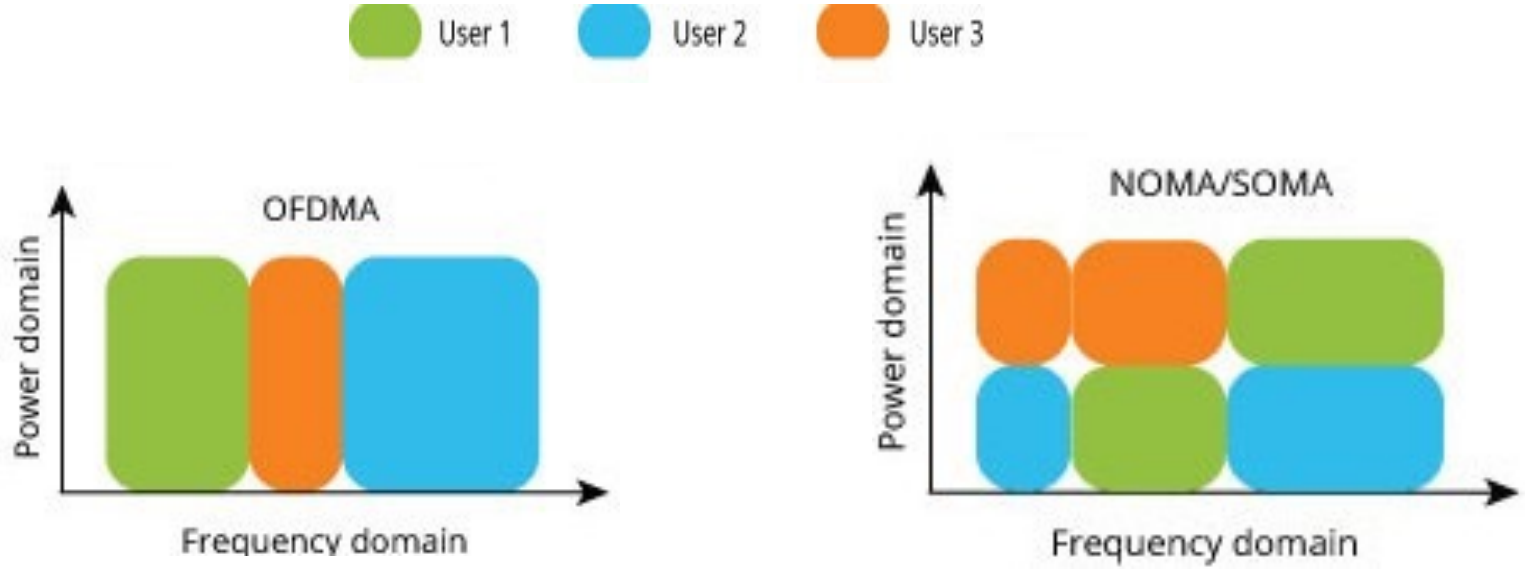
- Slot
  - Slot length gets different depending on different subcarrier spacing.
    - Slot length gets shorter as subcarrier spacing gets wider



- OFDM symbol
  - The number of symbols within a slot does not change with the numerology or subcarrier spacing.
  - The number of symbols per slot is 14 (in case of Normal CP)

5G NEW RADIO

- Access technics
  - › non-othogonal technics is also considered by allocation of the same radio resources to multiple users
    - Power domain NOMA: a Non-Orthogonal Multiple Access using power to domain to diiferentiate the users
    - Sparse Code Multiple Access (SCMA) a combination of OFDMA and CDMA.

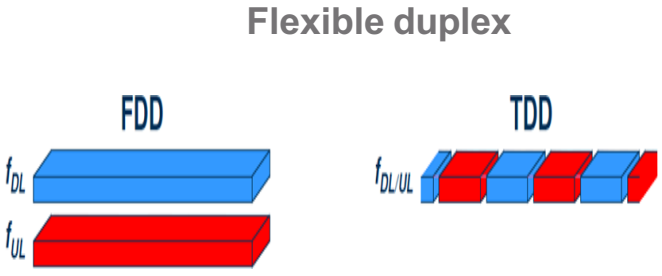


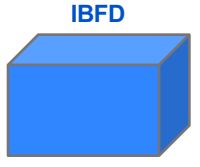
5G NEW RADIO

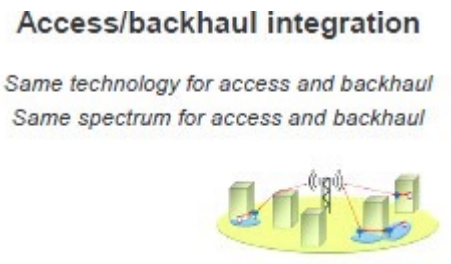
- Spectum flexibility
  - › From licensed spectrum to unlicensed spectrum
    - Unlicensed to increase capacity
  - › More flexible TDD-FDD operation
  - › Dynamic TDD
    - From a static split of the uplink and downlink to a dynamic one

    The network can use the spectrum resources for either the UL or the DL to cope with dynamic traffic variation
  - › In-Band Full Duplex (IBFD)
    - to share the same time and frequency
    - Full Duplex will allow simultaneous Transmission and Reception
- Access and backhaul integration

  The use of the same spectrum between the access and the backhaul remove the traditional division between access and backhaul
  - › Same technology for access and backhaul
  - › Same spectrum for access and backhaul





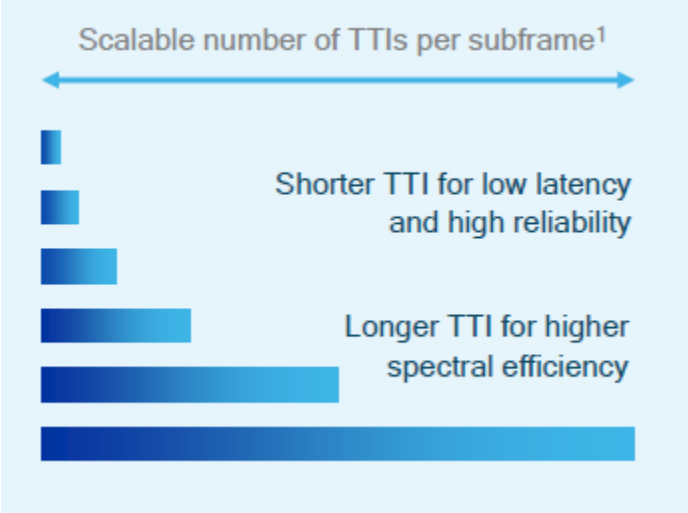


5G NEW RADIO

- Low latency

  Some of the aspects to be considered to lower the latency

  - › Reduction of the time transmission interval where the resources are assiged to the terminal (TTI)
  - › Immediate access instead of the request-grant phase prio to transmission
  - › Direct device-to-device transmission
  - › Service-aware TTI (different TTIs)



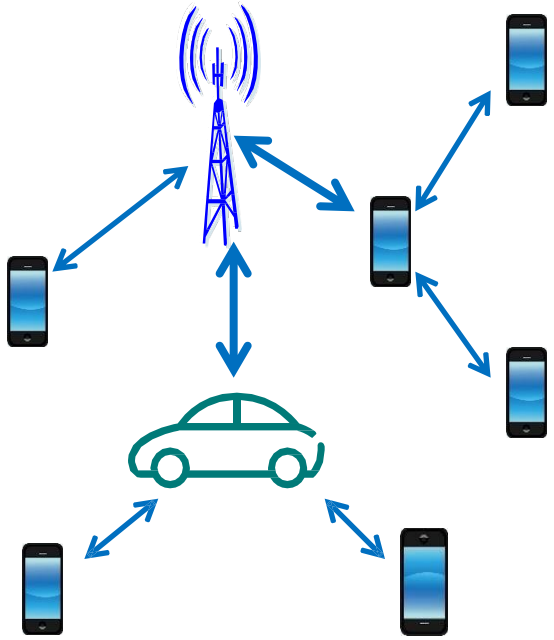
5G NEW RADIO

- Device to Device communication - D2D

  The existing split in the architecture of mobile networks between the infrastructure (the access nodes) and the terminal nodes (the mobile device) may not be applicable

  A terminal/device with D2D can have a dual role:

  - Acting as an inftrastucture node
  - Or acting as a terminal



5G NEW RADIO

- Some key technoloy areas:
  - Lean design

  In existing mobile network the control plan use resources on an always on basis (broadcast system information, pilot signal)

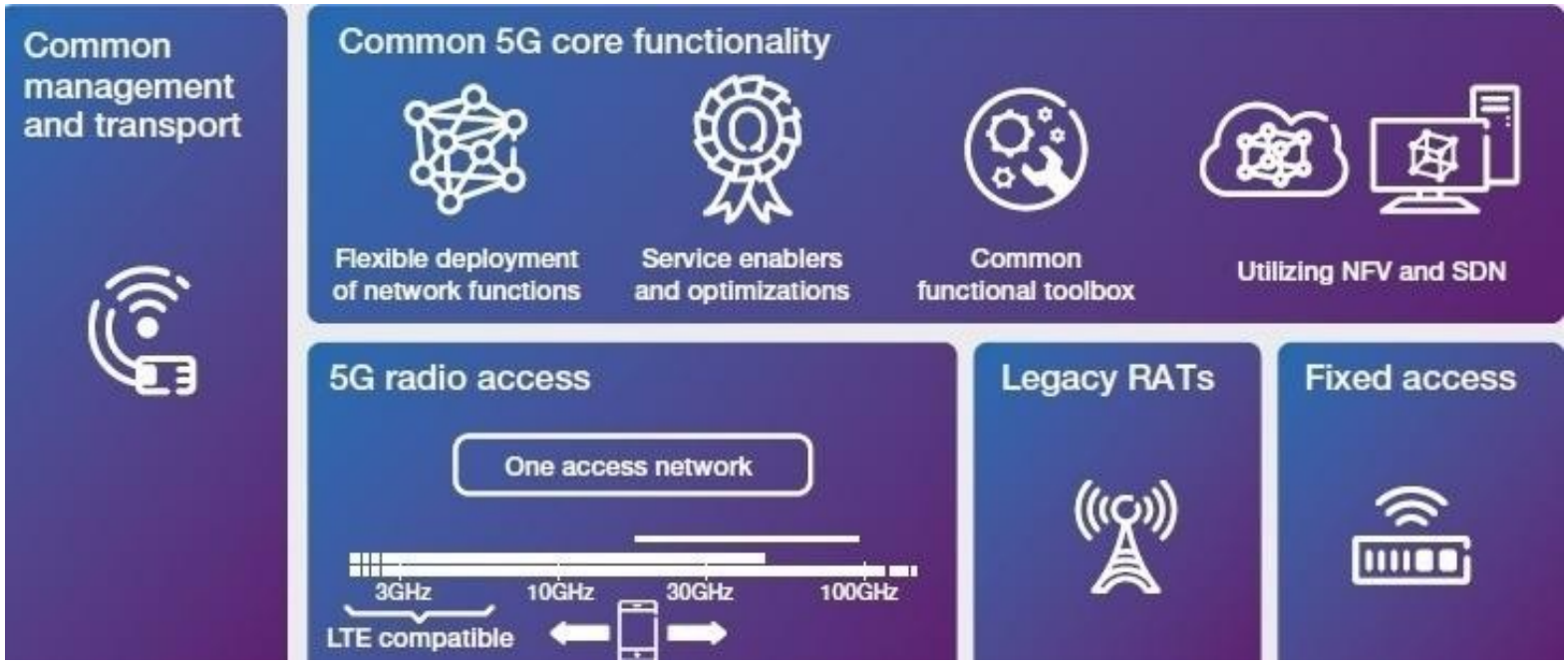
  In a network where the number of devices is x100 transmission needs to be minimize when not related to user data
    - Communication when only user data is to exchanged
    - Limit the interference and the power
    - Enhance the energy consumption

- Massive number of devices characterized by:
  - Simplicity, low cost, low energy consumption
  - And small amount of data

5G Core
5GC

The Technology evolution

- The overall 5G Architecture:
  - A 5G radio access supporting different types of radio acces technologies (RAT)
  - A common core supporting
    - The 5G access
    - The legacy RAT
    - The fixed access



5G Core

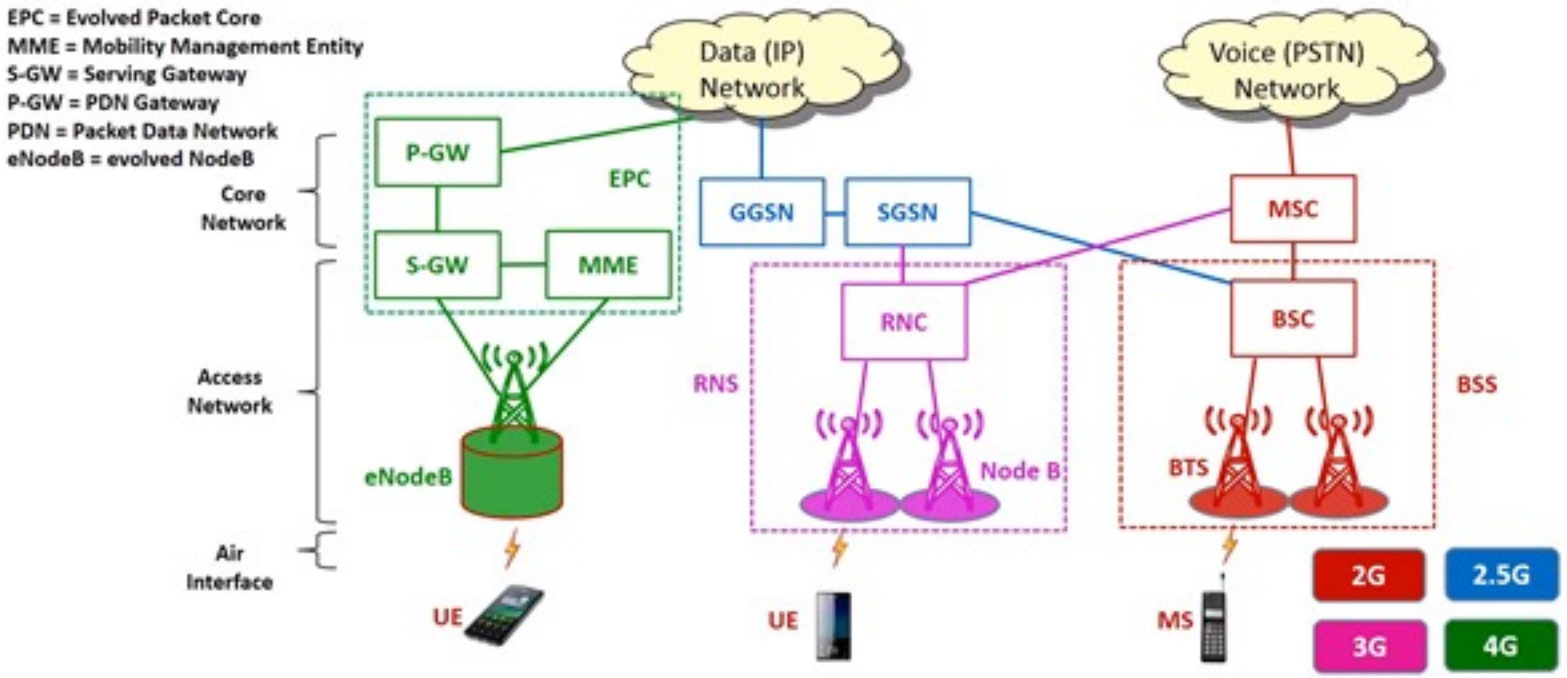
- Introduction to NGC
  - In order to support and enable all defined and future use cases the 3GPP has defined a new core network called:
  - **5G Next Generation Core : NG-Core or NGC or 5GC**

- 5G Core Network consists of the entities that provide support for the network features and telecommunication services. This support includes:
  - User location information
  - Control of network features and services,
  - The transfer (switching and transmission) mechanisms for signaling and for user generated information.

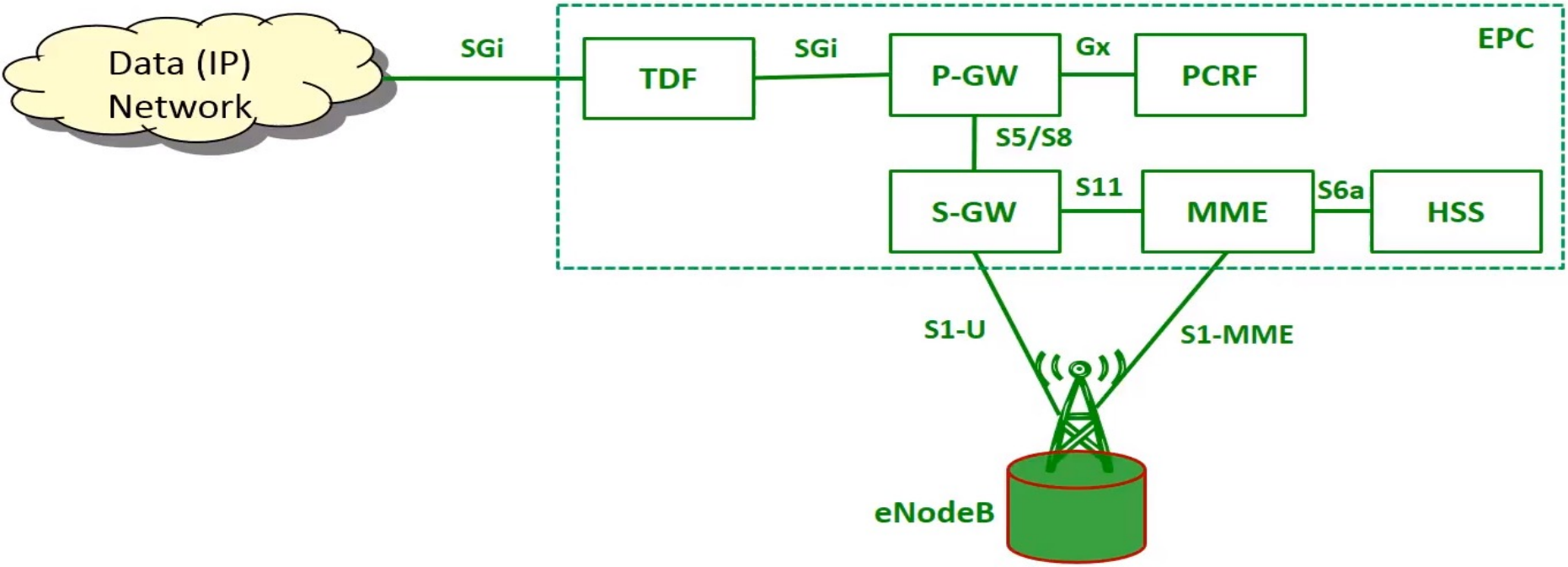
5G Core

- Evolution of network architecture for the core
  - Virtualization and Network functions virtualization
  - A service based architecture
  - Control Plane (CP) and user plane (UP) split
  - Mobility management and session management function decoupling
- Network Slicing for supporting the new business domains referred as “verticals”
  - The capability to run “logical” network on a common physical infrastructure

Architecture of 2G/3G/4G

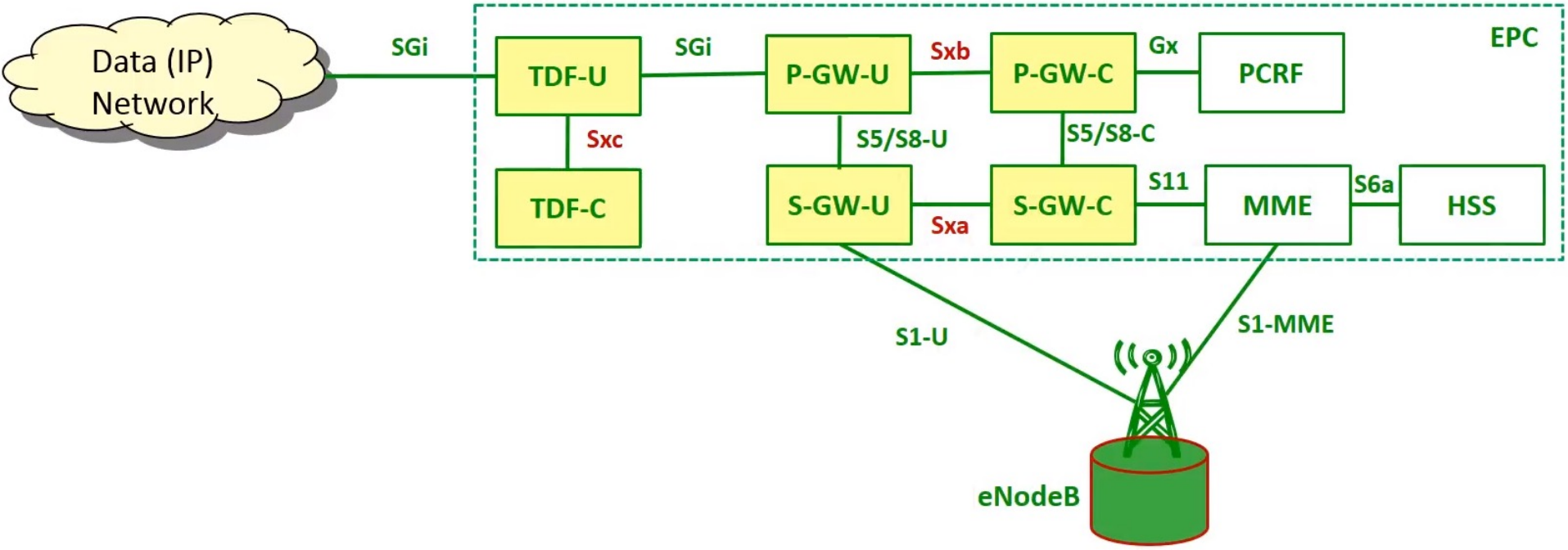


Architecture of 4G



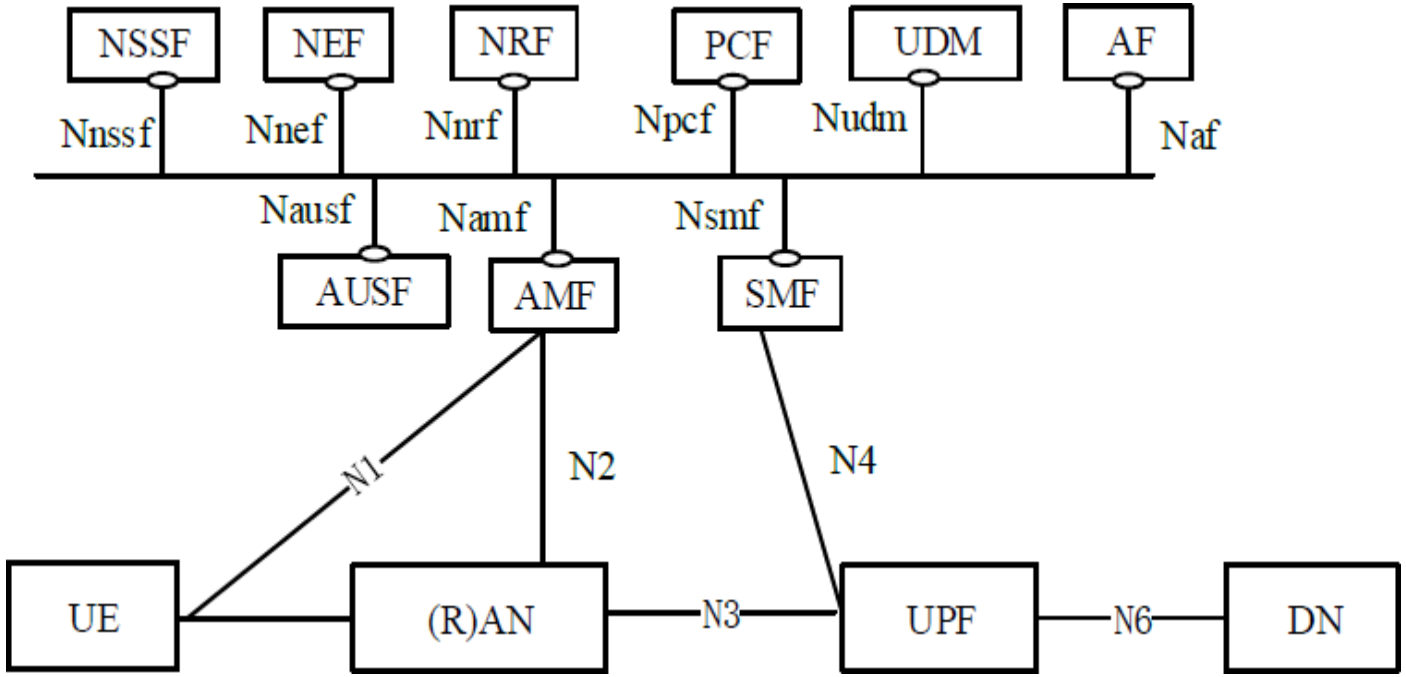
- Traffic detection functionality
- Packet Gateway P-GW: control (PCRF = Policy Charging Rule) + traffic
- Serving GW: control of mobilty

Separation between control and user plans



5G Core

3GPP Core Network Architecture & Interfaces



5G Core: NFs main tasks

- AMF (Access and Mobility management Function)
  - Access control (Authentication & Authorization)
  - Registration & Mobility management control
- SMF (Session Management Function)
  - Session Control (Session Establishment, modify and release)
  - UE IP address allocation and management;
  - Selection and control of UPF
- UPF (User Plane Function)
  - Handling User Data
  - Packet routing & forwarding and Packet inspection
  - QoS handling for user plane

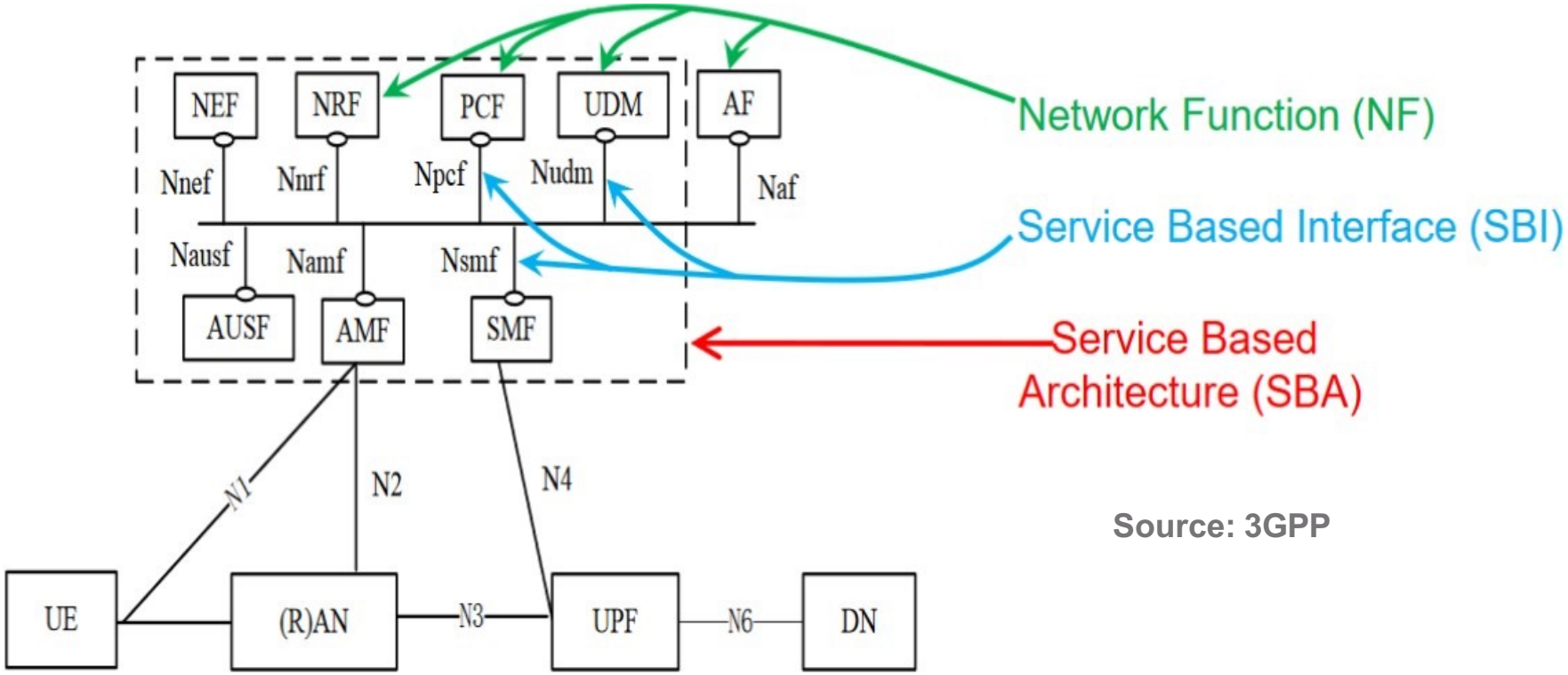
5G Core: NFs main tasks

- NRF (Network Repository Functions)
  - Provides profiles of Network Function (NF) instances and their supported services within the network
- NEF (Network Exposure Function)
  - provides external exposure of the capabilities of the network functions
- NSSF (Network Slice Selection Function)
  - Selecting the set of Network Slice instances serving the UE
- UDM (Unified Data Management)
  - supports Data Storage
- PCF (Policy Control Function)
  - Provides policy rules to Control Plane function
- AUSF (Authentication Server Function)
  - Supports authentication vectors for 3GPP access and untrusted non-3GPP access

5G Core: Service Based Architecture

- Service Based Architecture (SBA) Release 15
  - The main evolution compared to previous generation based on point to point interface between network element
  - Network Functions provides “Services” to other Network function via a common service base interfaces (SBI) allow a network function to discover the services offered by other network functions
  - Network Repository Functions (NRF) allows every network functions to discover the other network functions

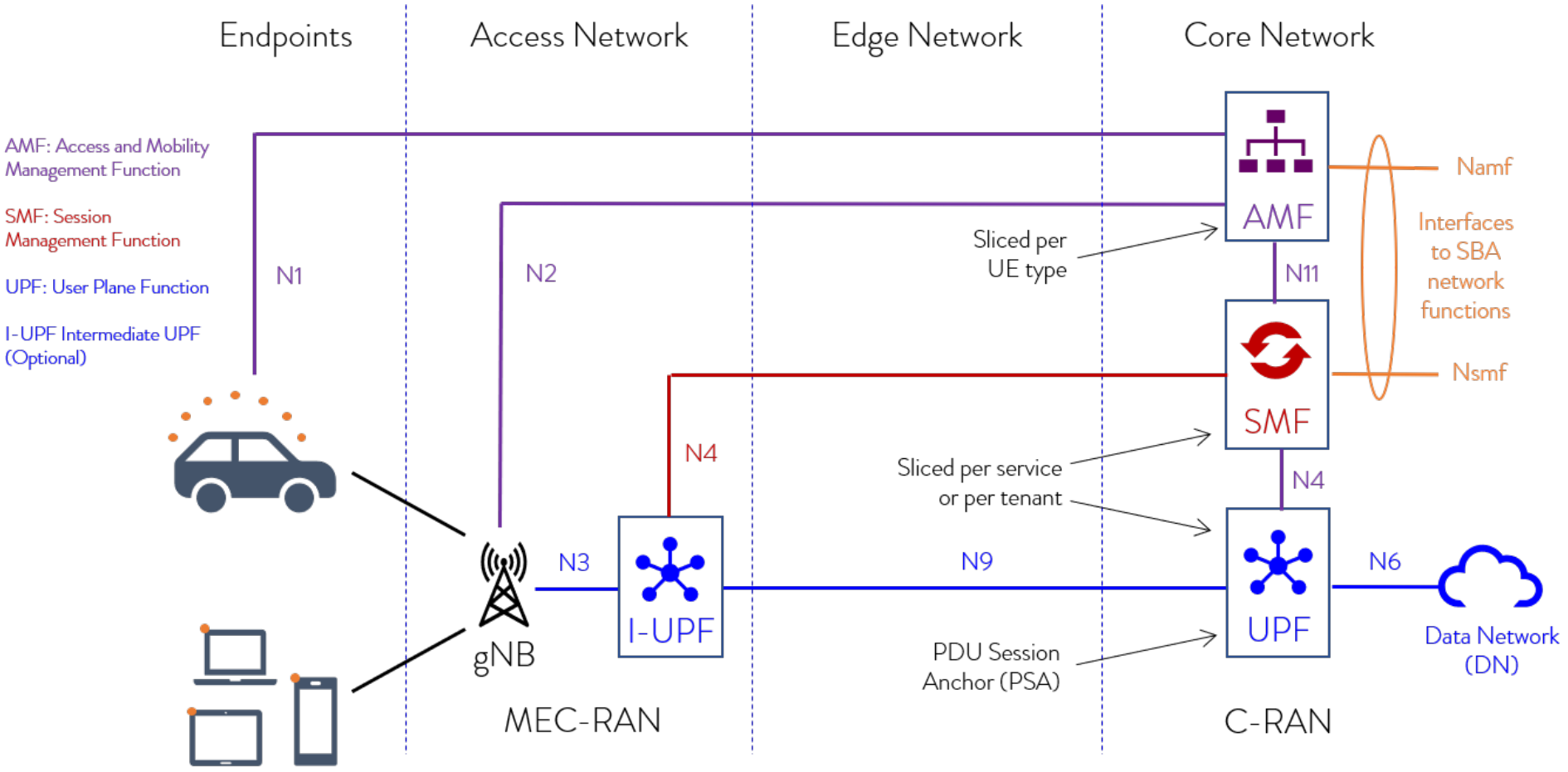
5G Core: Service Based Architecture



Source: 3GPP

NEF	Network Exposure Function
NRF	Network Repository Function
PCF	Policy Control Function
UDM	Unified Data Management
AF	Application Function
AUSF	Authentication Server Function

AMF	Access &Mobility Management Function
SMF	Session Management Function
UE	User Equipment
(R)AN	(Radio) Access Network
UPF	User Plane Function
DN	Data Network



- MEC-RAN: Multi-Access Edge Computing – Radio Access Network

5G NFV

Network Function Virtualization

Network Function Virtualization

- SDN and NFV
  - 5G Network functions implemented as virtualized software instances running in data centers.
  - Software Defined Networking/Network Functions Virtualization -SDN/NFV- simplifies scaling and management of network infrastructure.
  - SDN is the separation of the network control traffic (control plane) and the user specific traffic (data plane). SDN is based on the centralization of configuration and control, while ensuring a simple data plane architecture.
  - NFV is the virtualizing network functions (by implementing them in software) that can run on a range of standard hardware.

From

To

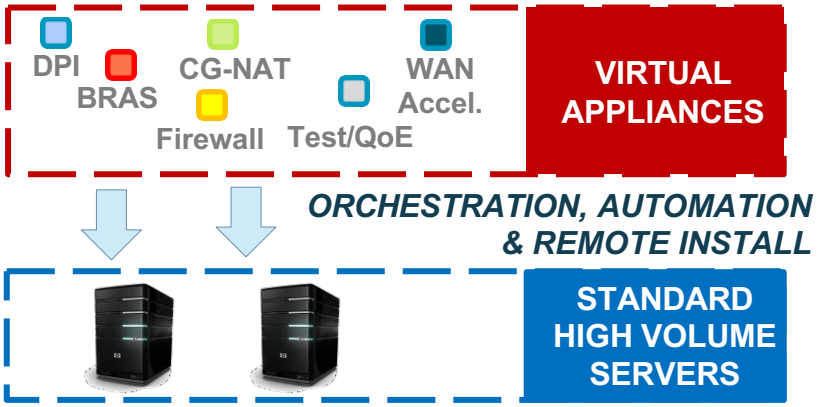
Network Function Virtualization

- Network Function Virtualization – NFV –
  - The objective: a network flexible, dynamic, and less dependent on hardware
  - –Telecom industry is going from proprietary hardware to ”on the shelf” IT harware
  - Such as server, data storage, switches
  - – The networks functions are implemented by sofware using virtualisation from the IT industry

Traditional Network Model: HARDWARE APPLIANCE APPROACH

- **Network Functions are based on dedicated hardware and software**
  - **One physical appliance per role**

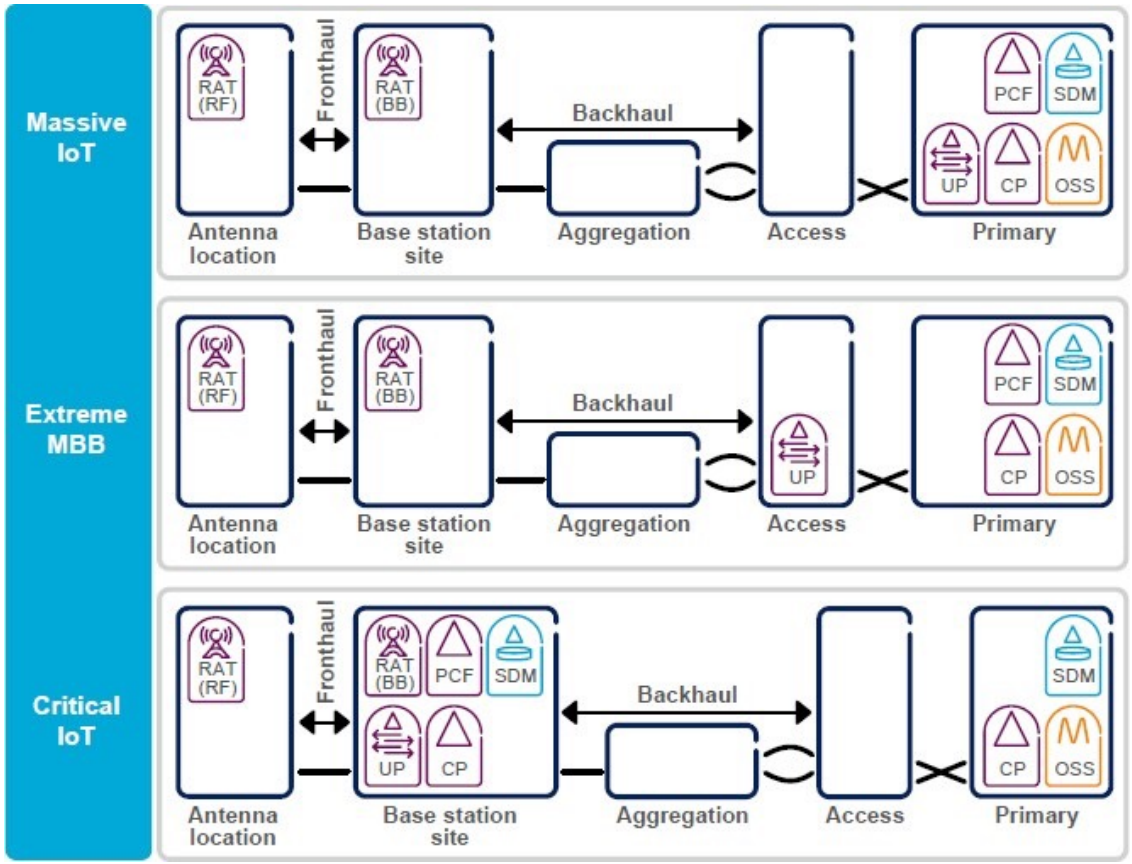
Virtualised Network Model: VIRTUAL APPLIANCE APPROACH



5G
Network Slicing

Network Slicing

- Network Slicing
  - Allows for the definition of multiple virtuals networks (or slices) on top of the same physical infrastructure



Source: Ericsson WP 5G Systems

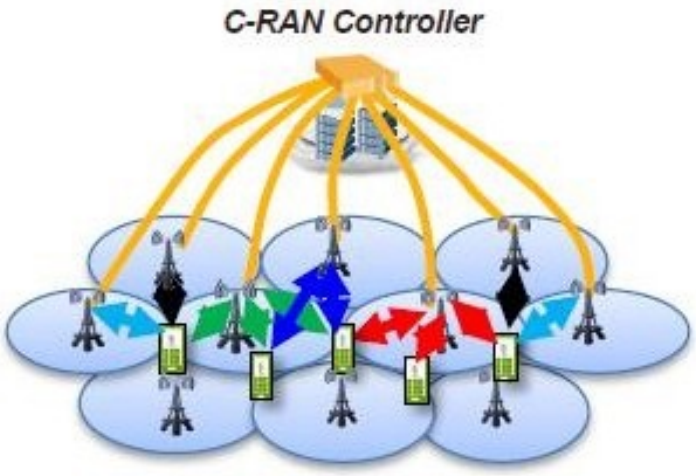
Network Slicing

- Example of slices
  - Automotive slice
    - A “connected” car will require high throughput for in-car entertainment, ultra reliability and low latency (URLLC) for autonomous driving, device to device communication, data gathering…
  - Industry automation slice
    - A factory may require URLLC slice for automation using edge data center
  - Enterprise
    - Eg a taxi company to dispatch and the manage the cars,
  - Massive IoT
    - Eg a transport traffic management to monitor and manage in real time
  - Augmented Reality (AR)/Virtual Reality
    1. AR/VR slice will require multimedia broadcast services, high density computing and QoS requirements

Cloud RAN

Cloud RAN

- CloudRAN/centralized-RAN: a new network architecture based on SDN
  - The base stations signal processing units installed at the base station level are moved to the cloud and centralized.
  - They communicate with the network radio heads, located closer to the antenna, over an optical fiber network (Radio over fibre technology).
  - This centralization makes it possible to obtain a complete overview of all of the stations deployed and to coordinate signal processing and manage interference between cells and devices
  - Allows for the separation of the radio unit with the base band functions that are centralized
  - Baseband processing (including RAN L1, L2 and L3 protocol layers) is located at a central location that serves multiple distributed



Source: https://5G-ppp.

Conclusion

- 5G will not replace LTE, they will coexist / complement for a significant period
  - LTE will still evolve

- The 5G challenge
  - To confirm the usecase for the industry for the vertical networks using network slicing
  - New frequency availability
  - To confrim the 5G requirements
  - Availability of terminals