

# **Český Institut Informatiky Robotiky a kybernetiky**

**ČVUT v Praze**

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### **BEZDRÁTOVÉ PŘENOSOVÉ SÍTĚ – VÝVOJ A POPIS – Od 0G k 5G**



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**Cíle:** Cílem tohoto kurzu je seznámit účastníky se novou generací mobilních 5G. Studenti se naučí novinky v systému 5 G jako je kompletní nová rádiová část, nové jádro sítě a nové služby v 5 G. Kurz poskytne přehled o nových technologických přenosu hlasu IMS, VoLTE a Vo5G a o nových technikách vysílání 5G NR (New Radio) a dále se kurz zabývá technikami 5G network slicing a virtualizací sítí – NFV. V neposlední řadě se věnuje i moderním Wi-Fi sítím Wi-Fi 6(E).

**Požadavky:** Doporučení

- Základní znalost mobilních sítí a mobilního internetu
- Základní znalost TCP/IP a VoIP, SIP
- Základní znalost ethernetu a fungování sítí

*Obsah:*

- Vývoj infrastruktury a služeb
- GSM, GPRS a jádro sítě (HLR, VLR, SGSN, GGSN)
- Mobilní internet 2,5 G a 3 G
- UTRAN (UMTS Terrestrial Radio UMTS)
- HSDPA, HSUPA, HSPA, HSPA +
- LTE, LTE Advanced
- 4G, OFDM, SAE, EPC, OFDM, MIMO
- M2M - LTE-M a NB-IoT
- IMS (HSS, SLF, BGF, BGCF, SBC, CSCF, MGCF, MGW, MRFC, MRFP, AS, PCFR)
- Požadavky na 5G IMT-2000
- 5G NR (nové rádio), OFDMA, SISO a MIMO
- 4 G eNB, 5G NR gNB, typ buňky, spektrální účinnost a pokrytí
- Agregace spektra, sdílení dynamického spektra
- Vývoj jádra sítě 2,5 G, 3 G, 4 G
- 5G jádro sítě (NSSF, NEF, NRF, PCF, UDM, AF, AUSF, AMF, SMF, UPF)
- Služby 5G
- Extreme Mobile Broadband
- Massive Scale Communication
- Ultra-Reliable Low Latency Service
- IoT, IIoT, Industry 4.0, Smart Home
- NGMN 5G Network Slicing, NFV, SDN
- Wi-Fi 6, Wi-Fi 6E, 6 GHz
- Ultra širokopásmové připojení - Ultra Wideband

*Obtížnost přehledová*

- Základní kurz:      *délka kurzu 1 den / 5.790. Kč za účastníka*
- Pokročilý kurz:      *délka kurzu 2 dny / 7.890. Kč za účastníka*  
*(Uvedené Ceny je bez DPH 21%)*

*Min. počet účastníků:*      5

*Max. počet účastníků:*      20  
*ceny pro větší skupiny po domluvě s pořádajícím*

*Technické vybavení:*      Bez nároků na laboratorní vybavení

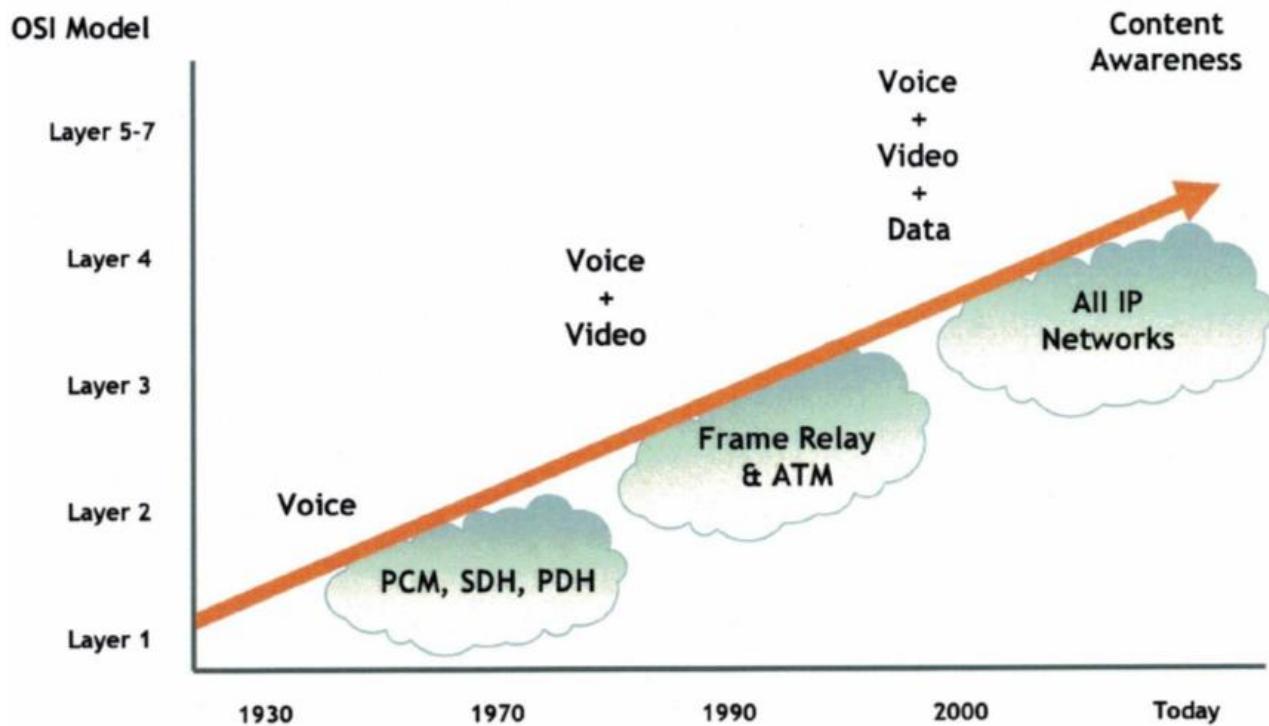
*Literatura:*      Všichni účastníci obdrží elektronickou verzi studijních materiálů.



## Mobile Internet evolution

- 0G – ARP, AMR – no data
- 1G – NMT, C-NET, AMPS – no data
- 2G – GSM 9,6 a 14,4 kbit/s – circuit switching
- 2,5G – GSM/GPRS Downlink 80 kbit/s, latency ~ 700 ms
- 2,75G – GSM/EDGE, Downlink 200 kbit/s, latency ~ 700 ms
- 3G – UMTS, CDMA2000, Downlink, Uplink 384 kbit/s, latency < 150 ms
- 3,5G – UMTS/HSDPA (High Speed Downlink Packet Access), 14.0 Mbit/s
- 3,75G – UMTS/HSUPA (High Speed Uplink Packet Access), 5.76 Mbit/s
- 3,8G – HSPA+ Downlink 168 Mbit/s, Uplink 22 Mbit/s, latency < 50 ms
- 4G – LTE, Downlink 172.8 Mbit/s, Uplink 57.6 Mbit/s, latency < 20 ms
- 4,5G - LTE-A, LTE Advanced LTE-A Pro, Downlink 300 Mbit/s, Uplink, latency < 10 ms

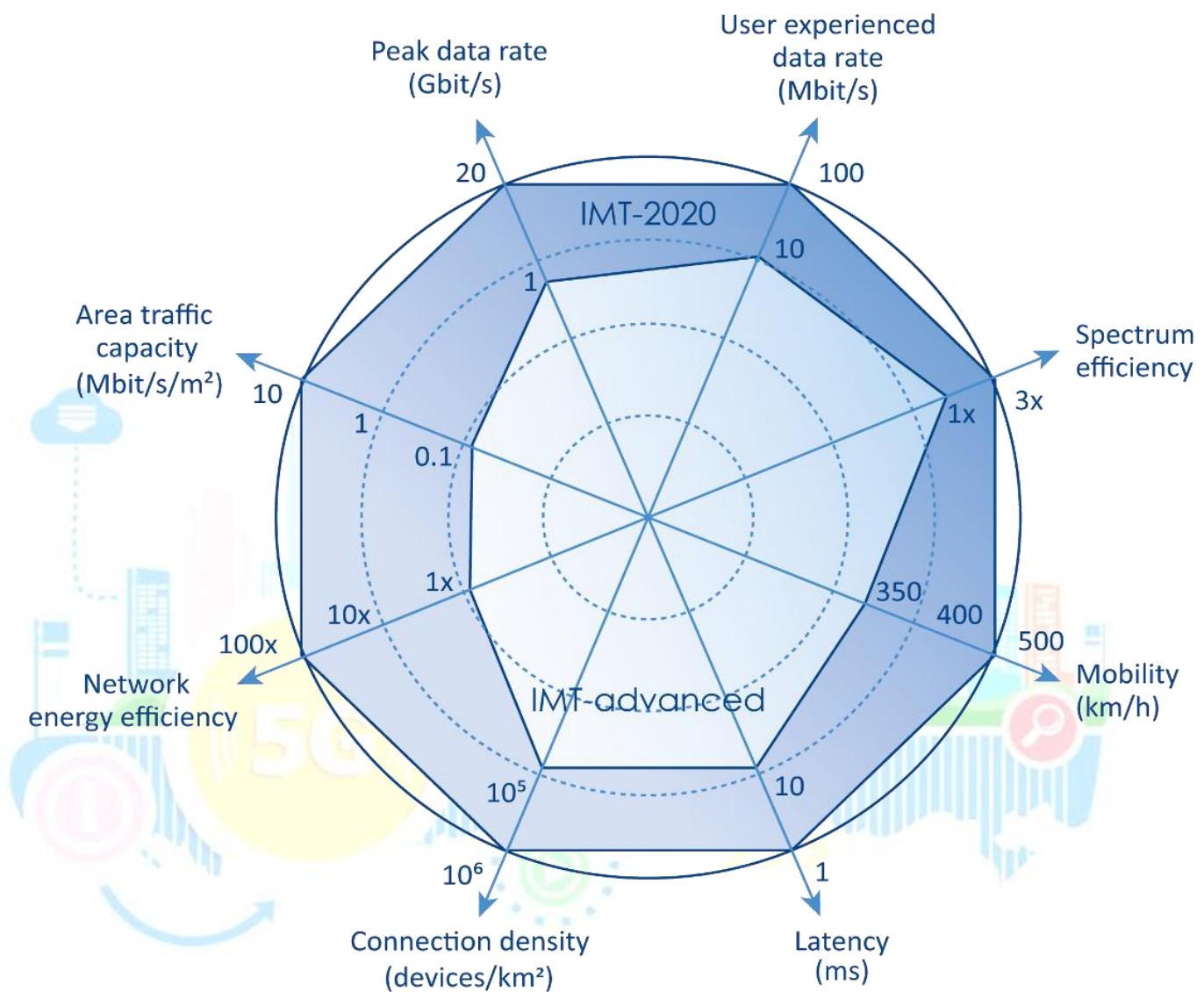
# The Evolution of Infrastructure & Shifting service



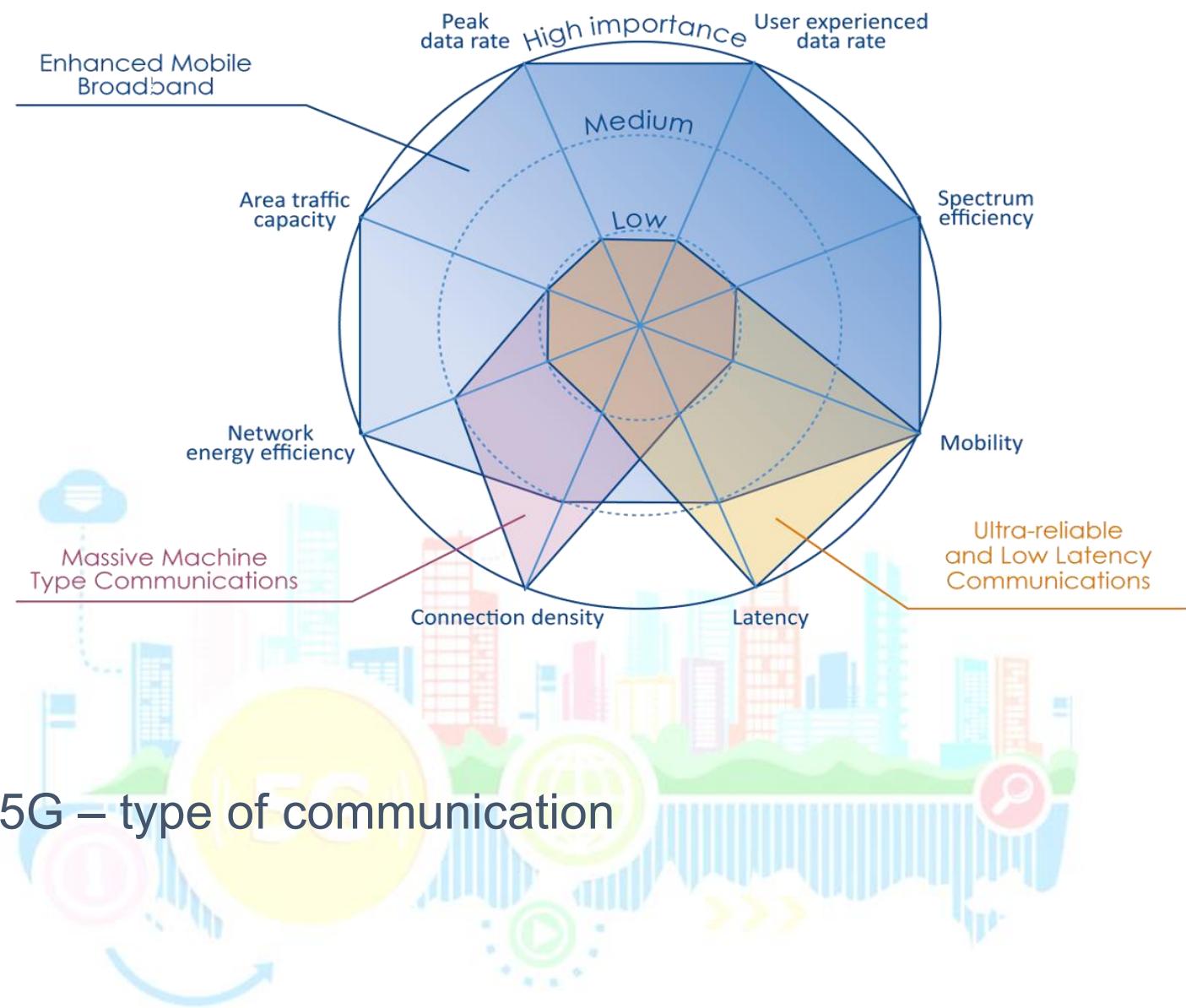
## 5G main requirements

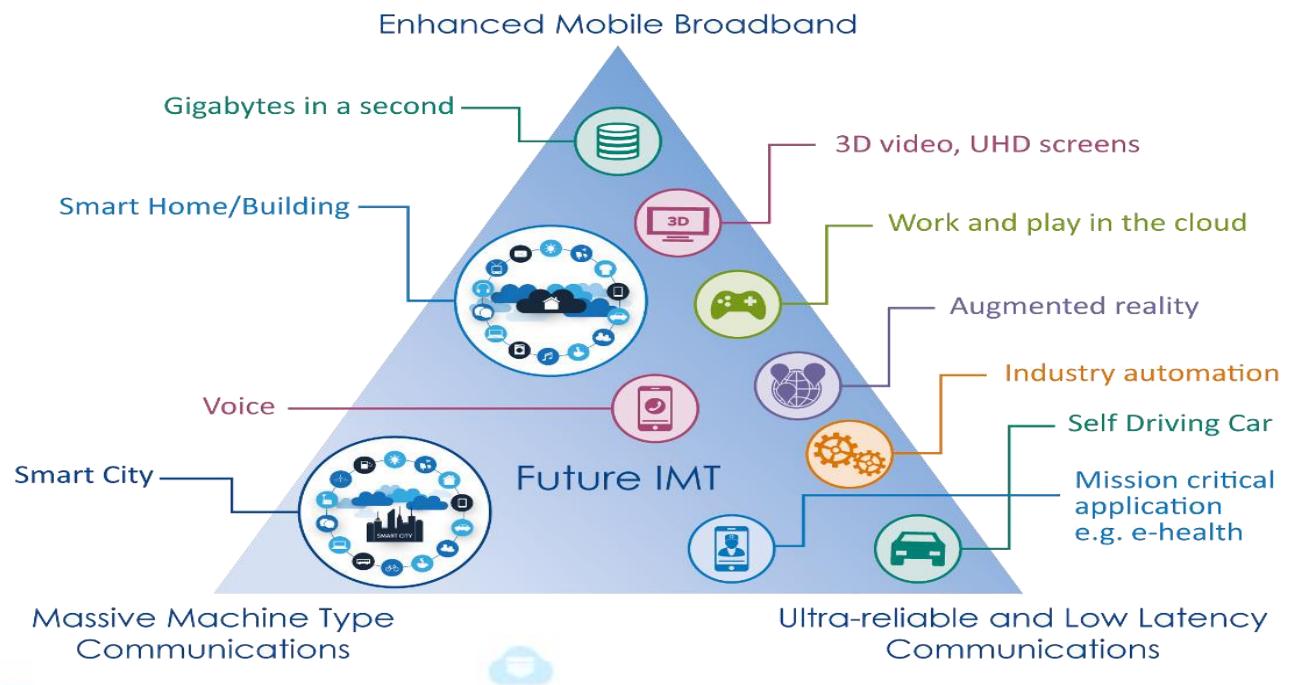
- 1-10 Gbit/s connections to end points in the field (i.e. not theoretical maximum)
- 1 millisecond end-to-end round trip delay - latency
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- Perception of 99.999% availability
- Perception of 100% coverage
- 90% reduction in network energy usage
- Up to 10 year battery life for low power, machine-type devices

## 5G – IMT-2020

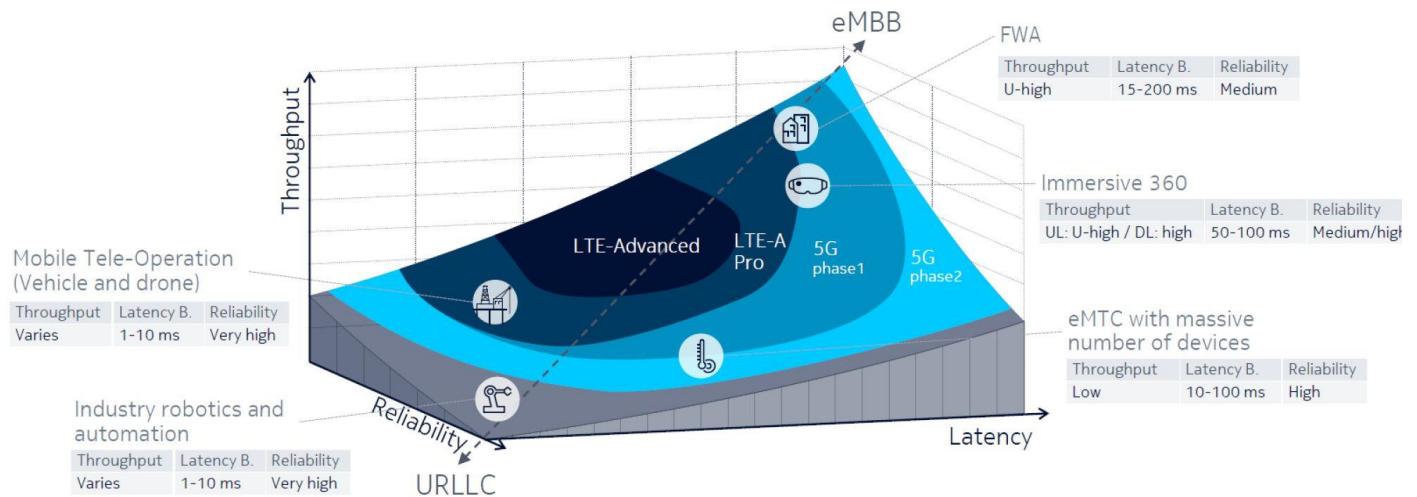


# 5G – IMT-2020





## Requirements for Different 5G Use Cases



## LTE vs 5G

LTE

5G

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

## 5G Use Cases and type of communication

Services:

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

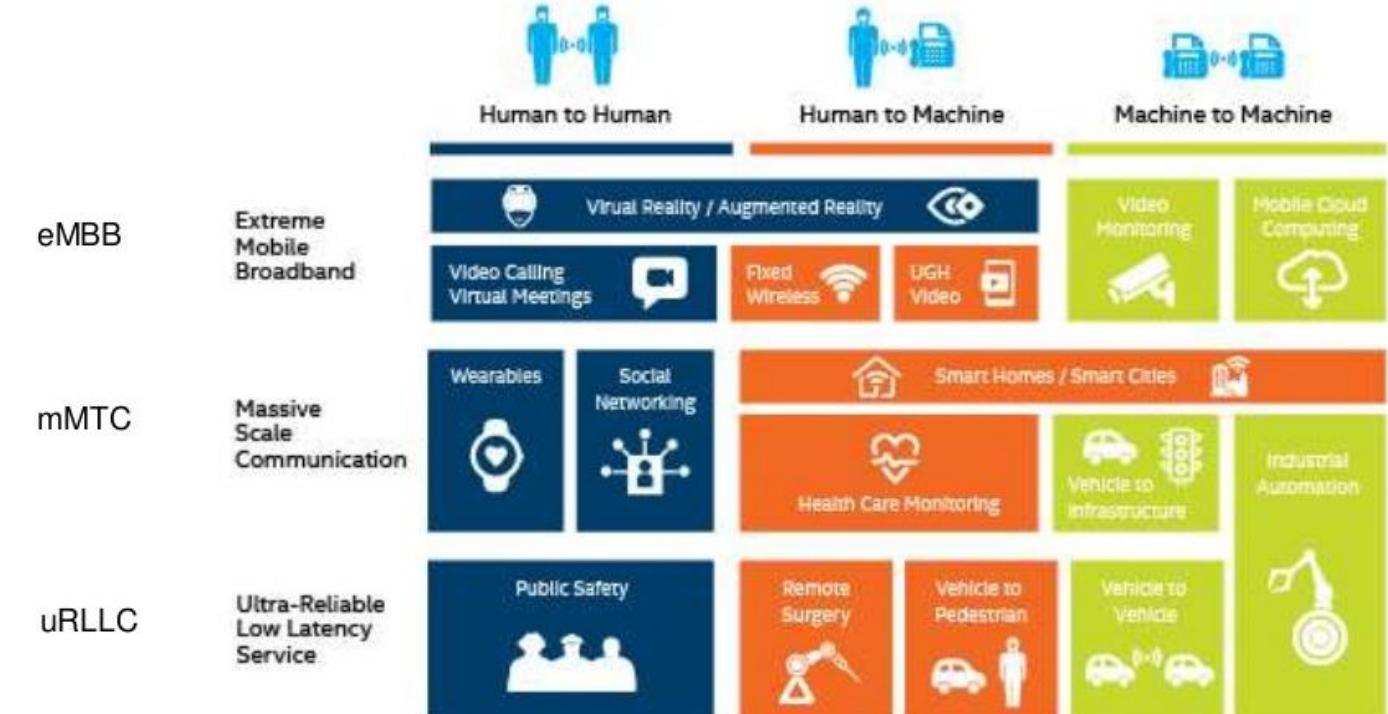
Type of communication:

- Human to Human
- Human to Machine

Machine to Machine



## 5G – type of communication



## From Silos to a Common Core for All

- Heterogeneous Access
  - 4G UE
  - 5G UE
  - Wi-Fi UE
  - CPE
  - Common Core – IMS

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- Heterogeneous Access
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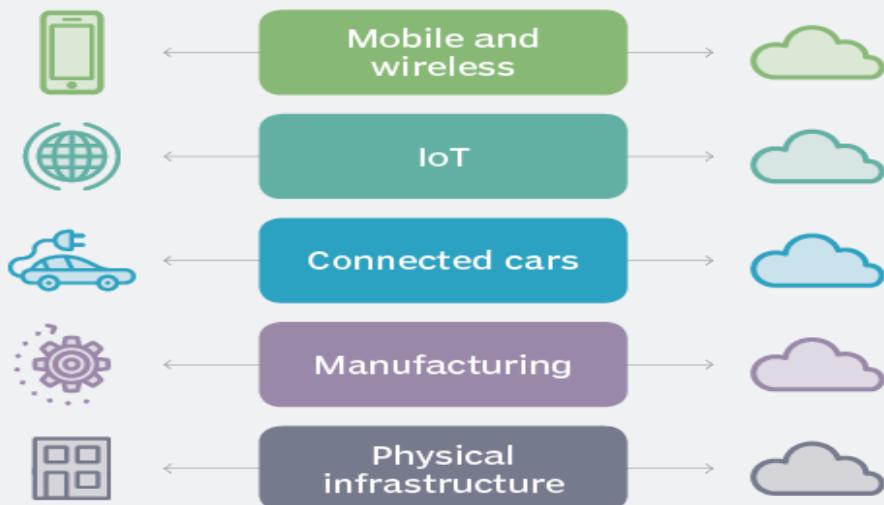
## 5G Cases according ITU

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

## NGMN 5G Network Slicing

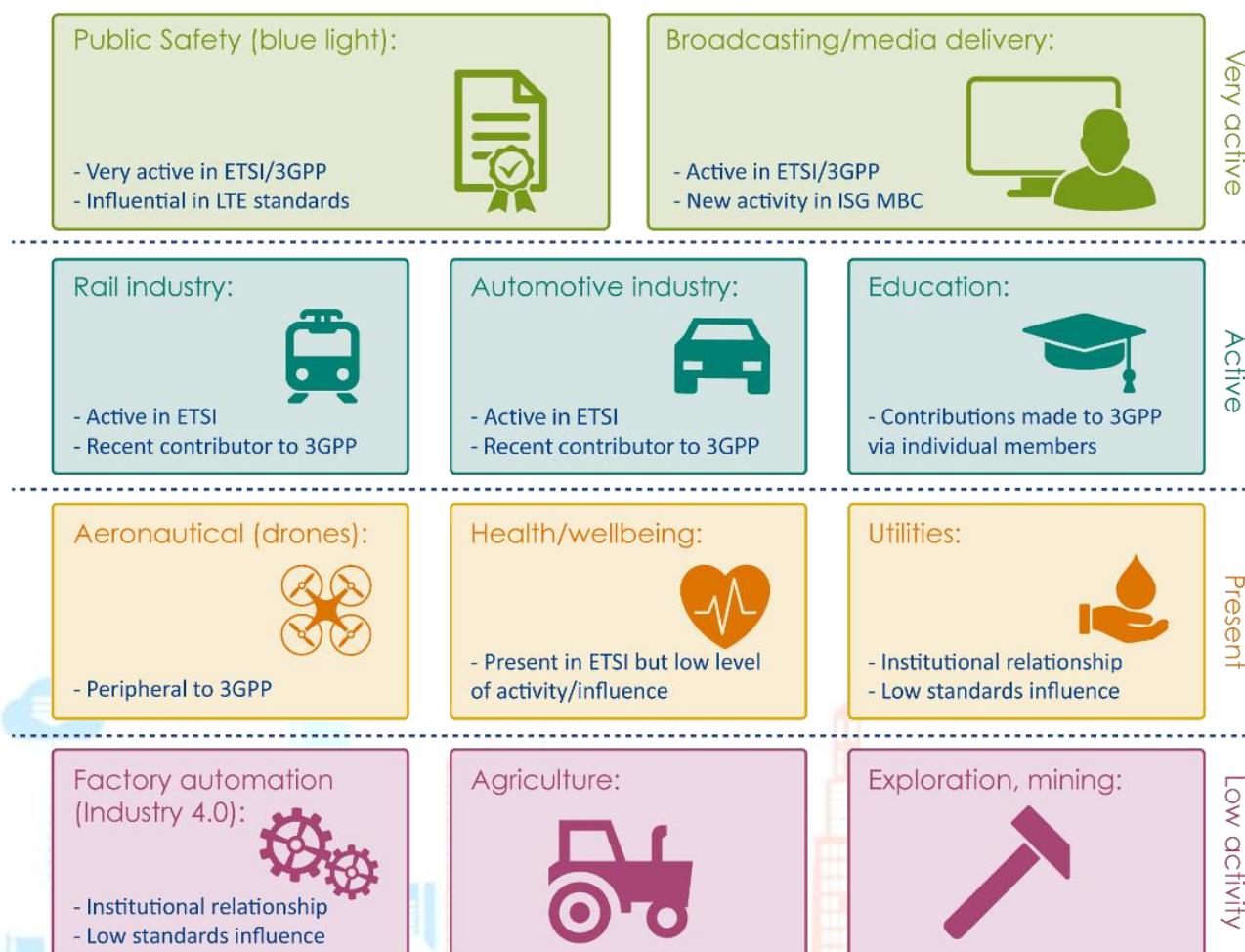
- Next Generation Mobile Networks
- Software Defined Networking (SDN)
- Network functions virtualization (NFV)

# What is network slicing?



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## 5G radio frequencies – New Radio

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

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

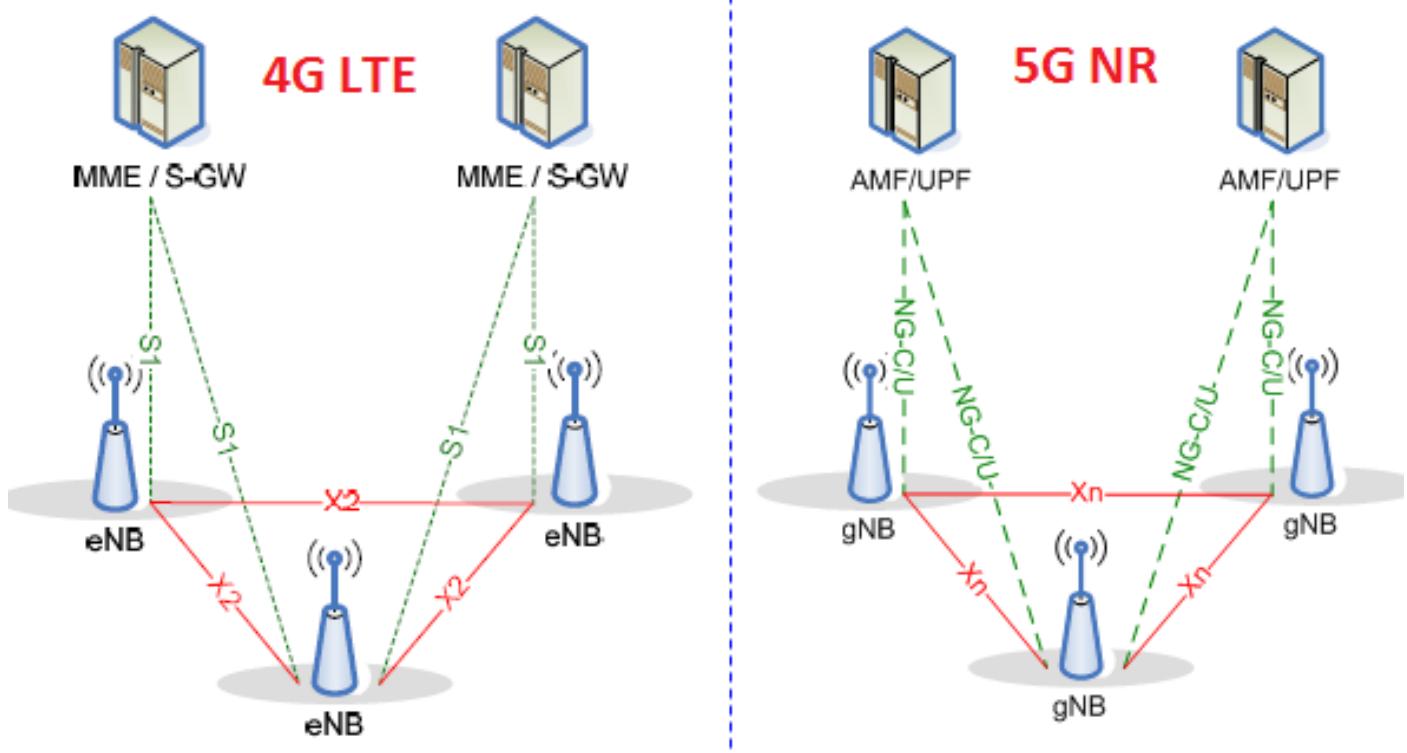
Frequency range 1 (< 6 GHz)

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

Frequency range 2 (> 24 GHz)

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

# New Radio – 4G LTE vs 5G NR



## 5G Cell types, users, coverage

	Cell types	Deployment environment	Max. number of users
5G NR FR2 $> 24 \text{ GHz}$	Femtocell	Homes, businesses	Home: 4–8 Businesses: 16–32
	Pico cell	Public areas like shopping malls, airports, train stations, skyscrapers	64 to 128
	Micro cell	Urban areas to fill coverage gaps	
	Metro cell	Urban areas to provide additional capacity	more than 250

## Mobile transformations

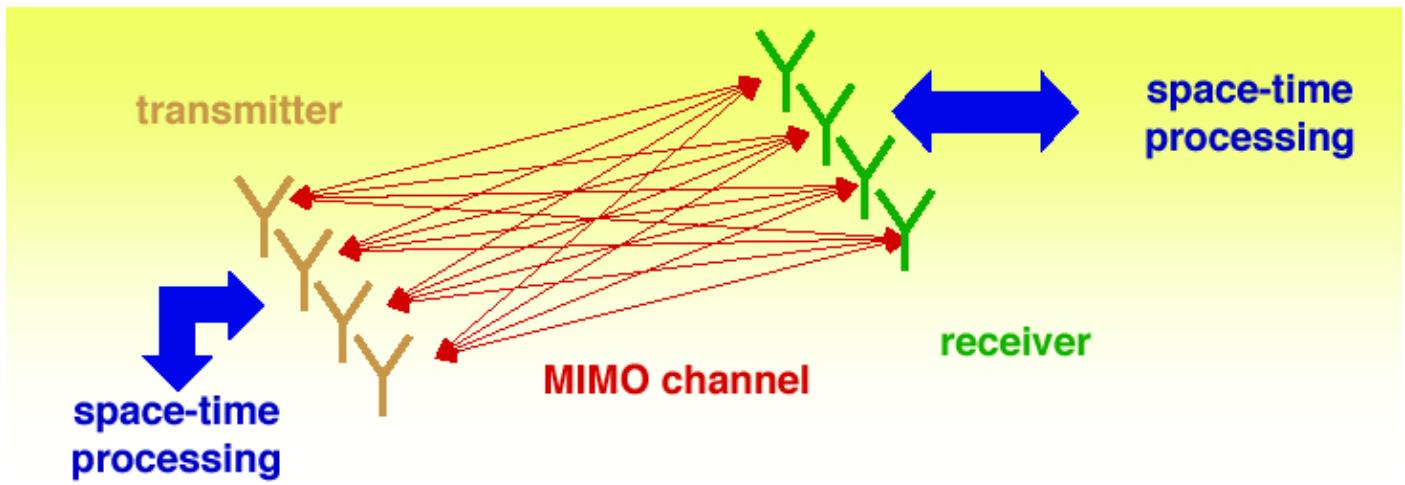
### Intensifying Role of Wireless Communications

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

- Artificial intelligence and machine learning

## MIMO antenna

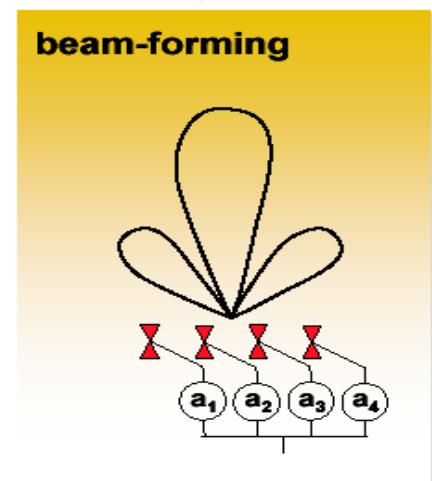
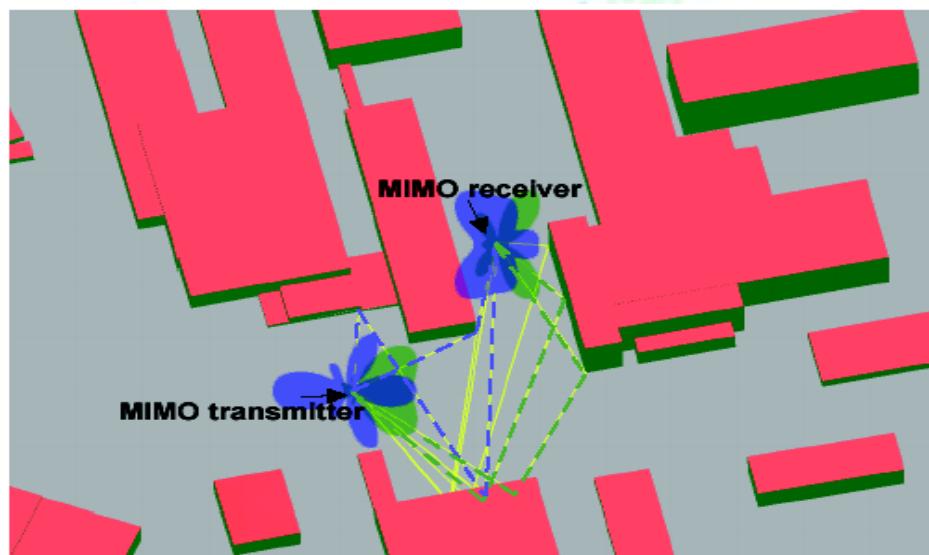
- Multiple Input, Multiple Output
- Smart antenna
- Diversity



## MIMO and Smart antennas

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

## MIMO, Smart ant and beam-forming

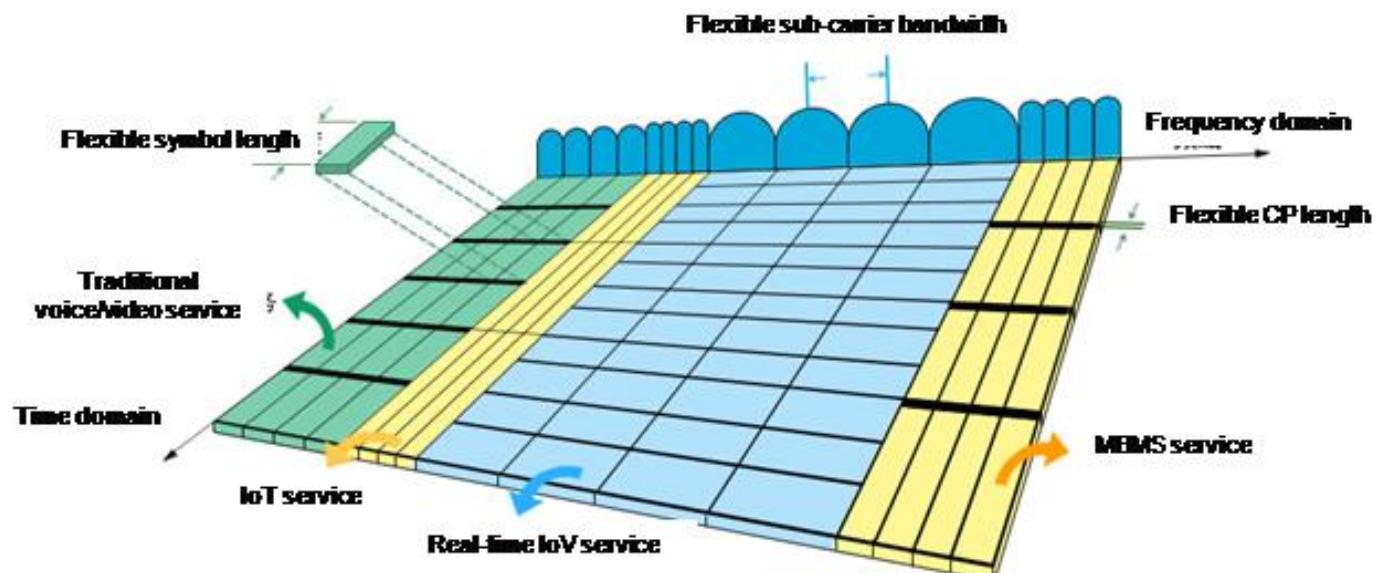


array with 4 dipoles  
 with  $\lambda/2$  spacing

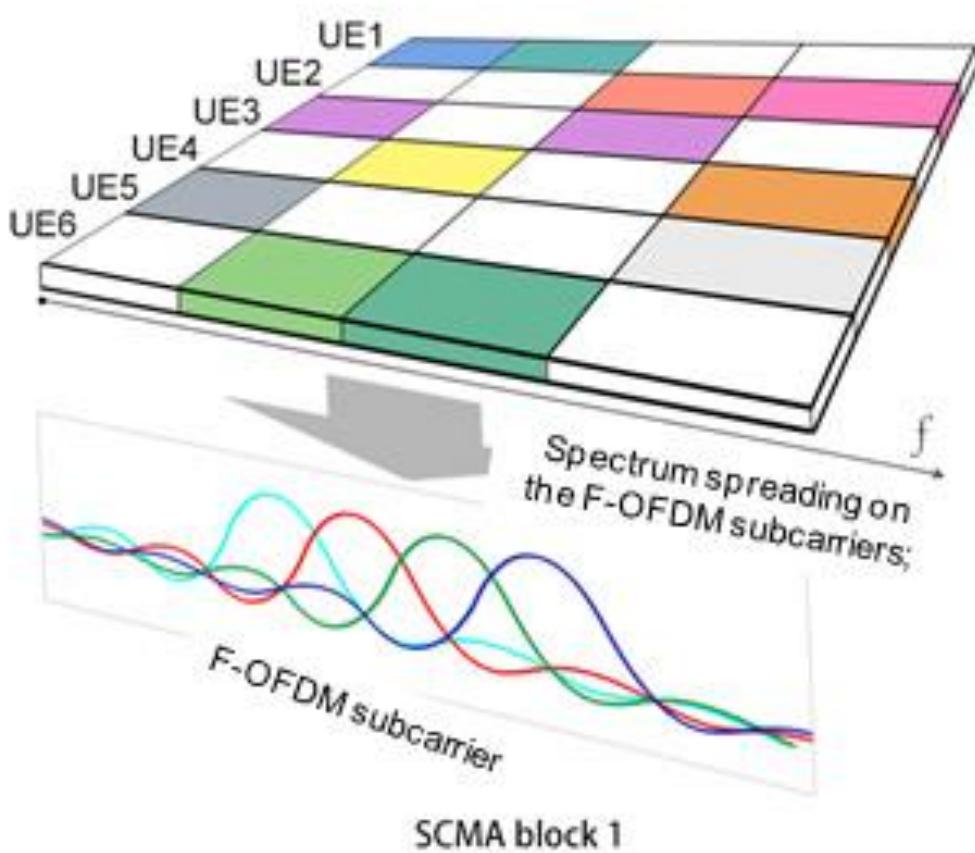
■ building  
 ■ propagation path

■ 1. sub channel  
 ■ 2. sub channel

# Flexible Radio Scheduling

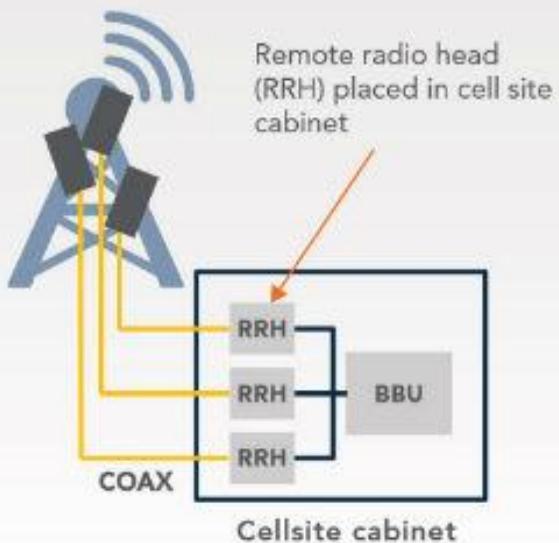


## New Radio

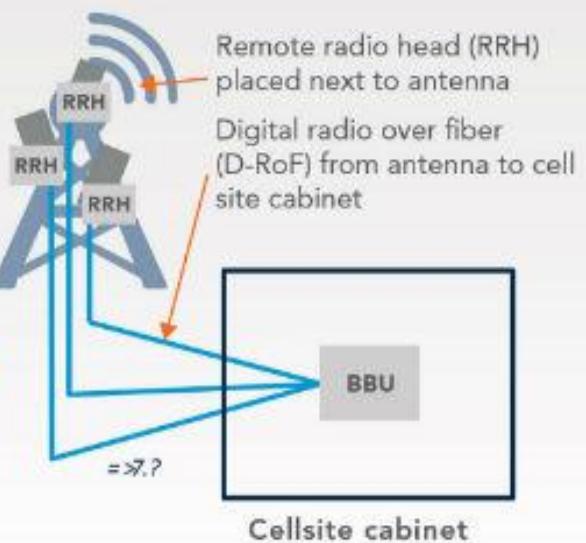


# Coax vs Fiber-connected Antenna

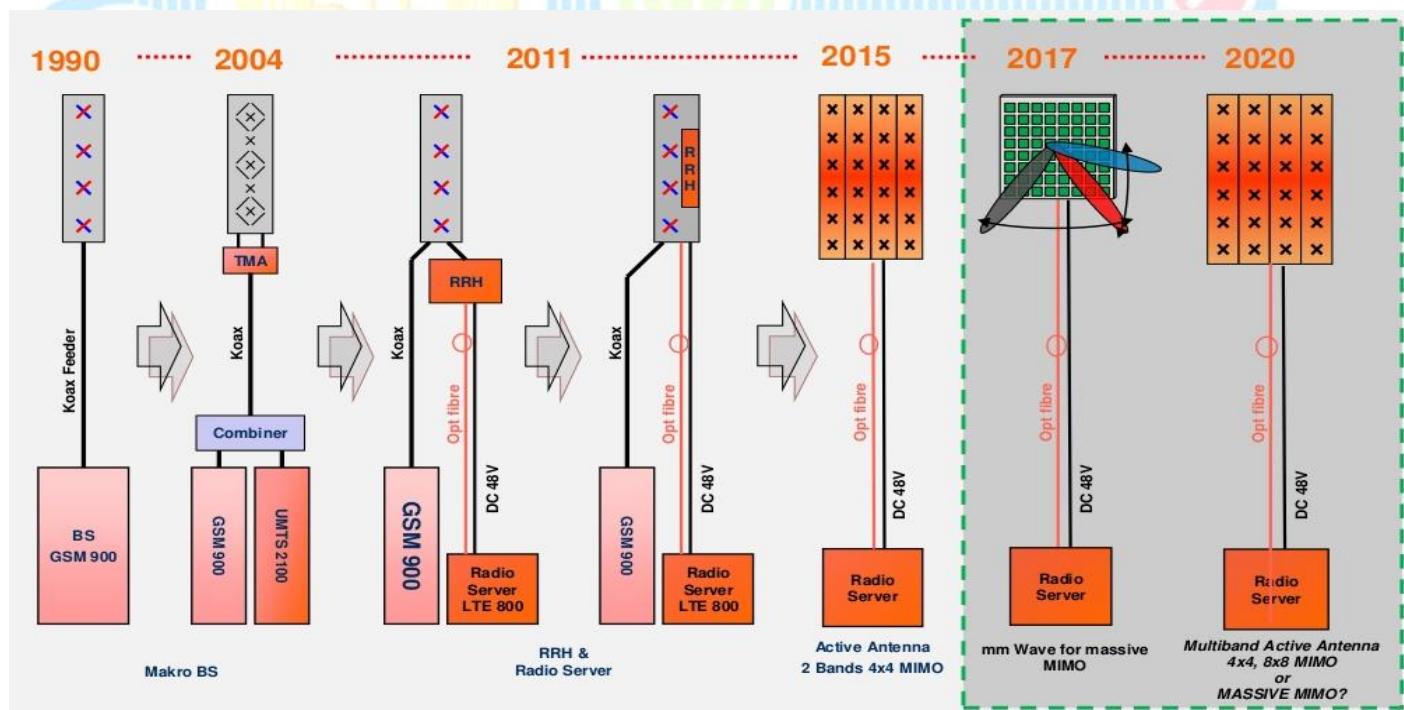
## Copper-connected Antenna



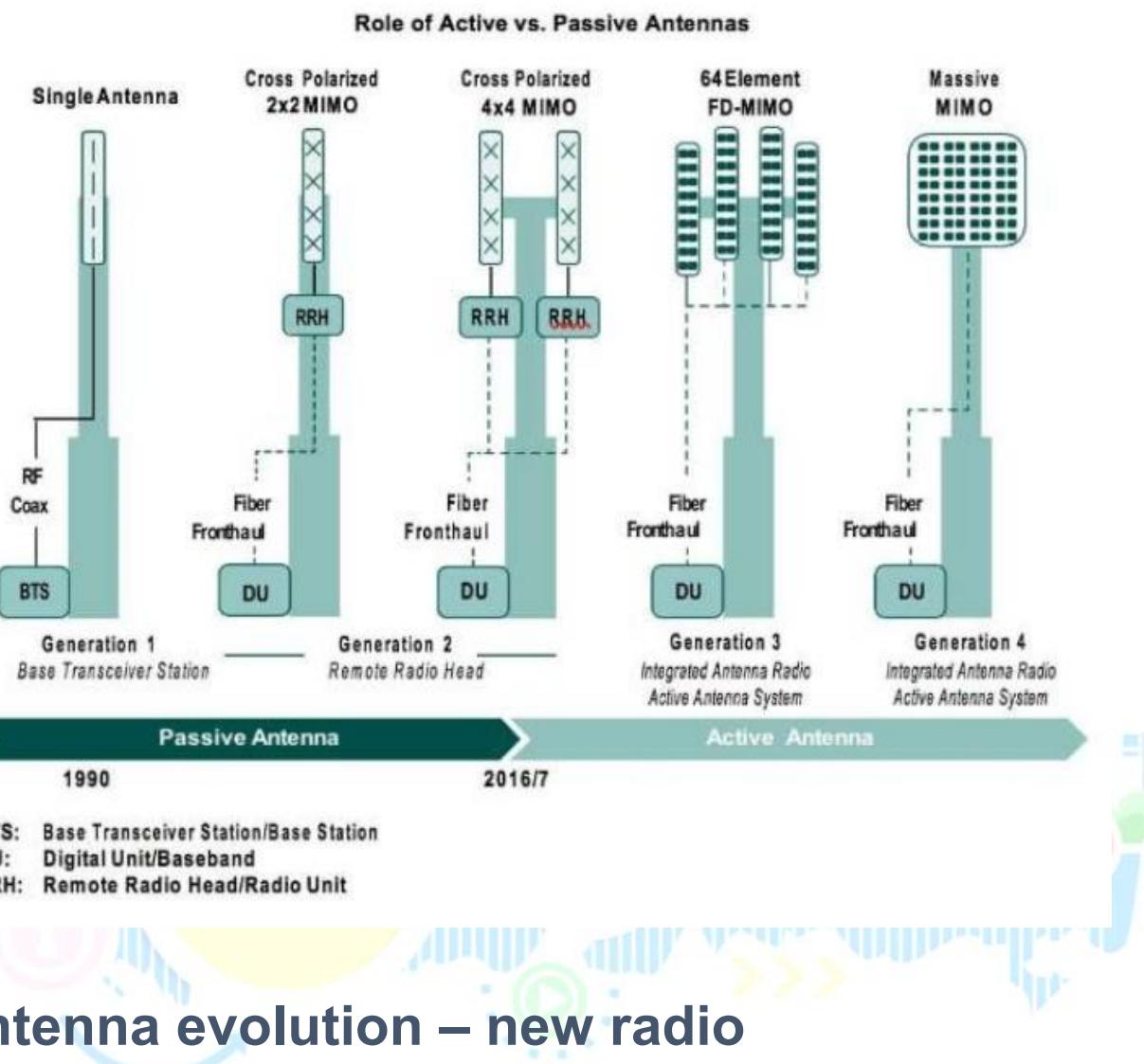
## Fiber-connected Antenna



## From coax feeder to fiber



# From coax feeder to fiber



## Antenna evolution – new radio

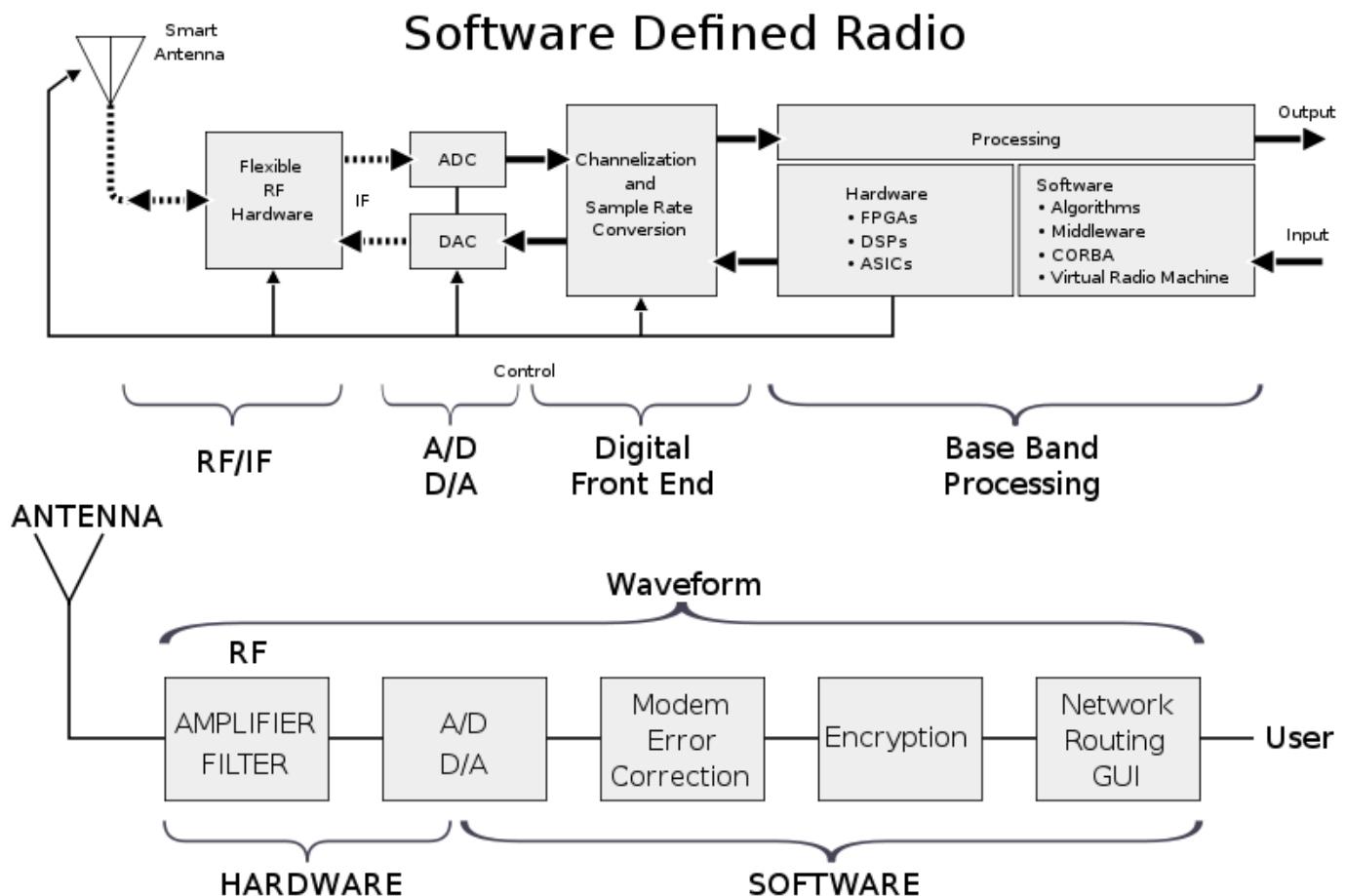
### Passive Antennas:

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

### Active antenna

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

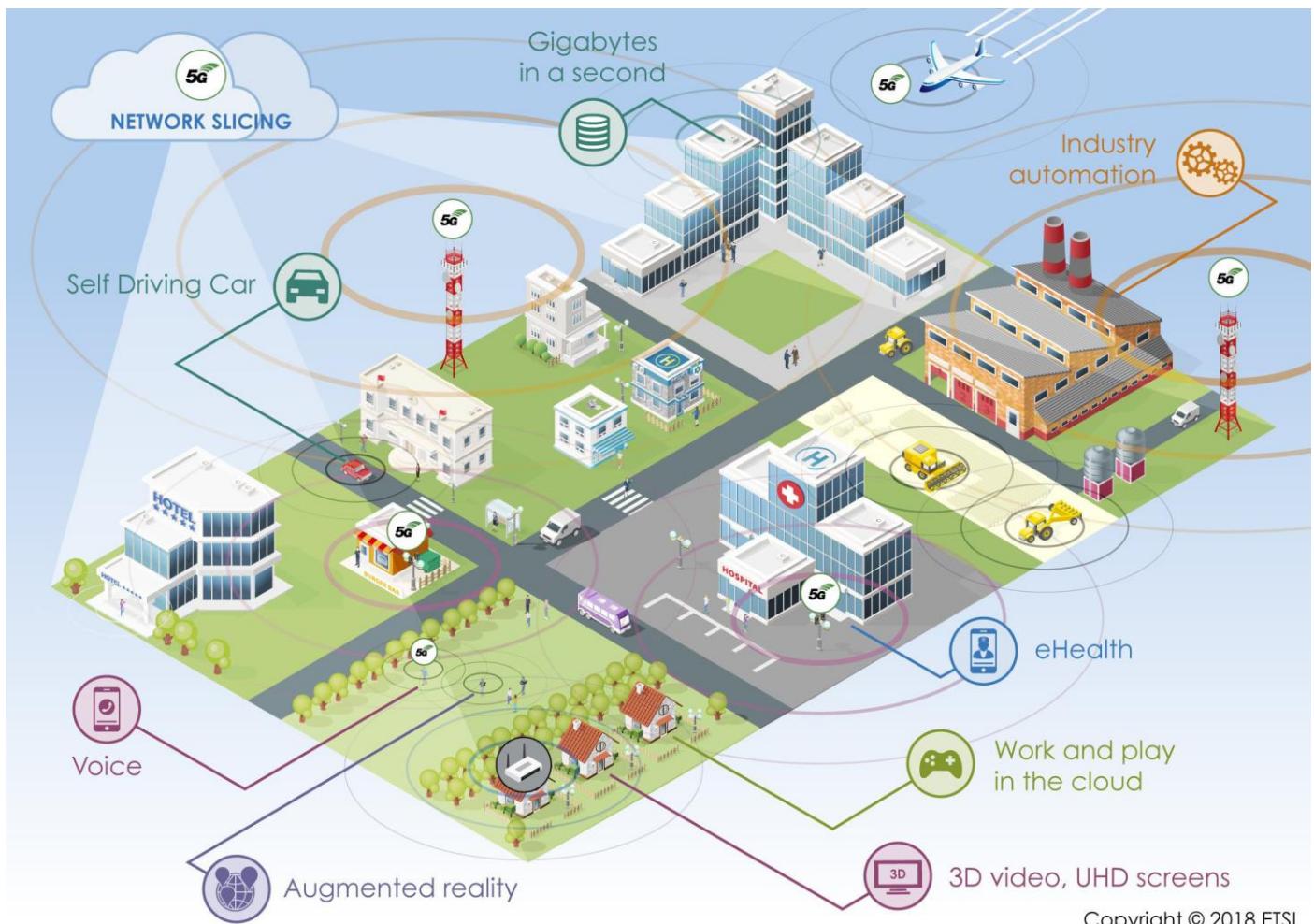
# Software-defined radio (SDR)



## 5G – Services

- Cloud / Edge computing
- Drone – Flying eNB
- Vehicular communication – V2X, Self driving car
- IoT – machine to machine communication
- Industry 4.0 – Industry automation
- Smart cities
- Intelligent transport
- eHealth
- Work and play in the cloud
- Enhance mobile broadband
- Voice, 3D video, UHD video
- Augmented reality

# 5G



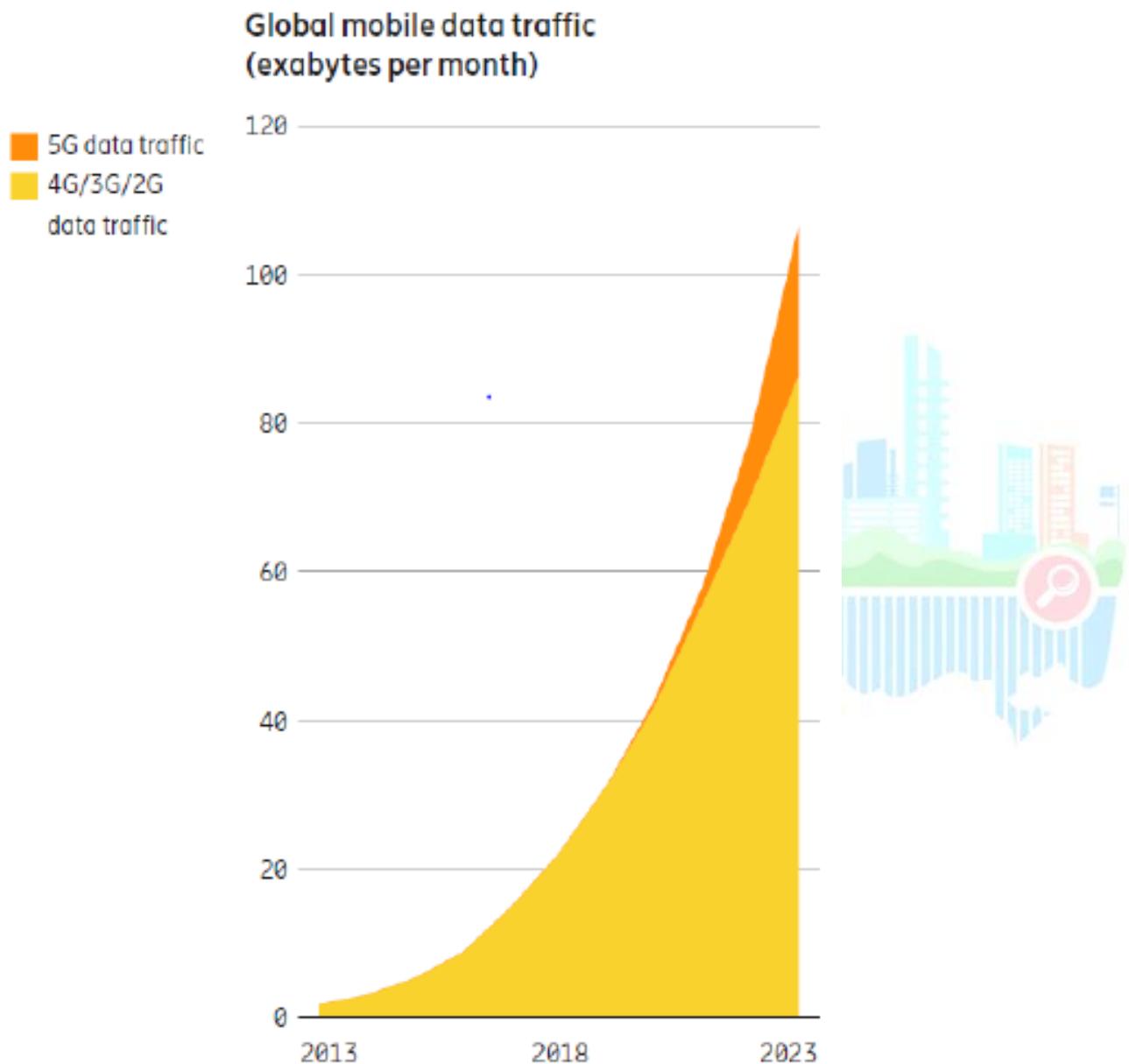
## 5G used case:

- High-definition and ultra-high-definition, such as 4K and 8K, and 3D video.
- Augmented and immersive virtual reality. Ultra-high-fidelity virtual reality can consume 50 times the bandwidth of a high-definition video stream.
- The tactile internet, bringing real-time, immediate sensing and control, enabling a vast array of new applications.
- Automotive functions, including autonomous vehicles, driver-assistance systems, vehicular internet, infotainment, inter-vehicle information exchange, and vehicle pre-crash sensing and mitigation.
- Monitoring of critical infrastructure, such as transmission lines, using long battery life and low-latency sensors.
- Smart transportation using data from vehicles, road sensors, and cameras to optimize traffic flow.
- Mobile health and telemedicine systems that rely on ready availability of high-resolution and detailed medical records, imaging, and diagnostic video.
- Public safety, including broadband data and mission-critical voice.
- Sports and fitness enhancement through biometric sensing, real-time monitoring, and data analysis.

# FWA – Fixed Wireless Access

- Point to Multipoint
- Substitution of ADSL, VDSL, SDSL ...
- FUP ?

## Traffic



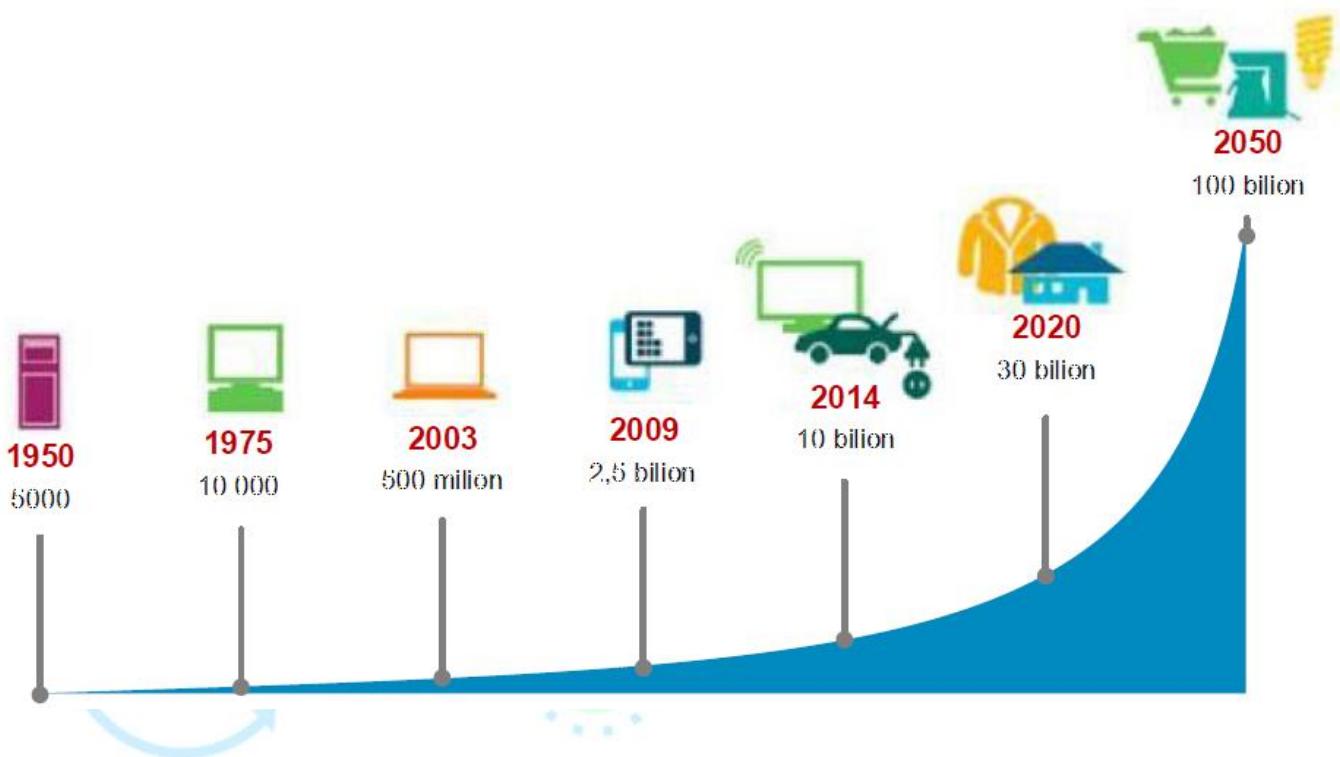
# Industry 4.0, Industrial robots, Co-Bots

- Industry 4.0
- IIoT
- MQTT
- Industrial Robots
- Co-Bots (Collaborative robots)

## The Internet of Things IoT

Experts estimate that the Internet of Things will include approximately 30 billion devices in 2020.

The market value is estimated at \$ 80 billion



## Smart Grid

- Smart Chargers for EV
- Open Charge Point Protocol (OCPP) - Application protocol for communication between EV (Electric vehicle) charging stations and a central management system
  - Device Management
  - Transaction handling
  - Security
  - Load balancing
  - RFID
  - Tariff & Costs

# Humanoid, Service, therapeutic Robots

## Autonomous Vehicle

- VX2ALL
- Vx2Vx

## Vehicle-to-everything - V2X

Vehicle-to-everything (V2X) - types of communication as:

- V2I (vehicle-to-infrastructure)
- V2N (vehicle-to-network)
- V2V (vehicle-to-vehicle)
- V2P (vehicle-to-pedestrian)
- V2D (vehicle-to-device)
- V2G (vehicle-to-grid)

Motivations for V2X are road safety, traffic efficiency, and energy savings.

There are two types of V2X:

- WLAN-based
- cellular-based

## Vehicle-to-everything - V2X

- IEEE 802.11p Dedicated Short Range Communicatio (DSRC) - US
- 3GPP (C-V2X) - 5G Automotive Association (5GAA)

Spectrum allocation:

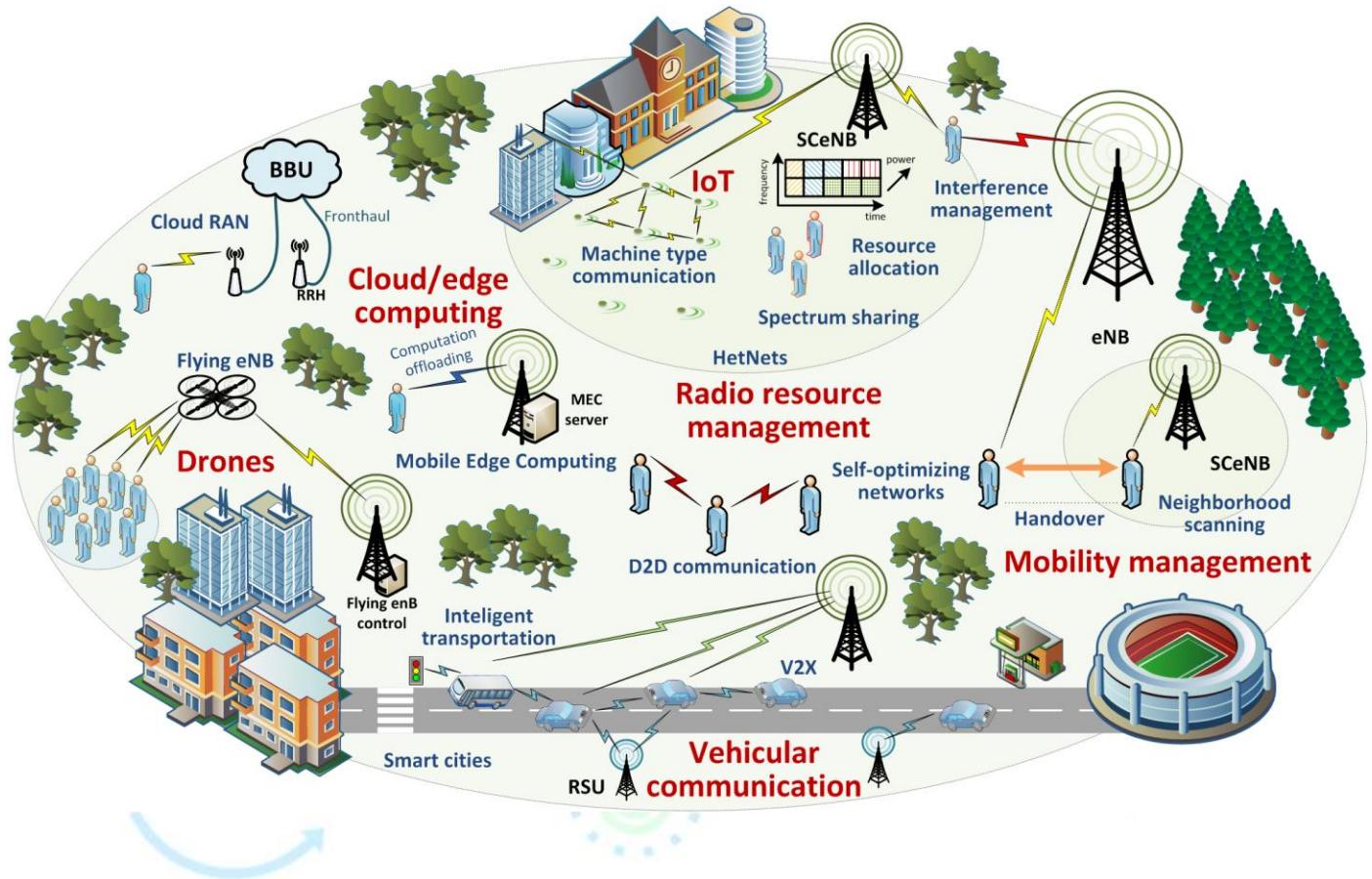
Country	Spectrum (MHz)	Allocated bandwidth (MHz)
Australia	5855 – 5925	70
China	5905 - 5925 (trials)	20
Europe	5875 – 5905	30
Japan	755.5-764.5 and 5770 – 5850	9 and 80
Korea	5855 – 5925	70
Singapore	5875 – 5925	50
USA	5850-5925	75

# Smart City

## Very High Speed Train

- Mobility
- More 300 km/h

## 5G



## IoT applications

Consumer applications:

- Smart Home
- Elder care

Commercial applications:

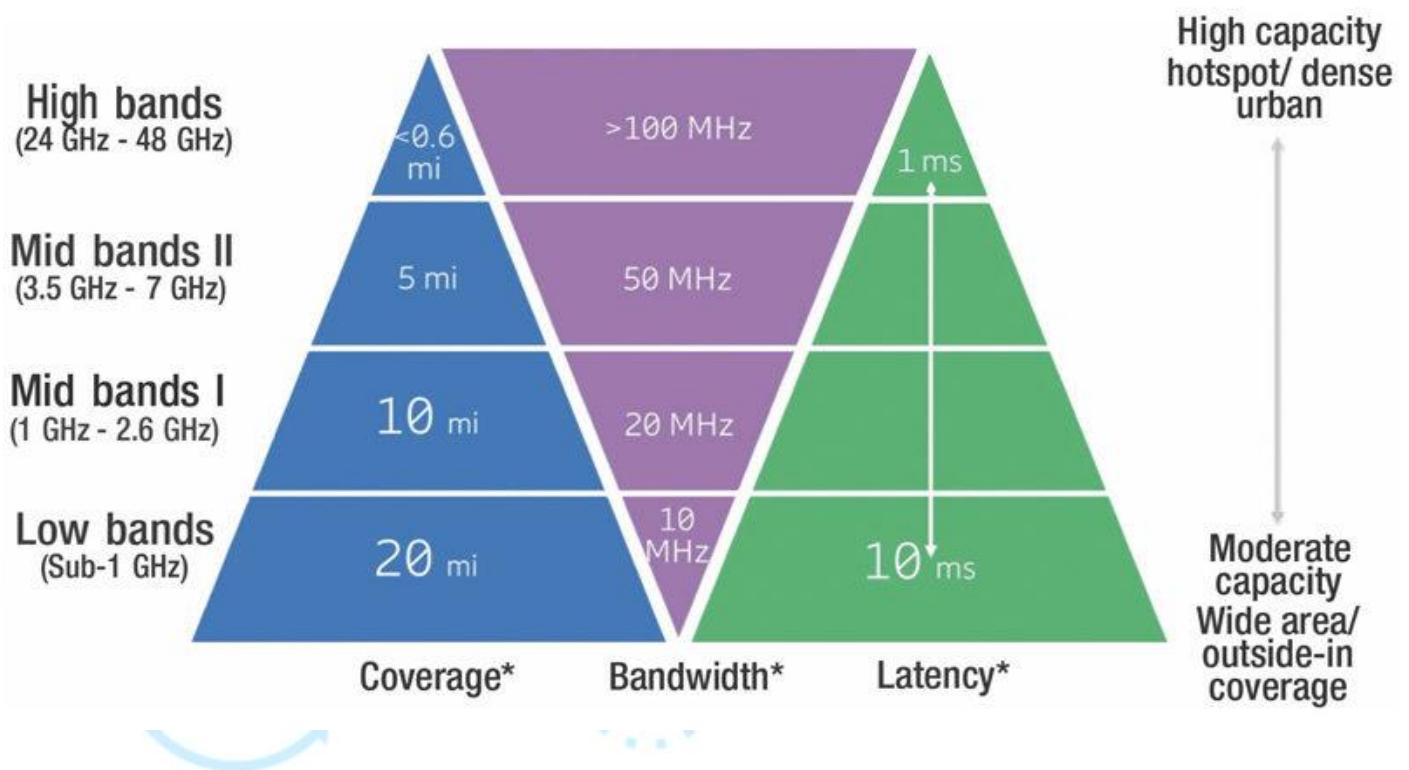
- Medical and healthcare
- Transportation
- V2X communications (Vehicle-to-everything)
- Building and home automation
- Industrial applications - IIoT - Industry 4.0 - fourth industrial revolution
- Agriculture

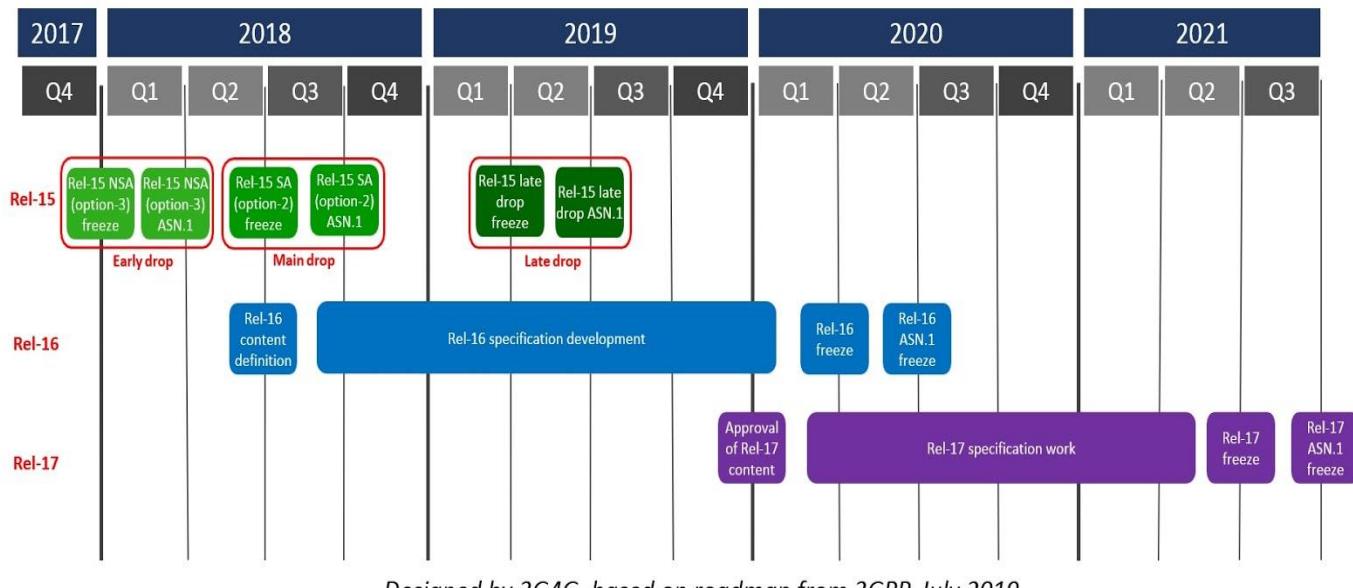
# Smart Home – Home automation

Applications like:

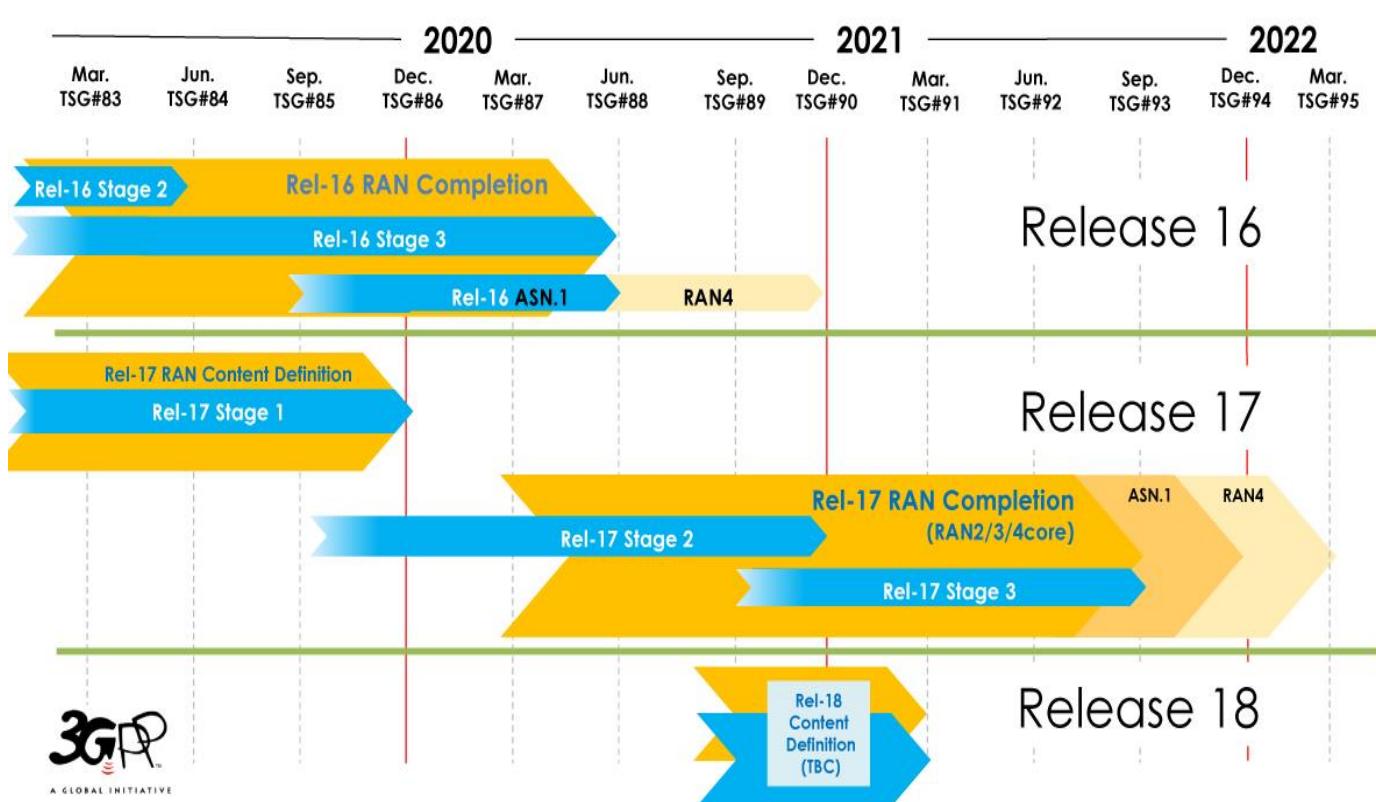
- Lighting control system
- Heating (Thermostats), ventilation and air conditioning (HVAC)
- Home security, access systems and cameras
- Smart grid and a smart meter (energy, water, gas ...)
- Pet and Baby Care
- Smart Kitchen and Connected Cooking
- Leak detection, smoke and CO detectors
- Home robots

## Coverage, bandwidth, Latency



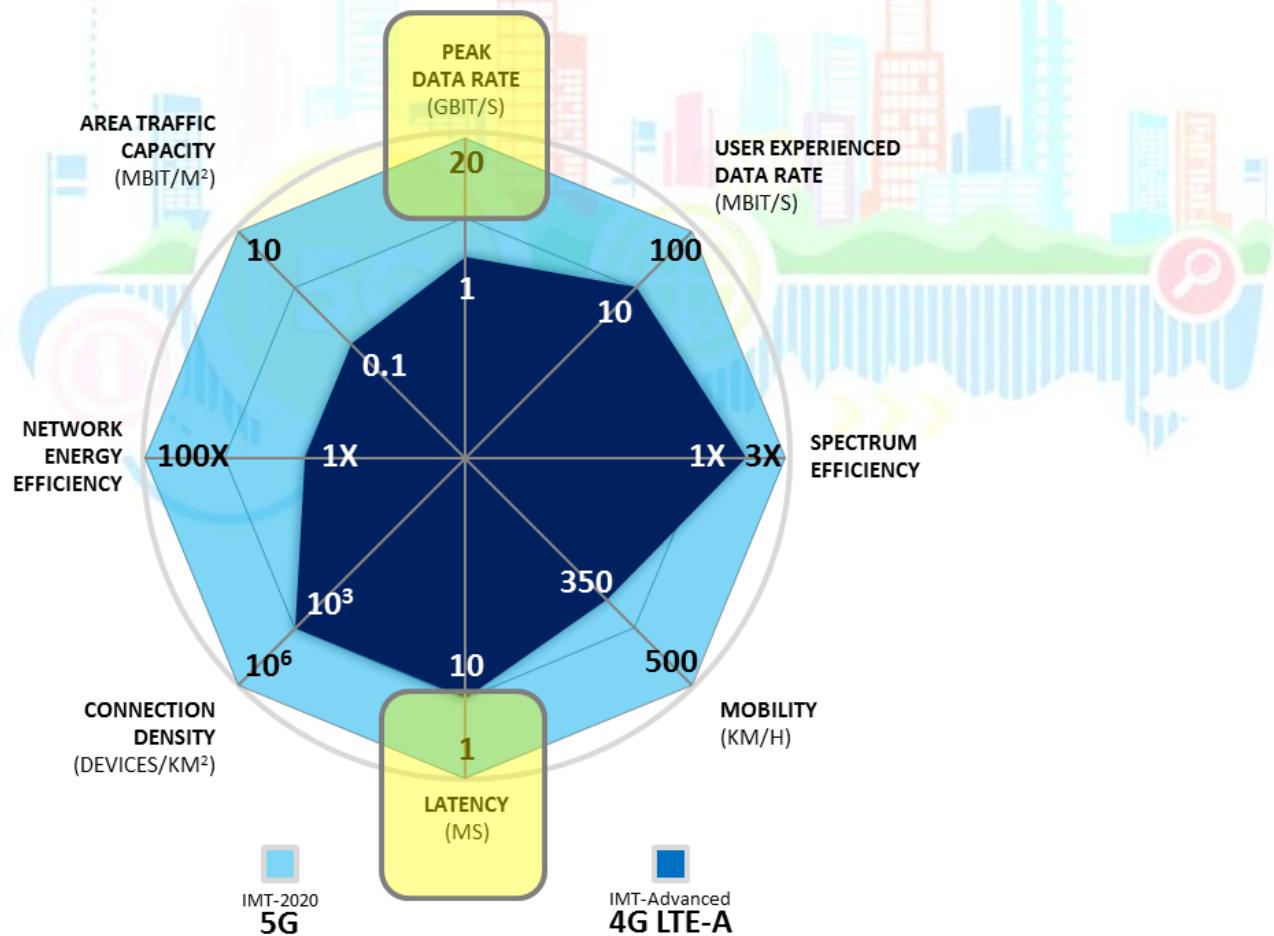


## From Rel 16 to Rel 18





## 5G – 4G LTE-A



**End**