ONAP
OPEN NETWORK AUTOMATION PLATFORM

5G OVERVIEW

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ONAP
OPEN NETWORK AUTOMATION PLATFORM

5G Key Concepts

Evolution of Wireless

Evolution of Wireless Technology

1G

1979 (NTT Car)
1983 (AMPS)
Basic Voice Wireless
Phone Calls

2G

1993 (GSM, CDMA)
SMS Texting
Simple e-Mail
PCS
PDA

UMTS

2001 (NTT DoCoMo)
Access to Web
Streaming Video

4G LTE

2009
HD Streaming
Facetime
Video Chat
Smart Phones

5G

2019
IoT
Smart Cities
Autonomous Cars
Remote Robotics

5G Key Concepts & Use Cases

eMBB (enhanced Mobile Broadband)

Media Anywhere

Broadband Experience
Everywhere Anytime
Virtual and Augmented Reality

Remote Surgery and Examination

Smart Infrastructure

Smart City

5G USE CASES

Smart Automated Vehicle Control

Factory Automation
Industry 4.0

Remote Device Control

Internet of Things (IoT)
M2M communications

Geographically spread devices

URLLC (Ultra Reliable Low Latency Communications)

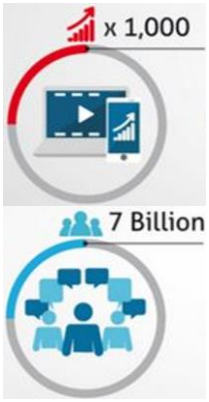
mMTC (massive Machine Type Communications)

- Smart
- Connected
- Collaborate
- Access
- Interactive
- Aware

5G Key Concepts & Use Cases

eMBB

(enhanced Mobile Broadband)

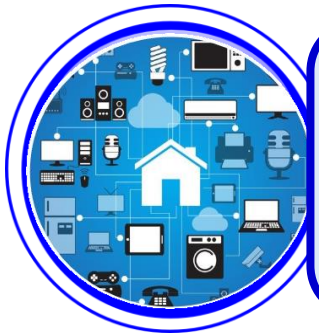


- Spectrum Extension
- Wireless Capacity x1,000 times
- Millimeter-wave network
- Connecting 7 billion people

URLLC

(Ultra Reliable Low Latency Communications)

- Tactile internet
- Ultra low Latency (<1ms)
- Perceived Zero downtime



mMTC

(massive Machine Type Communications)

- Massive Connectivity
- Machine to Machine
- IoT

5G Key Concepts & Use Cases

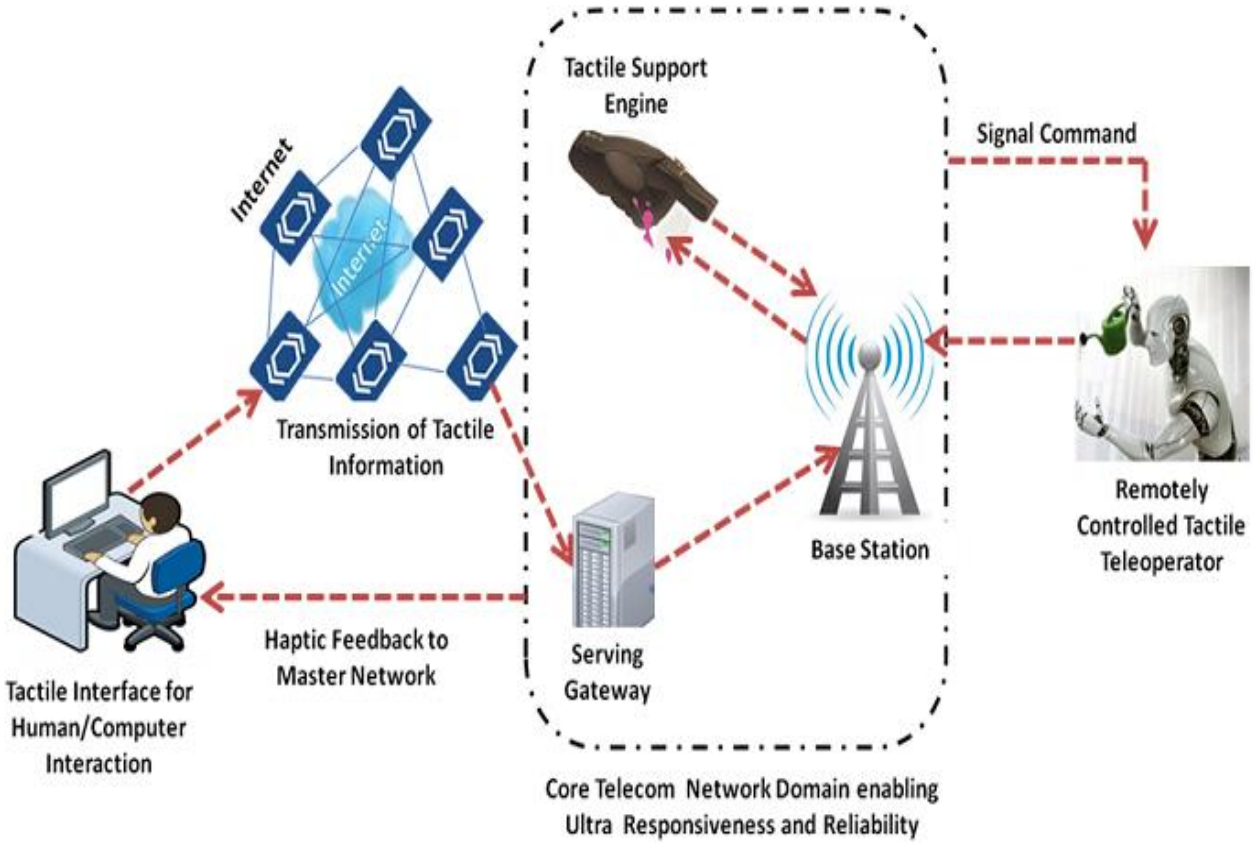
	3G	4G	5G
SPEED	384 Kbps (2001)	100 Mbps (2009)	10 Gbps (2020)
LATENCY	150ms	90ms	1ms
DOWNLOAD HD MOVIE	26 hrs	6 min	3.6 sec

Fly from New York to Sydney

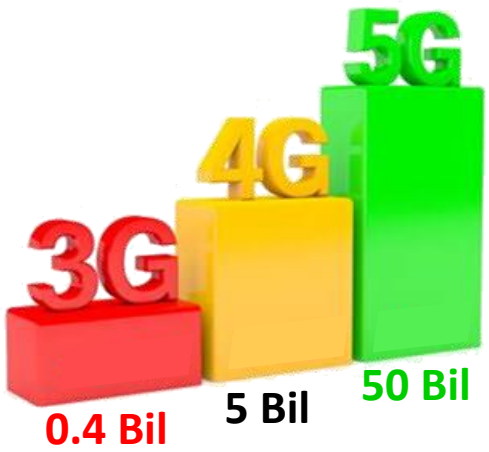
Run a quick km. Catch up on Facebook

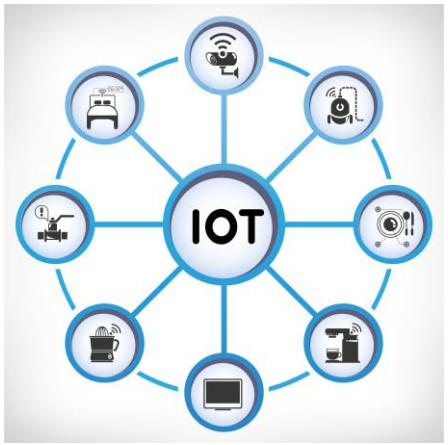
Ask, "Has it downloaded yet?"

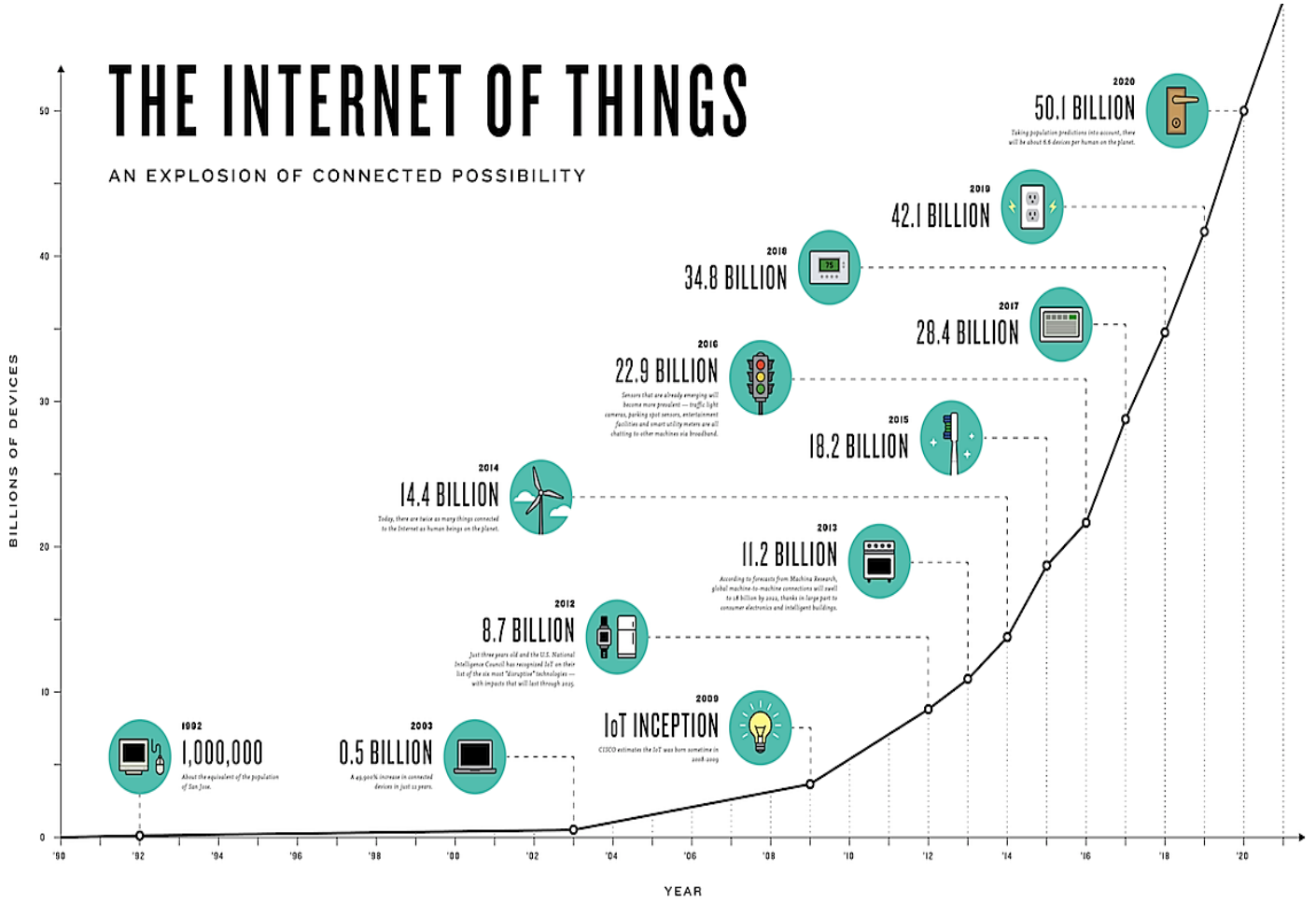
5G Key Concepts & Use Cases



5G Key Concepts & Use Cases







5G Key Concepts & Use Cases

eMBB

(enhanced Mobile Broadband)

SYSTEM CAPACITY

- 1000x Capacity / km^2
- 10 Gbps Peak Data Rates
- Spectrum Efficiency

URLLC

(Ultra Reliable Low Latency Communications)

MISSION CRITICAL

- High Reliability five 9's
- Ultra low Latency (<1ms)
- High Availability

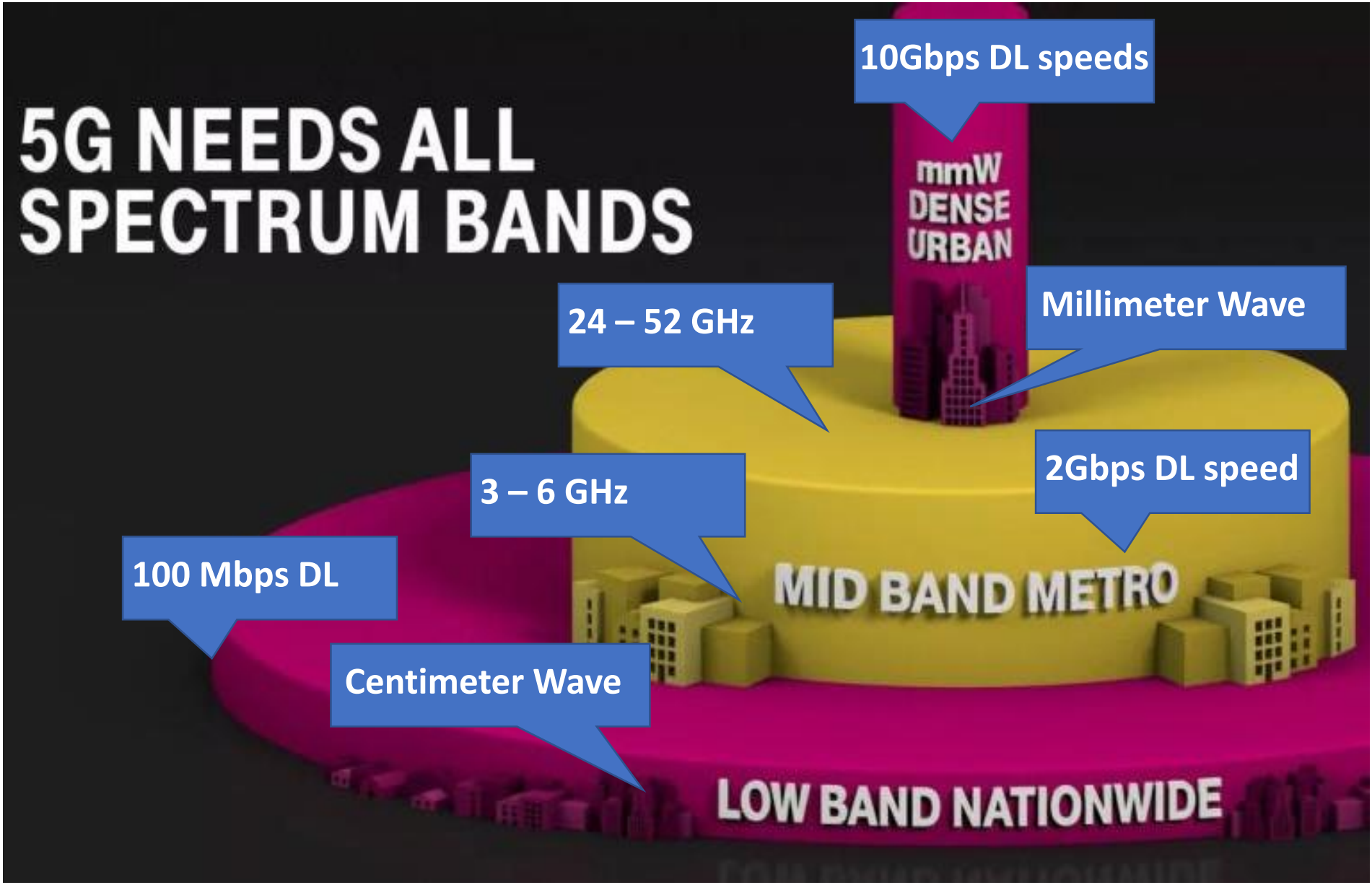
mMTC

(massive Machine Type Communications)

EXTREME DENSITY

- Massive Connectivity 1000x
- Machine to Machine
- IoT

5G Key Concepts & Use Cases



5G Key Concepts & Use Cases

Biggest pain points that 5G could help overcome, by industry:

Energy and utilities

1. > Integrating new technologies within the current infrastructure
2. > Reducing energy consumption
3. > Handling large volumes of data
4. > Automation across distribution, operations, energy efficiency and other areas

Manufacturing

1. > Connectivity issues, such as insufficient bandwidth, speed and latency issues
2. > Organizational culture, such as accepting change/ new processes and learning new skills
3. > Real-time communication between machines, i.e. low latency
4. > Long-term sustainability

Public safety

1. > Capturing reliable and accurate data
2. > Response time to emergencies
3. > Communication to coordinate response teams
4. > Improve consistency in the approach to emergencies

Healthcare

1. > High demand for data storage and security of patient data
2. > Effective capture of vast amounts of data
3. > Availability of suitable infrastructure
4. > Adaptability of medical equipment

Public transport

1. > Reducing congestion problems by providing real-time contextual information to passengers and drivers
2. > Reducing costs for customized infrastructure systems, online content and travel for consumers
3. > A better experience for travelers

Media and entertainment

1. > Communication with customers and other partners (for example, via social platforms)
2. > Better quality of content, speed of streaming/ download and latency
3. > Connectivity across multiple devices

5G Key Concepts & Use Cases

Resulted 5G Operators Benefits

Increased Network Performance

- Increased Capacity & Coverage
- High Speed Mobility
- Low Latency
- High Peak & Cell edge Data rates
- Programmability & Scalability
- Massive Device Connectivity
- Embedded Security
- Service Awareness

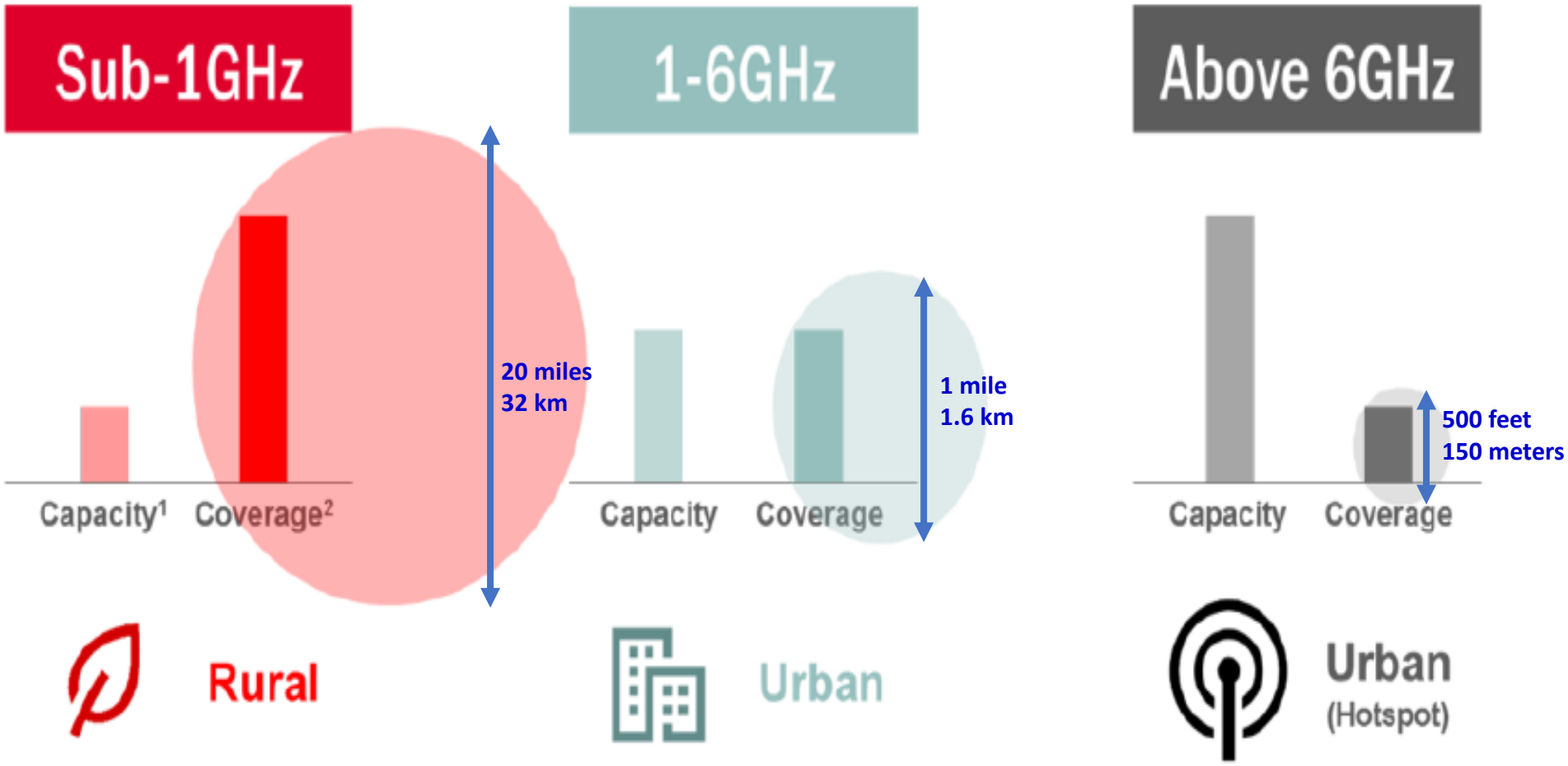
Higher Costs Efficiency

- Reduced CAPEX & OPEX
- Energy efficient Network infrastructure
- Sustainability

New Business potential

- New Business Models
- Possibility to differentiate from OTTs
- New Revenue Opportunities
- Effective support of vertical Use cases
- Reduced Time-to-Market
- Uniform user experience anywhere

5G Key Concepts & Use Cases



λ=30cm

λ=4cm

λ=7.7 mm 39 GHz

λ=5.7 mm 52.6 GHz

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5G Key Applications

5G Applications

Human to Human | Human to Machine | Machine to Machine

Enhanced Mobile Broadband

- Virtual Reality / Augmented Reality
- Video Calling Virtual Meetings
- Fixed Wireless
- UHD* Video
- Video Monitoring
- Mobile Cloud Computing

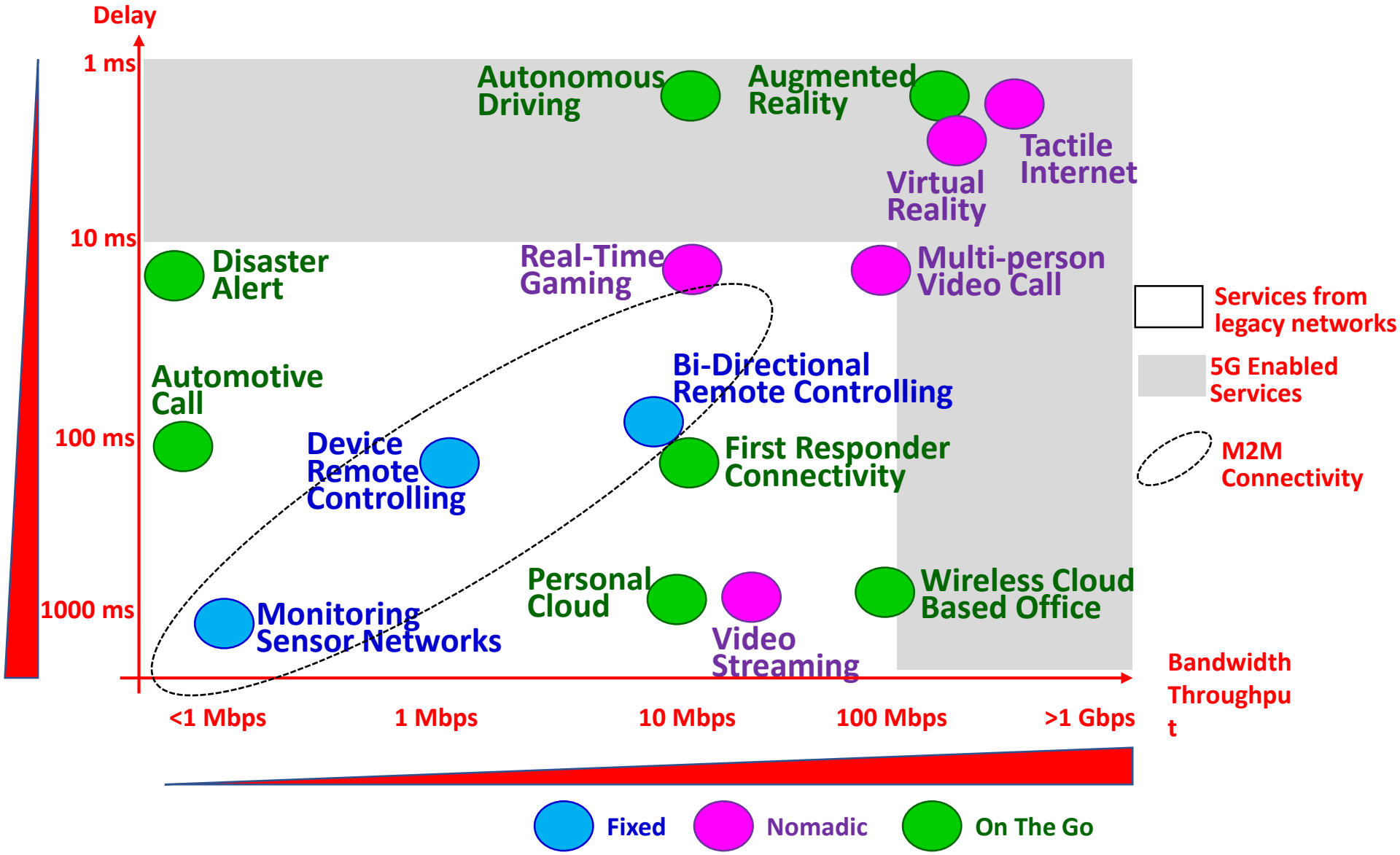
Massive Machine Type Communications

- Wearables
- Social Networking
- Smart Home / Smart Cities
- Health Care Monitoring
- Vehicle to Infrastructure
- Industrial Automation

Ultra-Reliable Low Latency Communications

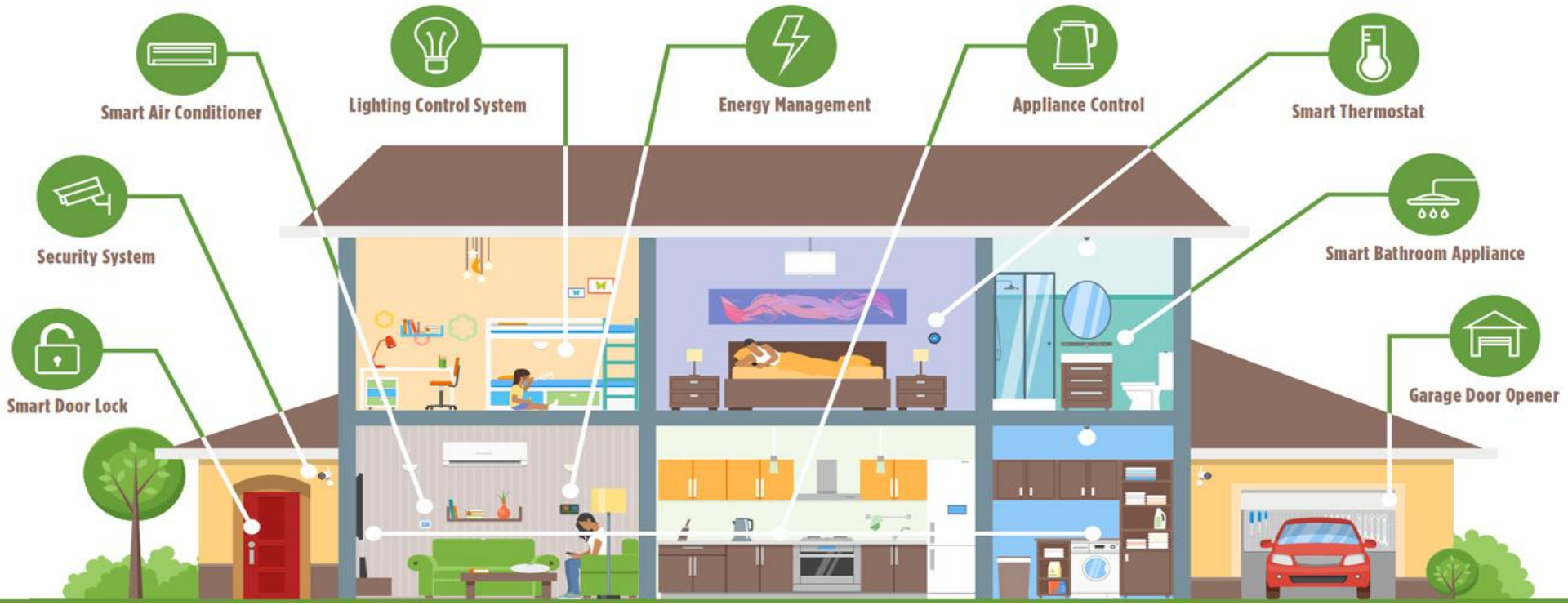
- Public Safety
- Remote Surgery
- Vehicle to Pedestrian
- Vehicle to Vehicle

5G Applications



5G Applications – Smart Home

- Security Monitoring
- Environment Control
- Entertainment
- Communications Home Phone
- Informatics (Echo, Alexa)
- Profile Execution
- Audio/Video
- Energy Management
- Safety Management
- Telecontrol
- Appliance Control
- Lock & Access Control



5G Applications - Wearables

- Monitoring
- Social Networking
- Entertainment
- Communications
- Informatics
- Streaming
- Audio/Video
- Internet Access
- e-Commerce
- Telecontrol
- Smart Clothing
- Augmented Reality

$43 BILLION

the estimated worth of the smart retail market by 2024

5G Applications – Smart Cities

- Emergency Services
- Power Management
- Disaster Recovery
- Public Safety
- Public Transportation
- Smart Parking
- Augmented Reality
- Internet of Things Services
- Connected Car Service
- Sanitation Management
- Transportation Analytics
- Water Management

$135 BILLION

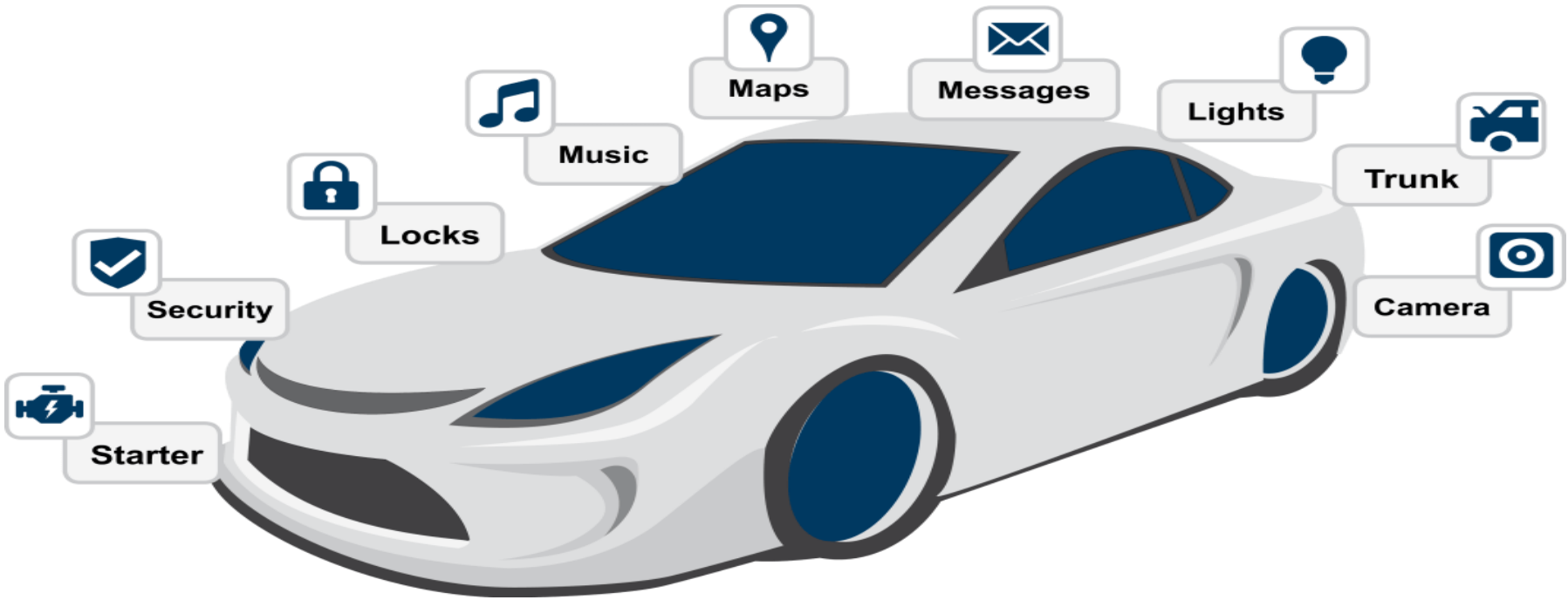
the total smart city technology spending by the year 2021

5G Applications - Automotive

- Telematics
- Roadside
- Entertainment
- Collision Avoid
- Diagnostics
- Low-Speed Net
- Audio/Video
- Security
- Wireless Network
- ADAS*
- DSRC* (V2V)
- S/W Updates

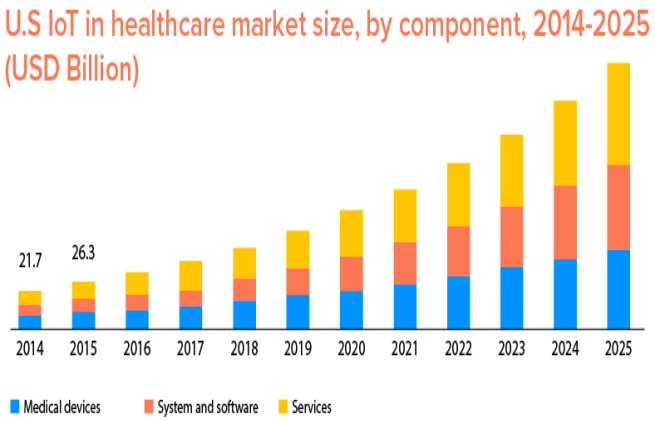
*Advanced Driver Assistance System

*Dedicated Short-Range Communications



5G Applications – Health care

- Automatic Check-in
- Patient Privacy
- Data Analytics
- Asset Tracking
- Patient Monitoring
- Medical Response
- Post-visit Care
- Smart Access Control
- Indoor Navigation
- Remote Medical Care
- Patient Safety
- Smart Diagnostics



5G Applications – Industry 4.0

- Safety Monitoring
- Assembly Line Management
- Just in Time Management
- ERP*

*Enterprise Resource Planning

- Cyber Physical Systems
- Internet of Things M2M
- RF ID Control
- Factory Security
- Advanced Robotics
- PLC (Control)
- MES / MOM (Planning)
- SCADA (Supervision)

*Programmable Logic Controller
*Distributed Control System (DCS)

*Manufacturing Operations Management
*Management Execution System

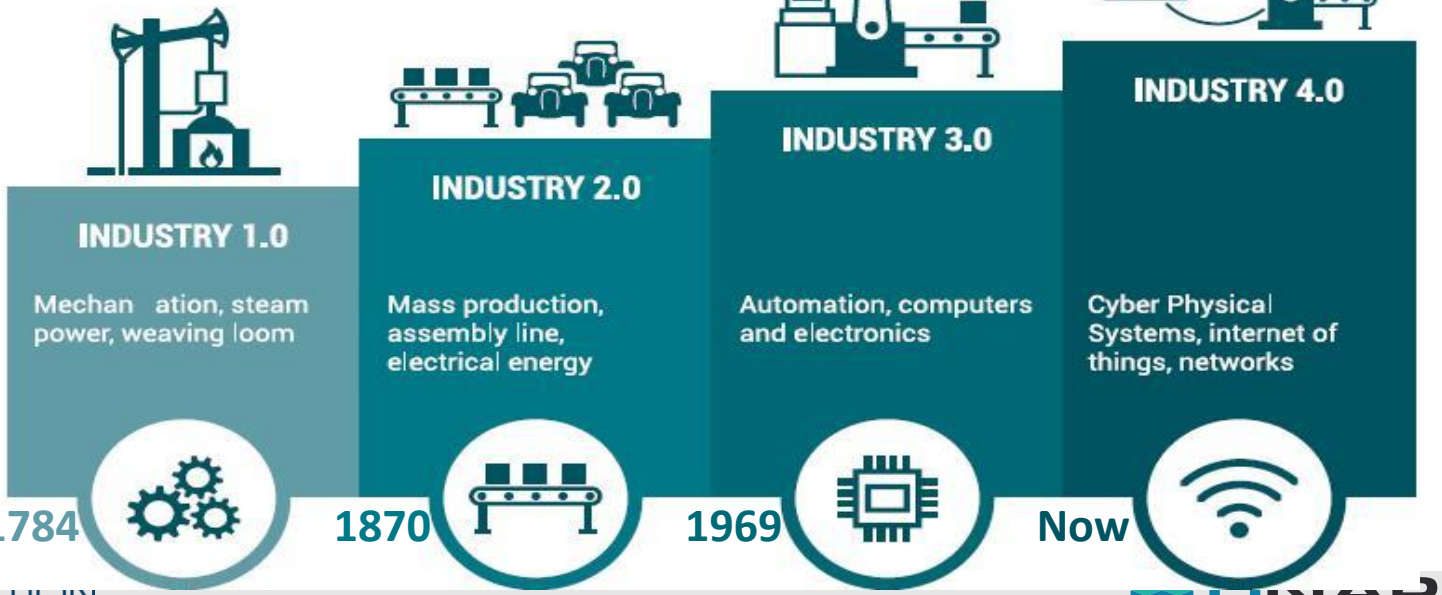
*Supervisory Control & Data Acquisition

of early-movers say IoT is now critical to competitive advantage.

of early movers in manufacturing say IoT is increasing insight into customer preferences and behaviors.

of early-movers are using IoT to measure risks, protect company assets and improve staff safety.

of early-movers are improving the reliability or performance of products and services with IoT.



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5G Fundamentals

5G Fundamentals

Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
FIXED WIRELESS ACCESS • Broadband WLAN • Fixed Location • Cost Effective	**2019** **CONSUMER SMARTPHONES** • Mobile Connectivity for smartphones	**ENHANCED MOBILE BROADBAND (eMBB)** • High peak speed • High Average speed • Spectral efficiency • High Capacity	**2021+** **5G LPWA/ MASSIVE IOT (mMTC)** • Low power • Low Cost • High coverage • High density	**2021+** **FUTURE 5G** • Low latency, high reliability URLLC • Non-Public Network (NPN) • Satellite (NTN) • Enhanced V2X
				

5G Key Performance Requirements

Capability	Description	5G target	Usage scenario
Peak data rate	Maximum achievable data rate	DL 20 Gbit/s UL 10 GB/s	eMBB
User experienced data rate	Achievable data rate across coverage area	DL 100 Mbit/s UL 50 Mbit/s	eMBB
Latency	Radio network contribution to packet travel time	User Plane 1-4 ms Ctrl Plane 20 ms	URLLC
Mobility	Maximum speed for handoff and QoS requirements	300 mi/h (500 km/h)	eMBB/URLLC
Connection density	Total number of devices per unit area	$2.59x10^6/mi^2$ $(1x10^6/km^2)$ ~1 device/ft^2	MMTC
Energy efficiency	Data sent/received per unit energy consumption (by device or network)	Equal to 4G	eMBB
Spectrum efficiency	Throughput per unit wireless bandwidth and per network cell	3-4x 4G Avg DL 3.3-9 bit/s/Hz UL 1.6-6.75 bit/s/Hz	eMBB
Area traffic capacity	Total traffic across coverage area	10 (Mbit/s)/m^2	eMBB
Bandwidth	Transmission Carrier Bandwidth	100 MHz	eMBB
Reliability	1-10^{-5} success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1ms	1-10^{-5} L2PDU 32b/1ms	URLLC

eMBB (enhanced Mobile Broadband)
URLLC (Ultra Reliable Low Latency Communications)
mMTC (massive Machine Type Communications)

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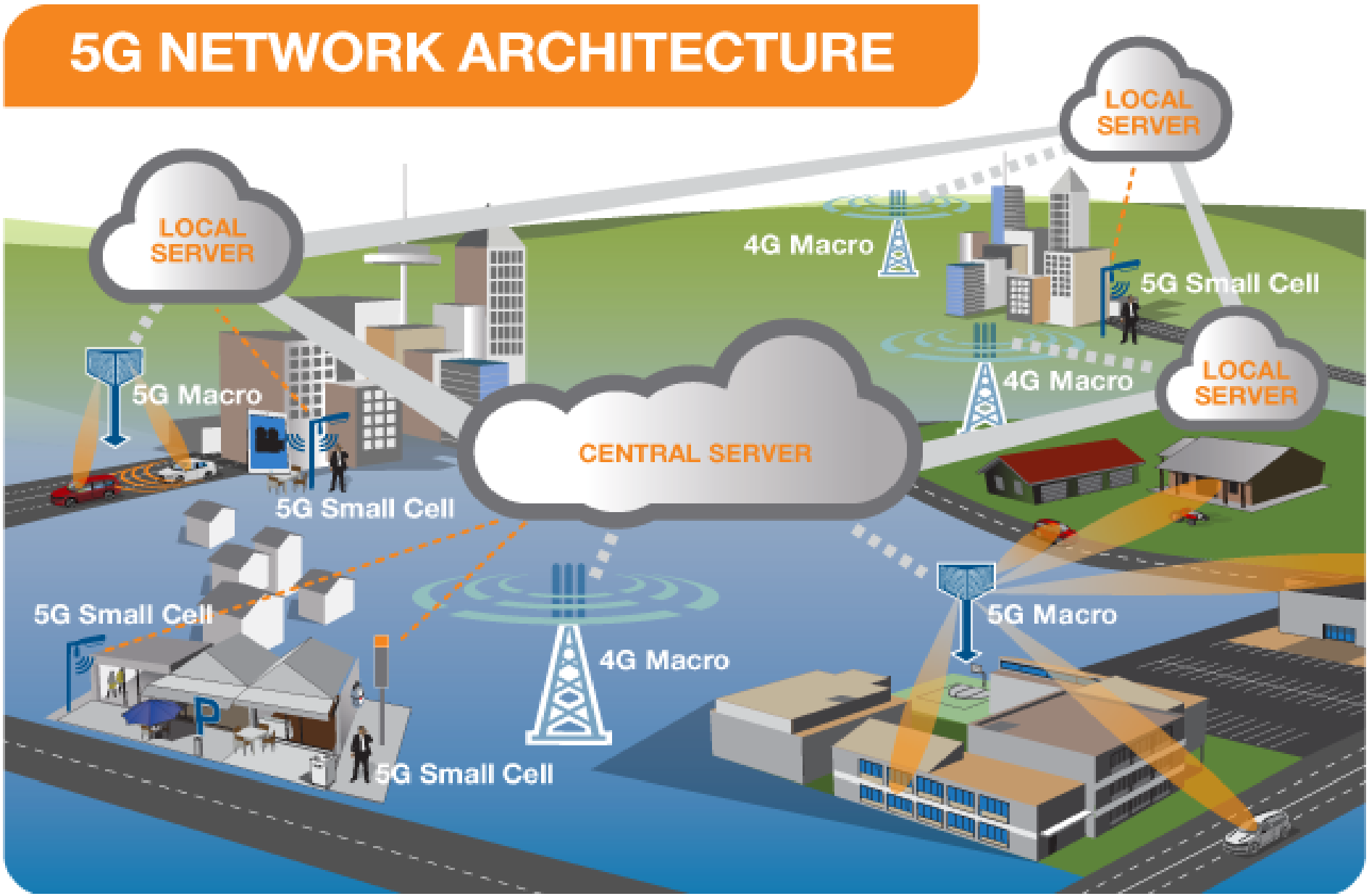
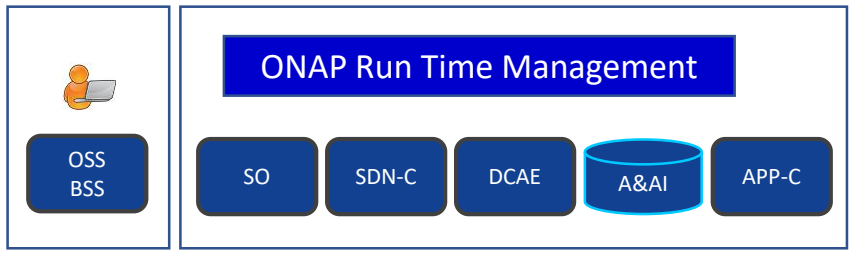
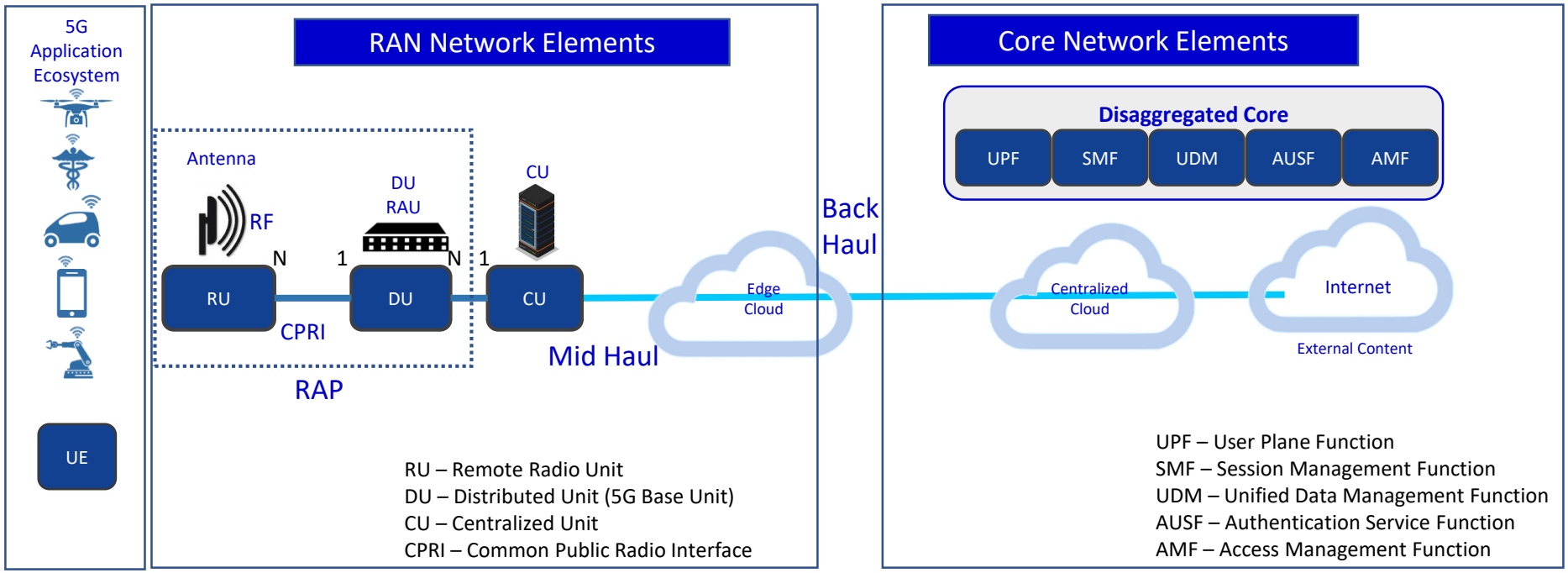


5G RAN Wireless Network



SO – Service Orchestrator
SDN-C – Service Design Network Controller
DCA&E – Data Collection Analytics & Events
A&AI – Available & Active Inventory
APP-C – Application Control



RU – Remote Radio Unit
DU – Distributed Unit (5G Base Unit)
CU – Centralized Unit
CPRI – Common Public Radio Interface

UPF – User Plane Function
SMF – Session Management Function
UDM – Unified Data Management Function
AUSF – Authentication Service Function
AMF – Access Management Function

5G Key Technology Components

New Spectrum (Rel 15, 52.6 GHz/39 GHz, Rel 16 > 52.6 GHz)

Software Defined Networking (SDN)

Advanced Beamforming

Network Functions Virtualization (NFV)

Multi-Connectivity (NSA, SA, Option 3, 4, 7)

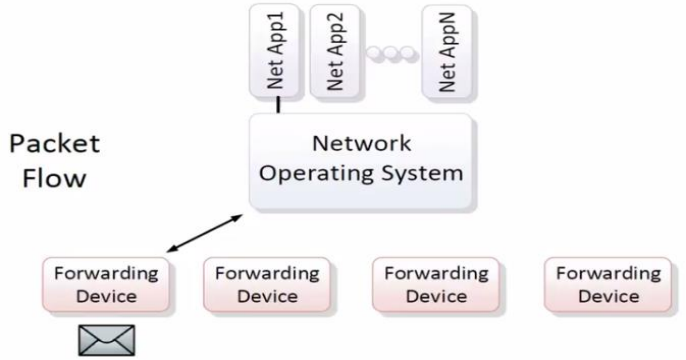
Edge Computing

Network Slicing

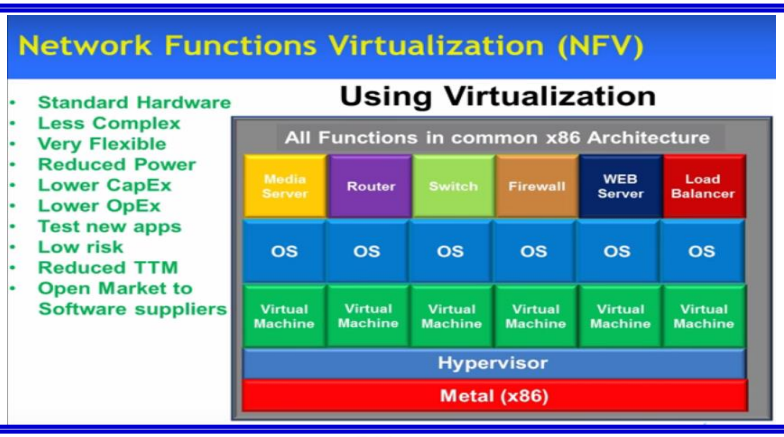
Fog Computing (FC)
Mobile Edge Computing (MEC)

5G Enablers

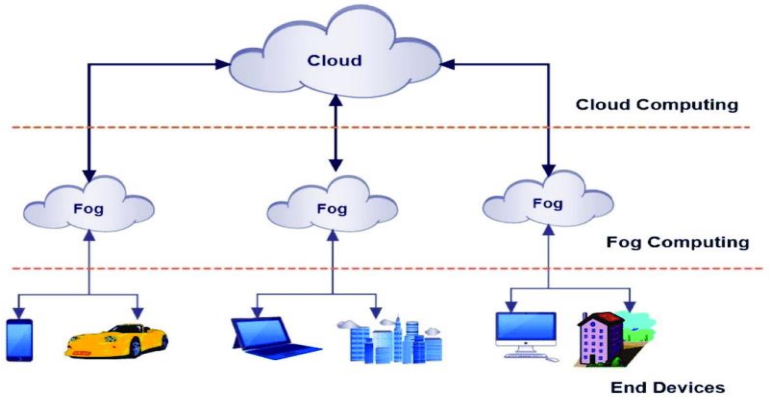
SOFTWARE DEFINED NETWORKING - is an approach to cloud computing that facilitates network management and enables programmatically efficient network configuration in order to improve network performance and monitoring



NETWORK FUNCTIONS VIRTUALIZATION (NFV) is an initiative to virtualize network services traditionally run on proprietary, dedicated hardware. With NFV, functions like routing, load balancing and firewalls are packaged as virtual machines (VMs) on commodity hardware. Individual virtual network functions, or VNFs, are an essential component of NFV architecture.

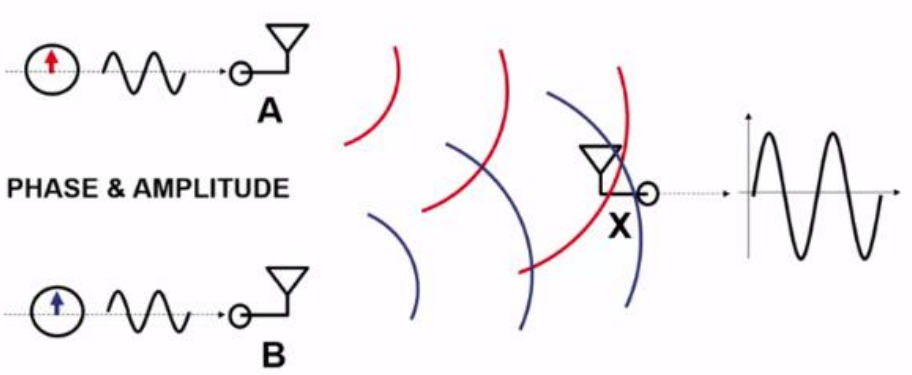


FOG COMPUTING - Fog networking, also known as fogging, is an architecture that uses edge devices to carry out a substantial amount of computation, storage, communication locally and routed over the internet backbone.

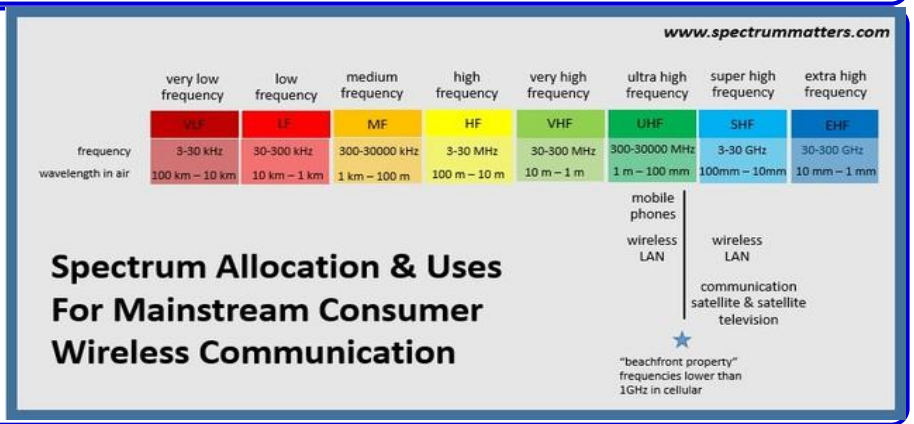


5G Enablers

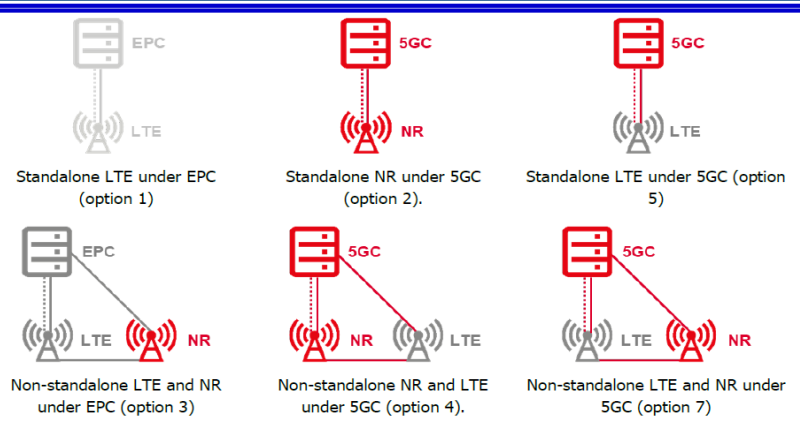
BEAMFORMING – Uses signal processir for directional signal transmission or reception. It is achieved by combining elements in an antenna array so that signals at key angles experience constructive interference while others experience destructive interference.



NEW 5G SPECTRUM ALLOCATION – Each country will allocation new spectrum for 5G in centimeter and millimeter wave bands.



MULTI CONNECTIVITY – 3GPP standards define connectivity to legacy 4G systems to compliment 5G networks. This allows 5G to roll out in areas without having to have a fully developed 5G network as 4G networks can cover areas that 5G doesn't have coverage yet.



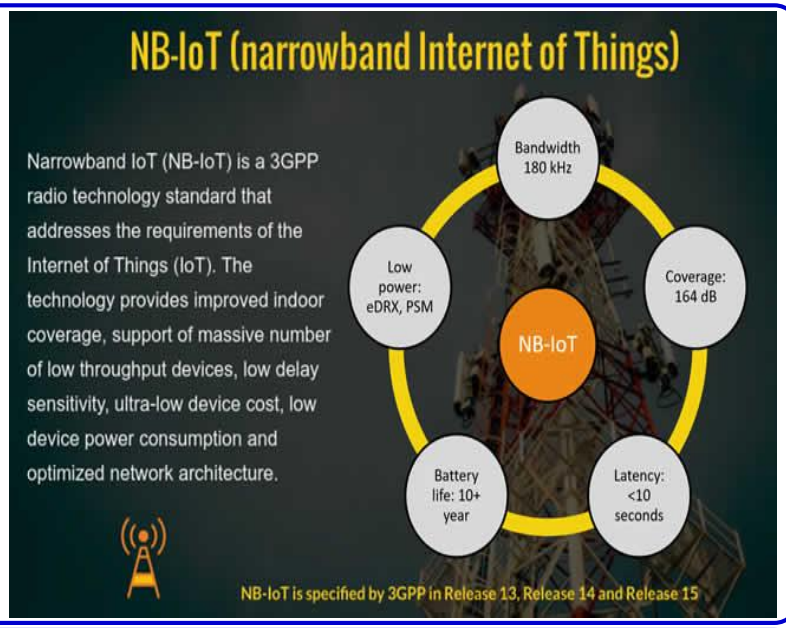
5G Spectrum Allocations in USA

5G Spectrum Allocations in the United States

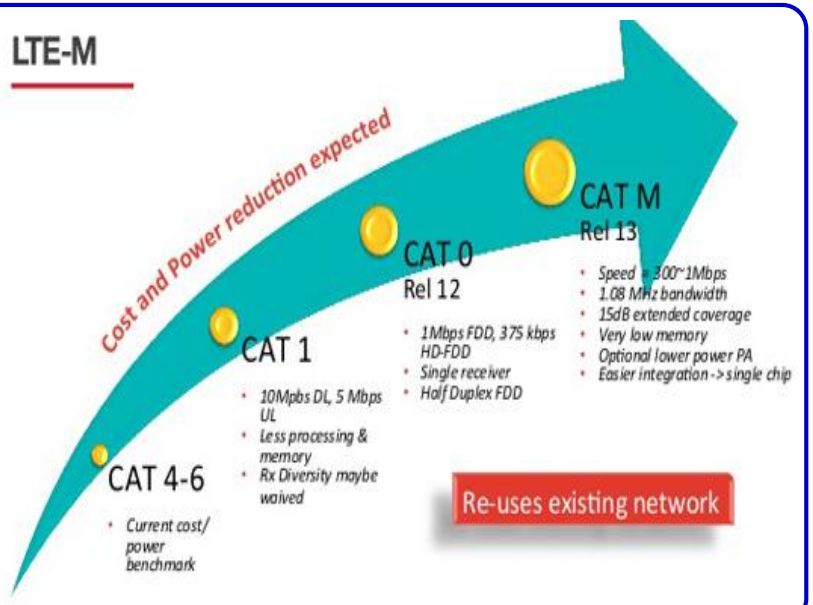
Frequency Band	Type
600 MHz (2 x 35 MHz Bands)	Licensed
2.5 GHz	Licensed (Existing LTE Band 41)
3.55 - 3.7 GHz	Unlicensed
3.7 GHz - 4.2 GHz	Licensed
5.9 - 7.1 GHz	Unlicensed
24.25 - 24.45 GHz	Licensed
24.75 - 25.25 GHz	Licensed
27.5 - 28.35 GHz	Licensed
37 - 38.6 GHz	Licensed Outdoors, Unlicensed Indoors
38.6 - 40 GHz	Licensed
47.2 - 48.3 GHz	-
64 - 71 GHz	Unlicensed

5G Fundamentals

NARROWBAND IOT - Narrowband Internet of Things (NB-IoT) is a Low Power Wide Area Network (LPWAN) 3GPP radio technology standard. It came in 3GPP Release 13 (LTE Advanced Pro), in June 2016. NB-IoT focuses on indoor coverage, low cost, long battery life, and high connection density. NB-IoT uses a subset of the LTE standard but limits the bandwidth to a single narrow-band of 200kHz. It uses OFDM modulation for downlink communication and SC-FDMA for uplink communications. NB-IoT cates to applications with frequent communications.

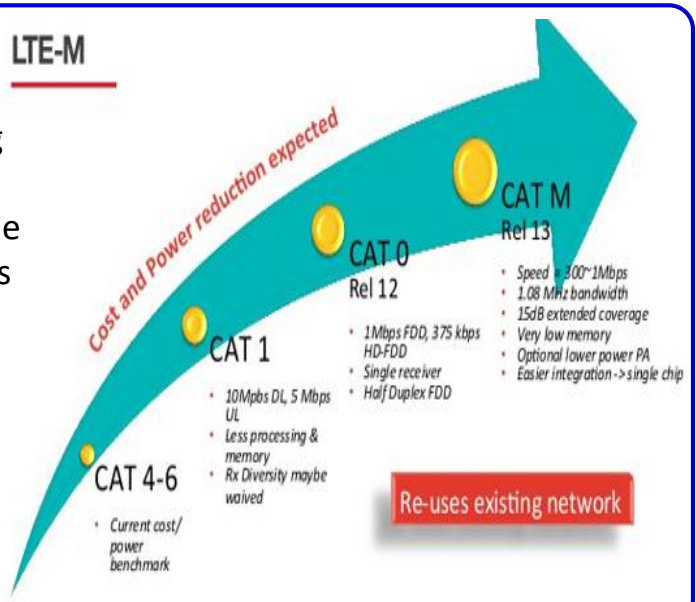


CATEGORY M (CAT-M) – IoT needs are different than what LTE network was built for. LTE Cat M1 (LTE CAT-M, or LTE-MTC) is a low-power wide area (LPWA) cellular technology, designed for the Internet of Things (IoT) and machine-to-machine (M2M) communications. LTE Cat-M uses less bandwidth, requiring only 1.4MHz bandwidth, and supports download & upload data speed less than 1Mbps. LPWA cellular LTE Cat M1 consumes much less power than LTE Cat.3 or Cat.4. This allows battery lifetime up to 10+ years, with the modem costs reduced to 20-25% vs EGPRS modems. LTE Cat-M provides better network coverage in buildings and underground. LTE CAT-M competes with other LPWA options (Wi-Fi, Bluetooth, ZigBee, and Zwave).



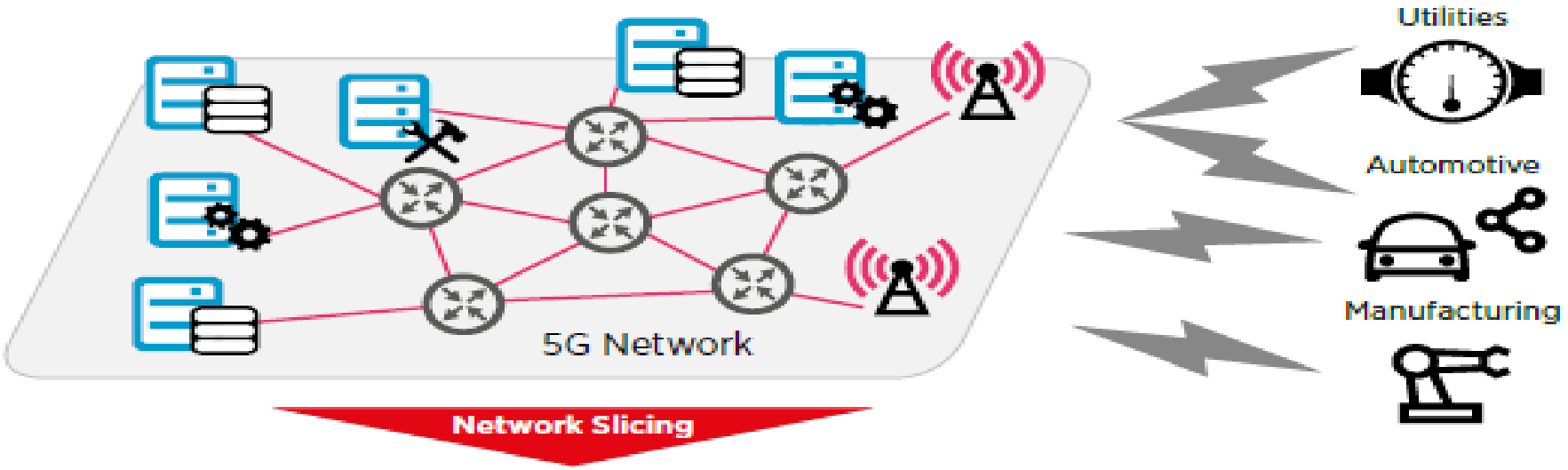
5G Fundamentals

eMTC (Enhanced Machine-Type Communication) - LTE-M including eMTC (enhanced Machine Type Communication) is a low power wide area network (LPWAN) 3GPP standard enabling machine-to-machine and Internet of Things applications. The specification for eMTC (LTE Cat-M1) was in 3GPP Release 13 June 2016 (LTE Advanced Pro). The advantage of LTE-M over NB-IoT is its comparatively higher data rate, mobility, and voice over the network, but it requires more bandwidth, is more costly, and cannot be put into guard band frequency band. In March 2019, over 100 operators have deployed either NB-IoT or LTE-M networks.

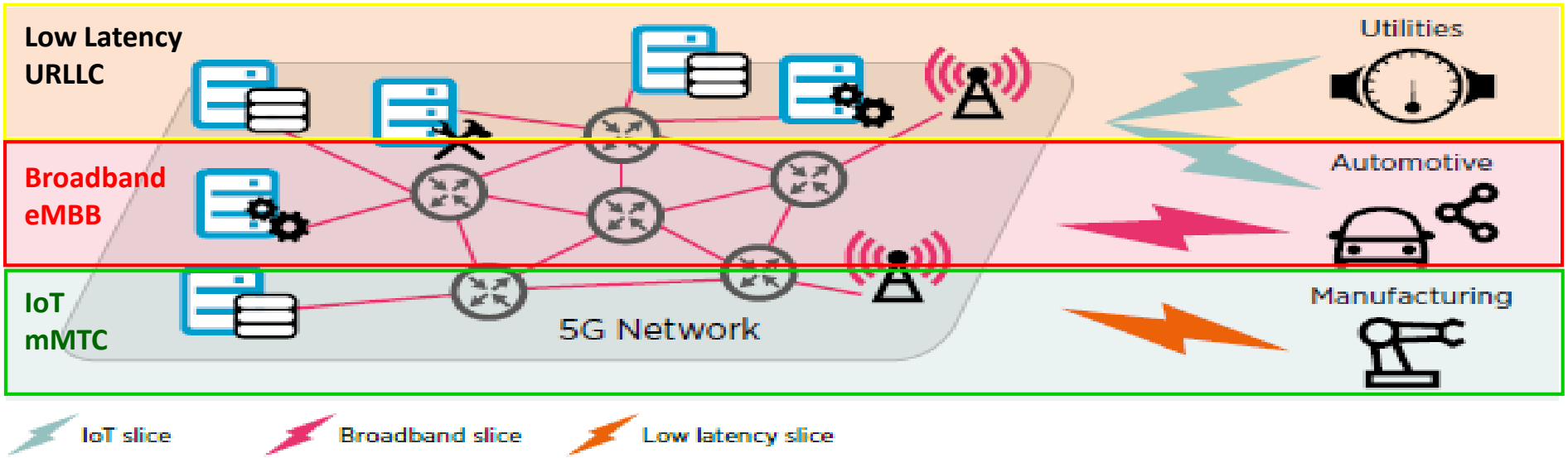


5G Fundamentals – Network Slicing

5G networks need to serve customers with very different needs

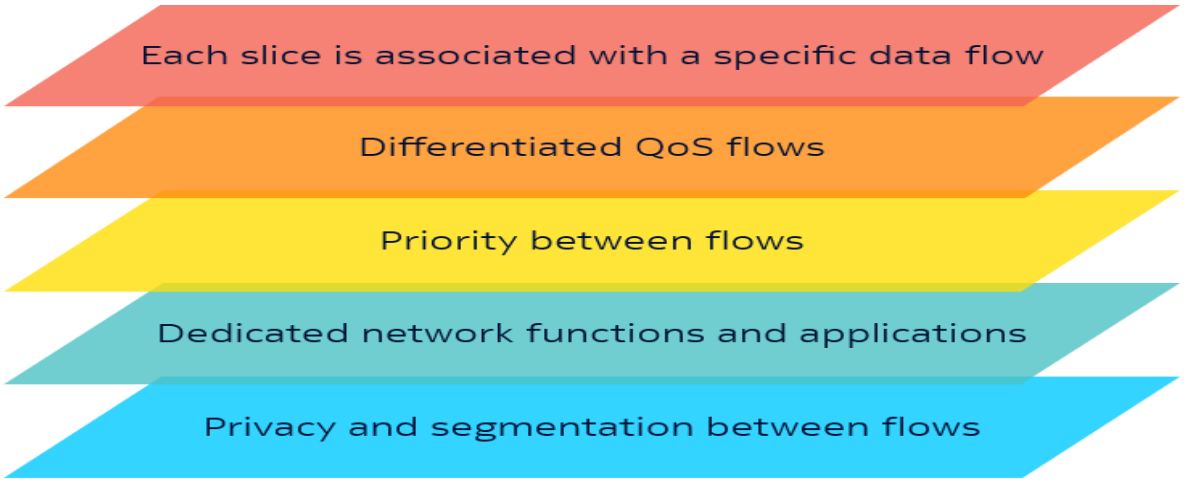


5G networks subdivided into virtual networks each optimised for one business case

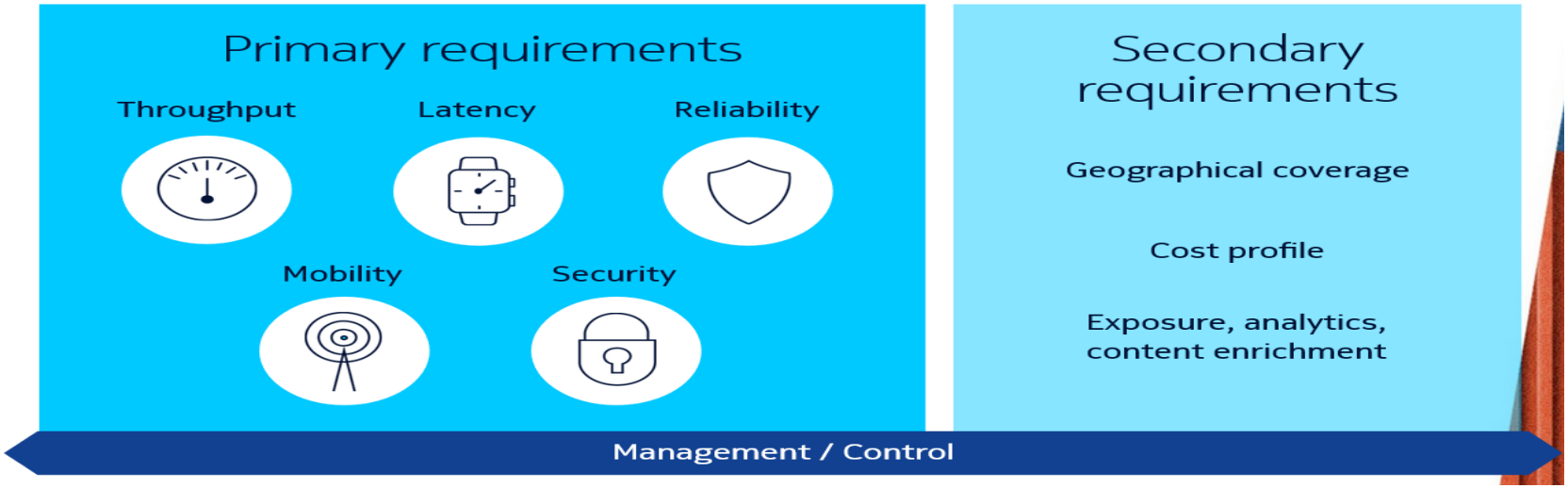


5G Fundamentals – Network Slicing

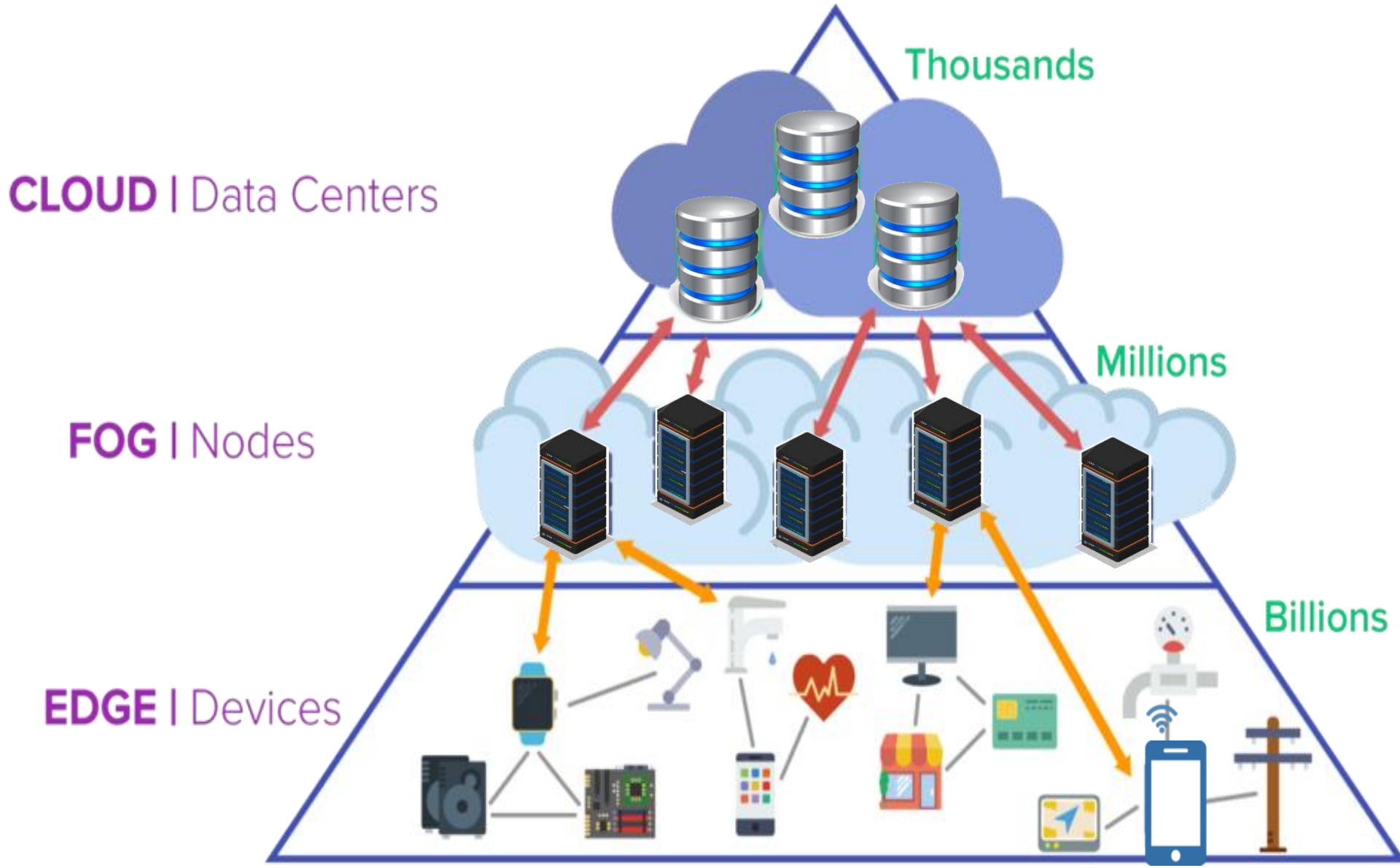
Network slicing features



Network slicing requirements



5G Fundamentals - MEC



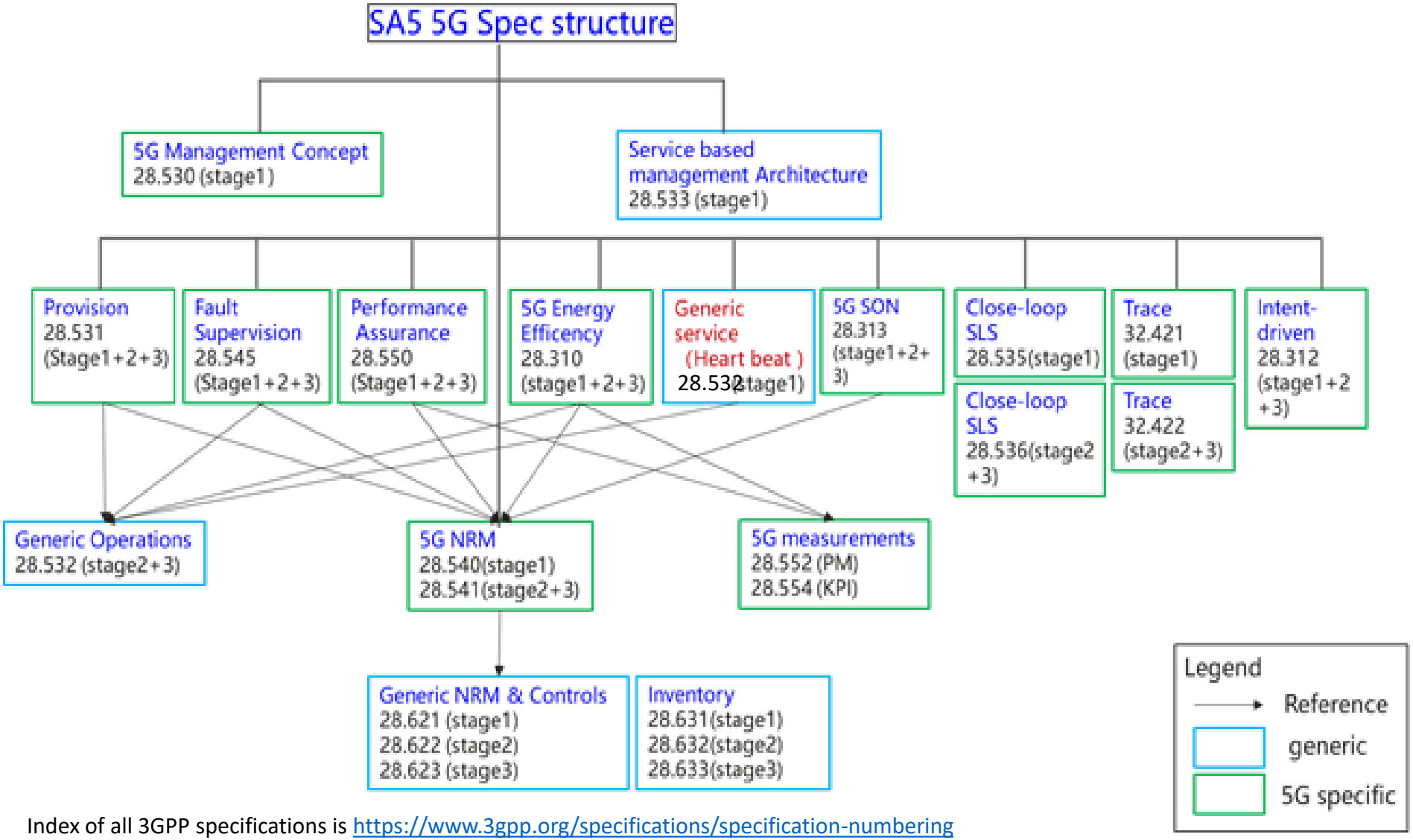
5G Fundamentals - MEC

ICON	TOPIC	DESCRIPTION
	**ON PREMISES**	The Edge is local, meaning that it can run **isolated from the rest of the network**, while having access to local resources. This becomes particularly important for Machine-to-Machine scenarios, for example when dealing with security or safety systems that need high levels of resilience.
	**PROXIMITY**	Being close to the source of information, Edge Computing is particularly useful to **capture key information** for analytics and big data. Edge computing may also have direct access to the devices, which can easily be leveraged by business specific applications
	**LOWER LATENCY**	As Edge services run close to end devices it considerably **reduces latency**. This can be utilized to react faster, to improve user experience, or to minimize congestion in other parts of the network
	**LOCATION AWARENESS**	When a Network Edge is part of a wireless network, whether it is Wi-Fi or Cellular, a local service can leverage low-level signaling information to determine the location of each connected device. This gives birth to an entire family of business-oriented use cases, including **Location Based Services**, Analytics, and many more.
	**NETWORK CONTEXT INFORMATION**	**Real-time network data** (such as radio conditions, network statistics, etc.) can be used by applications and services to offer context-related services that can differentiate the mobile broadband experience and be monetized. New applications can be developed (which will benefit from this real-time network data) to connect mobile subscribers with local points-of-interest, businesses and events.

ONAP
OPEN NETWORK AUTOMATION PLATFORM

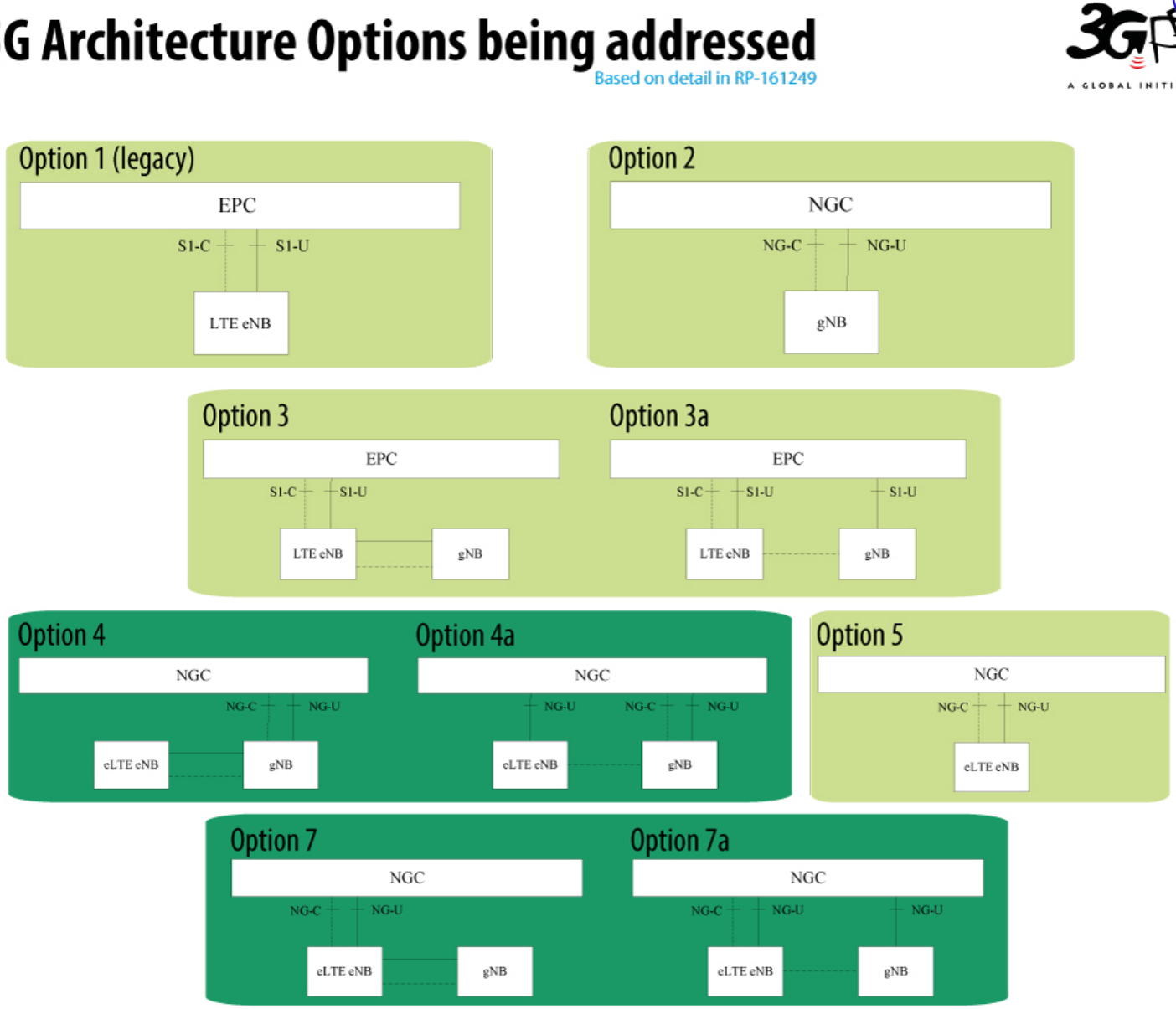
5G Standards

5G 3GPP Standards Map

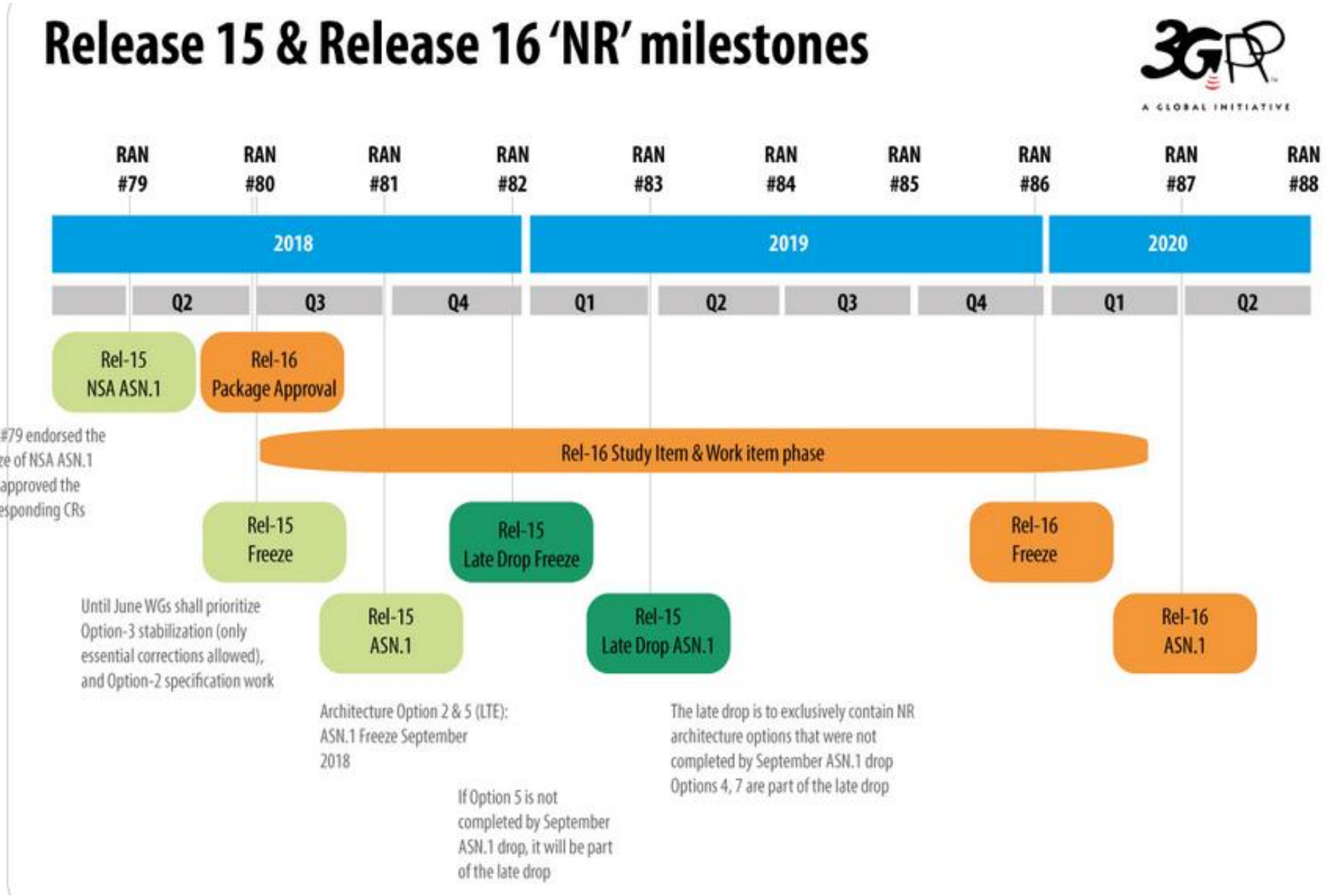


Index of all 3GPP specifications is https://www.3gpp.org/specifications/specification-numbering
OAM specifications are either 28.xxx series or 32.xxx series.
Many of the legacy 32.xxx have been replaced by the newer versions in 28.xxx space.
An overview “map” of 5G OAM specifications is in the S5-197548

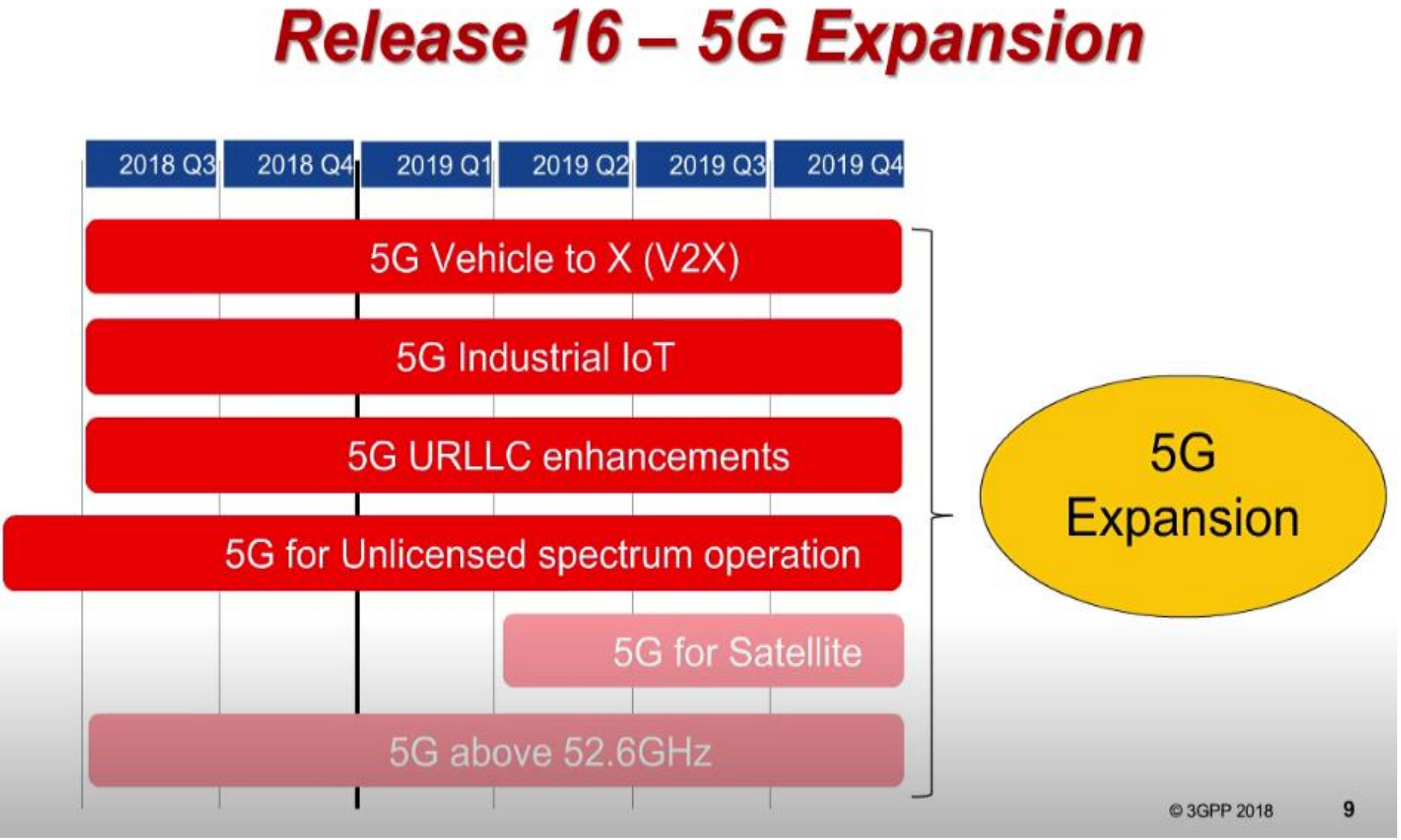
3GPP Release 15&16 – 5G



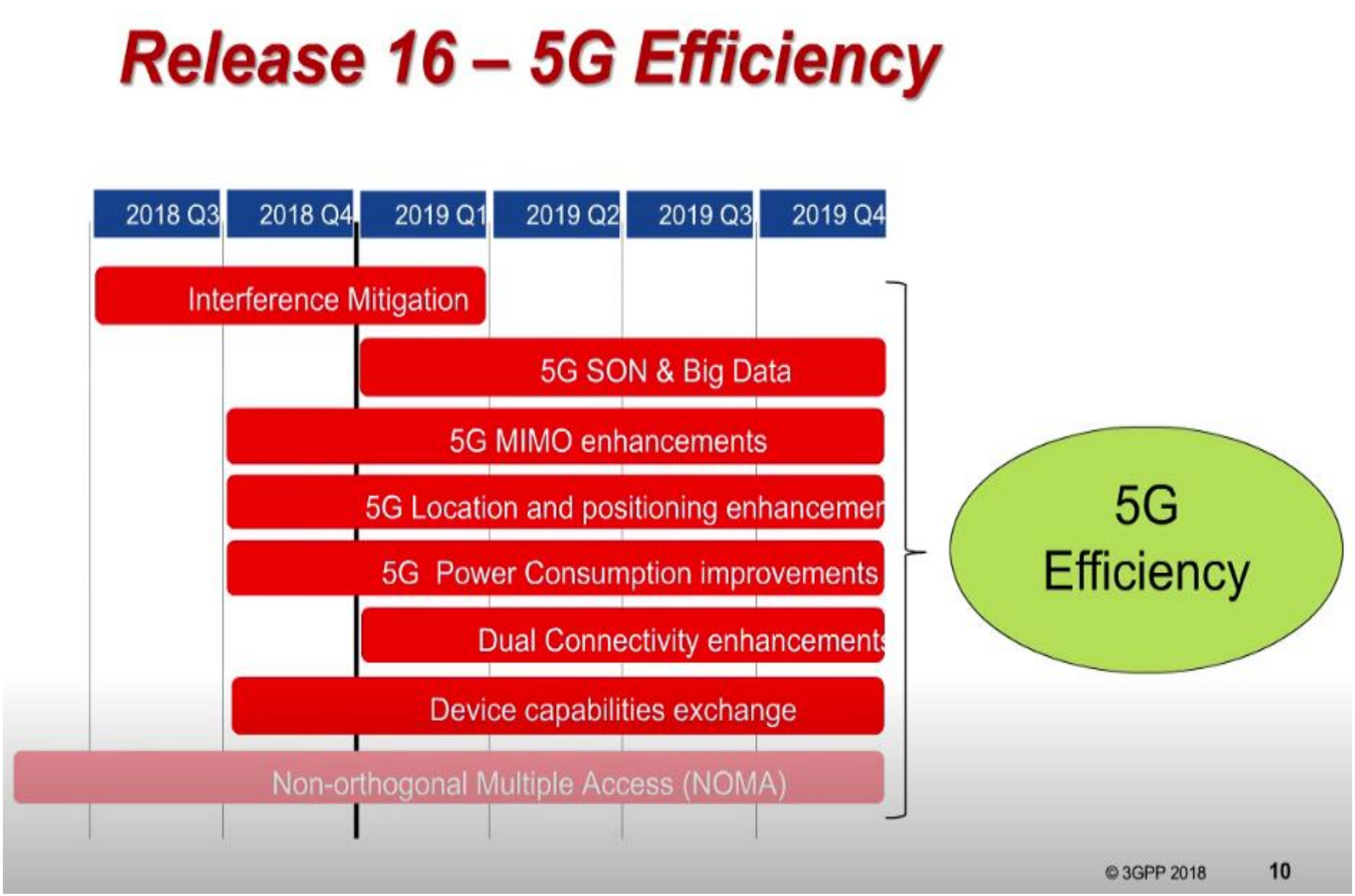
3GPP Release 15&16 – 5G



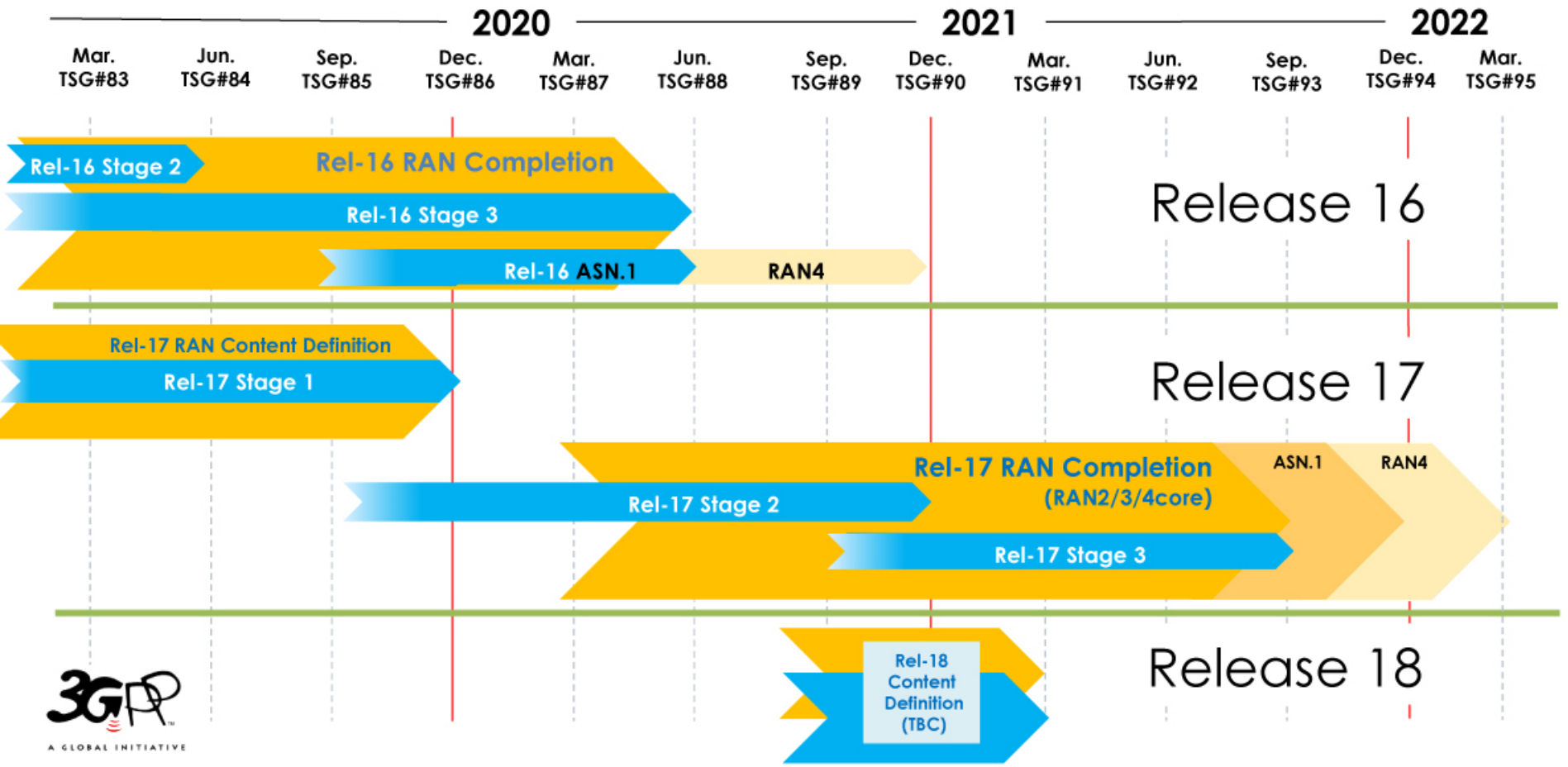
5G Release 16



5G Release 16



5G 3GPP Release 17



Source: 3GPP TSG SA#87e, 17-20 March 2020, e-meeting document SP-200222

5G 3GPP Release 17

Release 17

- NR MIMO
- NR Sidelink enh.
- 52.6 - 71 GHz with existing waveform
- Dynamic Spectrum Sharing (DSS) enh.
- Industrial IoT / URLLC enh.
- Study - IoT over Non Terrestrial Networks (NTN)
- NR over Non Terrestrial Networks (NTN)
- NR Positioning enh.
- Low complexity NR devices
- Power saving
- NR Coverage enh.
- Study - NR eXtended Reality (XR)
- NB-IoT and LTE-MTC enh.
- 5G Multicast broadcast
- Multi-Radio DCCA enh.
- Multi SIM
- Integrated Access and Backhaul (IAB) enh.
- NR Sidelink relay
- RAN Slicing
- Enh. for small data
- SON / Minimization of drive tests (MDT) enh.
- NR Quality of Experience
- eNB architecture evolution, LTE C-plane / U-plane split
- Satellite components in the 5G architecture
- Non-Public Networks enh.
- Network Automation for 5G - phase 2
- Edge Computing in 5GC
- Proximity based Services in 5GS
- Network Slicing Phase 2
- Enh. V2x Services
- Advanced Interactive Services
- Access Traffic Steering, Switch and Splitting support in the 5G system architecture
- Unmanned Aerial Systems
- 5GC LoCation Services
- Multimedia Priority Service (MPS)
- 5G Wireless and Wireline Convergence
- 5G LAN-type services
- User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)

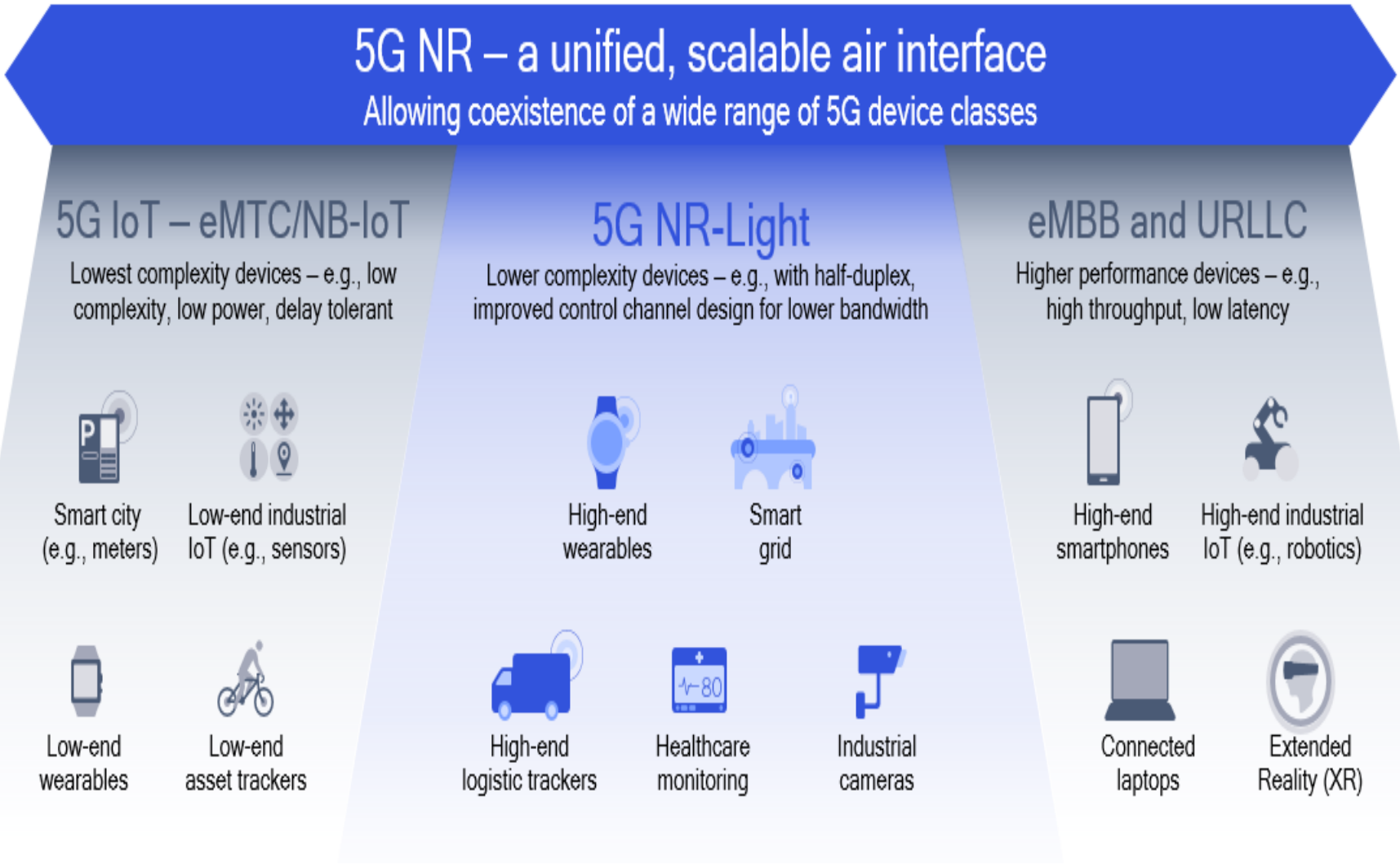
These are some of the Rel-17 headline features, prioritized during the December 2019 Plenaries (TSG#86)

Start of work: January 2020

Full details of the content of Rel-17 are in the Work Plan: www.3gpp.org/specifications/work-plan

5G 3GPP Release 17

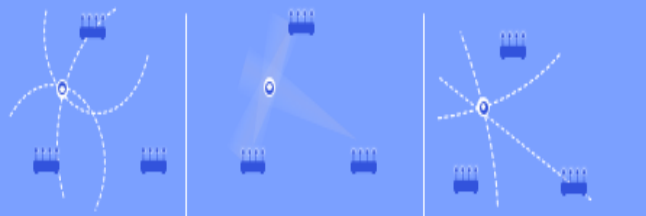
3GPP 5G Release 17 (2021)



5G 3GPP Release 17

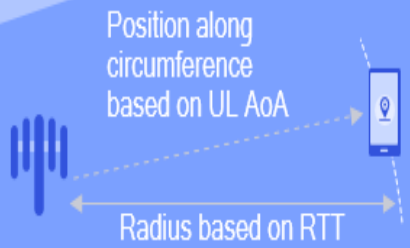
Release 16

Meeting initial accuracy requirements of ~3-10 meters



Roundtrip time (RTT) | Angel of arrival / departure (AoA/AoD) | Time difference of arrival (TDOA)

Single-cell positioning



Release 17

Enhancing capability and performance for a wide range of use cases

Centimeter level accuracy

Meeting accuracy of down to 0.3m

Lower positioning latency

Reducing latency to as low as 10 ms

New evaluation scenarios

Supporting IIoT channel models

Higher capacity

Scaling to millions of simultaneous devices

5G 3GPP Release 17

Enhanced eMBB in 3GPP Rel-17

Further improved MIMO for e.g., better mobility

Enhanced IAB with full-duplex and spatial multiplexing

DSS enhancements

Enhanced coverage for sub-7 GHz & mmWave

Supporting even higher bands, up to 71 GHz

Multicast for content delivery

Further power saving for idle, connected and small data

Further enhanced mobility for mixed topologies

Others such as, >4 Rx and multi-SIM

Enhanced foundation

Coverage, capacity, latency, power saving, mobility

Expanded deployments

New spectrum, topologies, integrated backhaul, ...

New services

Latency, reliability, positioning, use cases like XR

5G 3GPP Release 17 Extended Reality

Potential areas of enhancements

More simultaneous users	More seamless mobility
Reduced latency	Increased coverage
Optimized power consumption	Higher reliability

- Edge processing framework
- Traffic awareness
- System enhancements