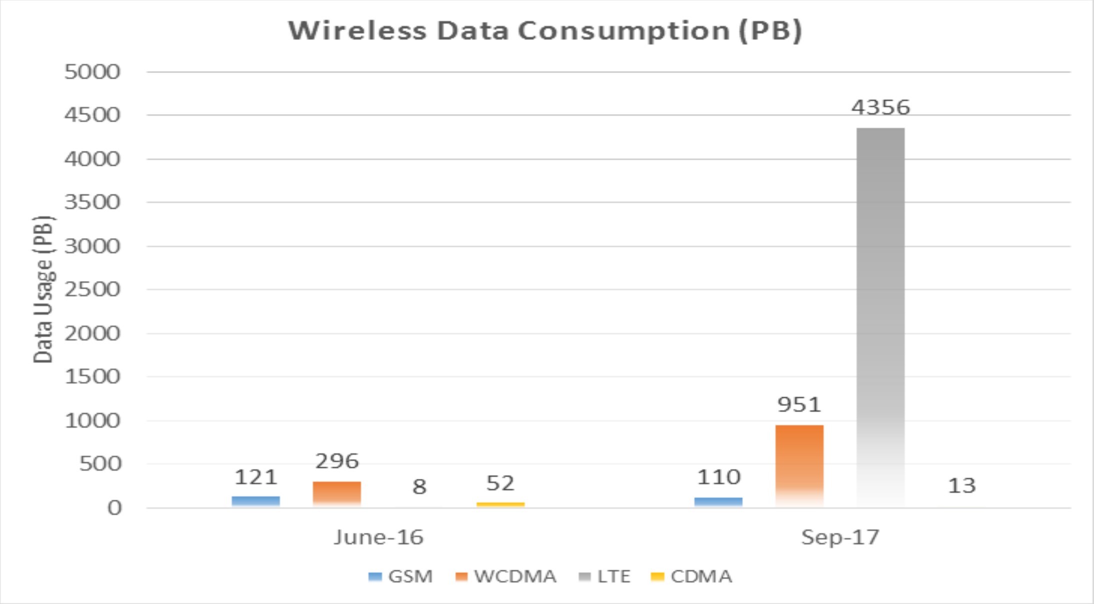
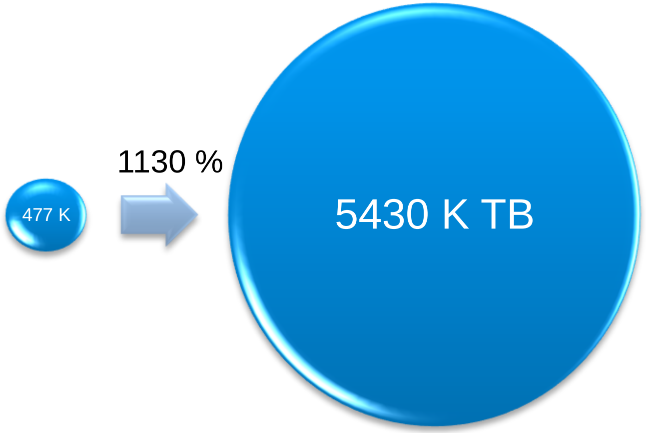
On the Road to 5G – Key Perspectives

18-05-2018

India's Data Consumption Growth Story – To be taken forward with 5G

- India was ranked 155th in the world for Mobile Broadband in 2016 with the total data consumption at 477 K Terabytes in the Quarter ending June 2016.
- By Sep 2017, India climbed to first rank in the world with Indians consuming more mobile broadband data than users in US and China – with the total data consumption rising to 5,430 K Terabytes.
- High Definition voice on cellular network was never experienced at such an unprecedented scale. India led the world in HD quality voice with VoLTE adoption at a scale never seen before anywhere in the world.





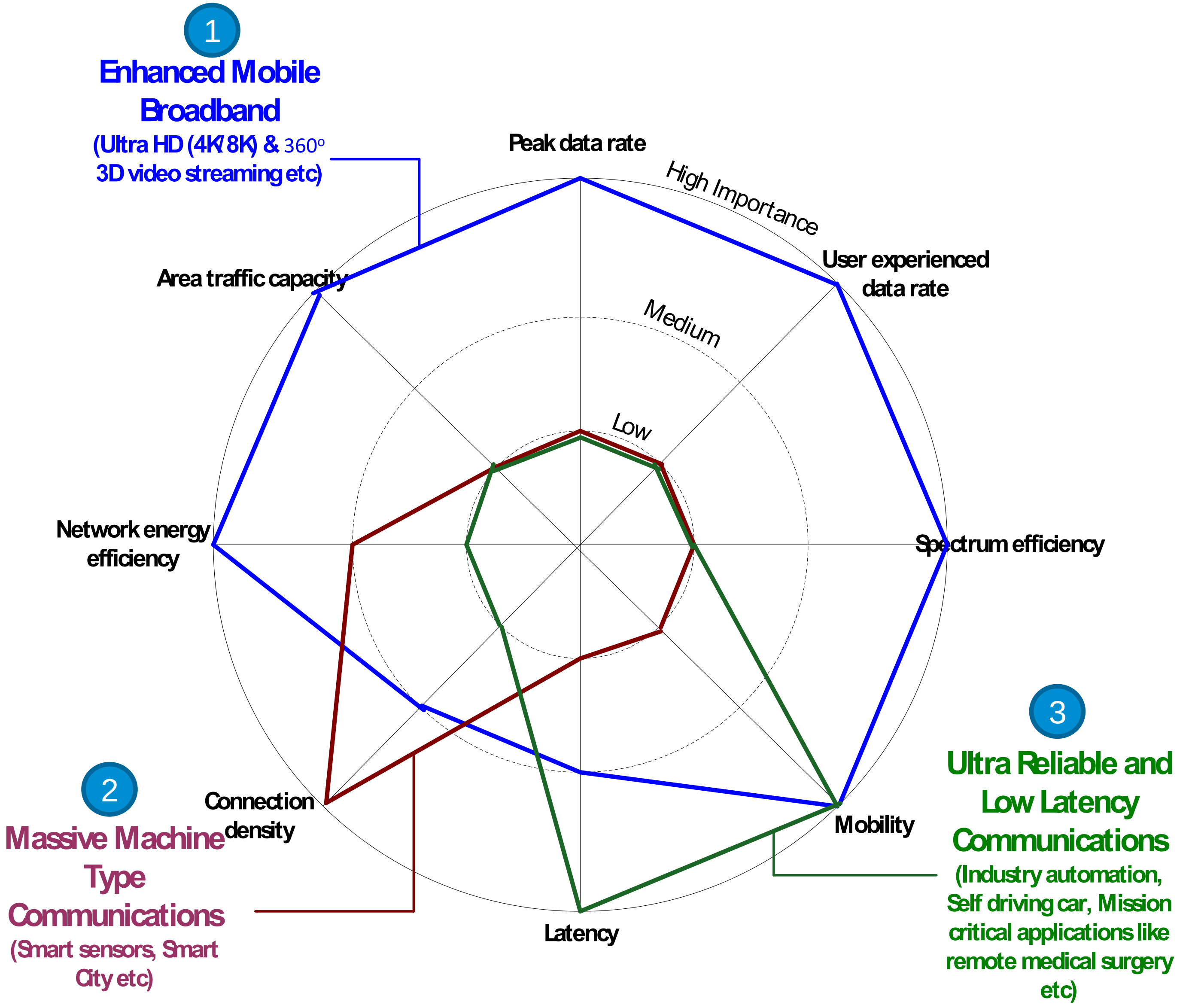
5G – Motivation

With connectivity at the heart of India's Digital transformation, 5G will be an innovation engine bringing disruptive changes spanning across businesses and society as a whole. The introduction of 5G will create enhanced services with new use cases, new revenue streams and new business models for operators and consumers.

Therefore the primary design objective of 5G is to create high capacity networks that can scale to the extreme requirements of data rate, mobility, latency, reliability and connection density which cannot be fulfilled with the 4G networks.

Prospective use cases - based on the requirements they put on the key performance attributes like data rate, connection density, latency, mobility and energy efficiency etc. can be broadly classified as:

- Enhanced Mobile Broadband (eMBB)
- Ultra-reliable and Low-latency Communications (uRLLC)



5G – Design Tenets

5G has set-out ambitious design targets – including high channel bandwidths, extremely high data rates, high mobility, ultra-low latency, high energy efficiency, large cell ranges and extreme connection density to name a few.

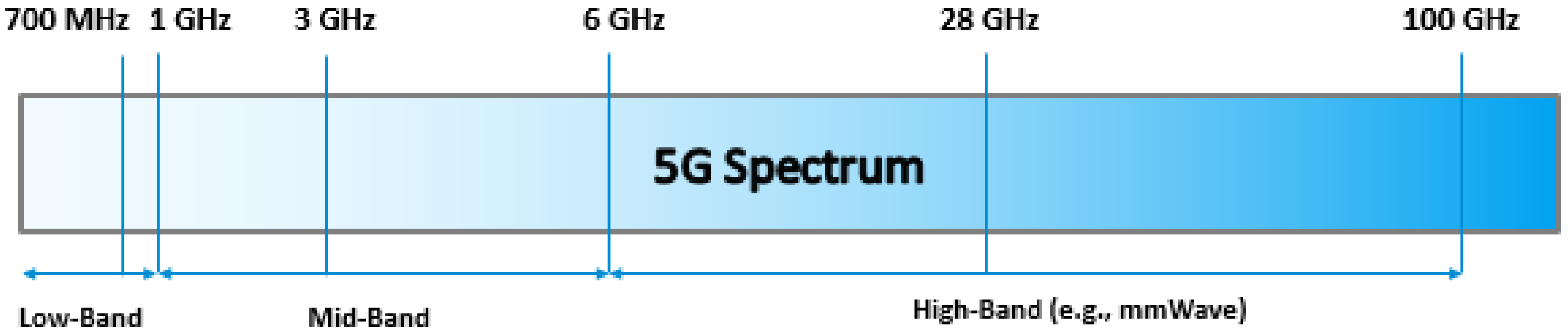
- **Downlink** Peak data rate is **20 Gbps**
- **Uplink** Peak data rate is **10 Gbps**
- **Downlink** peak **spectral efficiency** is **30 bps per Hz**
- **Uplink** peak **spectral efficiency** is **15 bps per Hz**
- **Downlink user experienced data rate** is **100 Mbps**
- **Uplink user experienced data rate** is **50 Mbps**
- At least 100 MHz and up to **1 GHz spectrum bandwidth**
- **Mobility** support from 0 kmph up to **500 kmph** vehicular speed

- Connection density: support at least **1 million connected devices per square kilometre** – to cover IoT devices
- **Maximum latency: 4 ms** for eMBB. 4G LTE networks give around 20 ms latency
- Latency of just **1 ms** for **URLLC**
- **Control plane latency** of **10 ms**
- **Mobility interruption time** should be **0 ms**
- **Target battery life** for mMTC (IoT) devices: **15 years**
- Network Function Virtualisation, Network Slicing

Spectrum Considerations

5G Spectrum Candidates

Owing to the need to serve a plethora of use cases ranging to extremes in coverage and capacities, 5G has varied Spectrum requirements - to have wide and ubiquitous coverage on one end to very high channel bandwidths to deliver speeds for MBB. Consequently, 5G needs spectrum in the three frequency ranges – low, medium and high.



Low-Band

- Deep Indoor Propagation and Wide Coverage critical for URLLC service delivery and mMTC.
- Limited availability (around 35 MHz) of paired spectrum.
- IMT has already standardized 700 MHz band for 5G.

Mid-Band

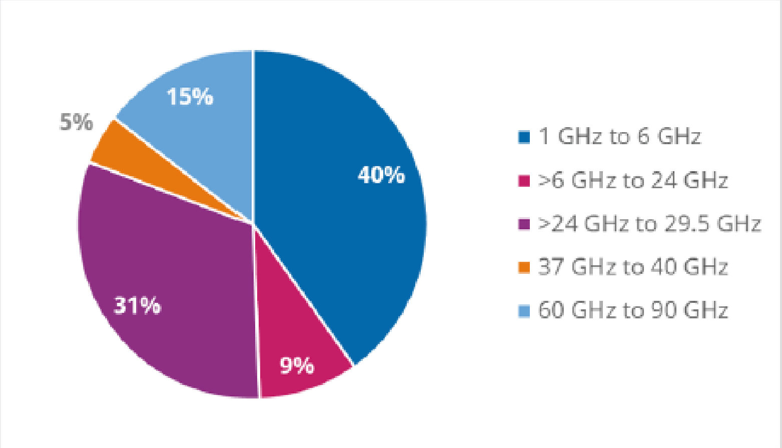
- Broadband service delivery over 5G with ubiquitous footprint.
- 100 MHz chunk of unpaired spectrum should be made available to each operator.
- Spectrum around 3.5 GHz serves as an attractive option for initial 5G rollout.

High-Band

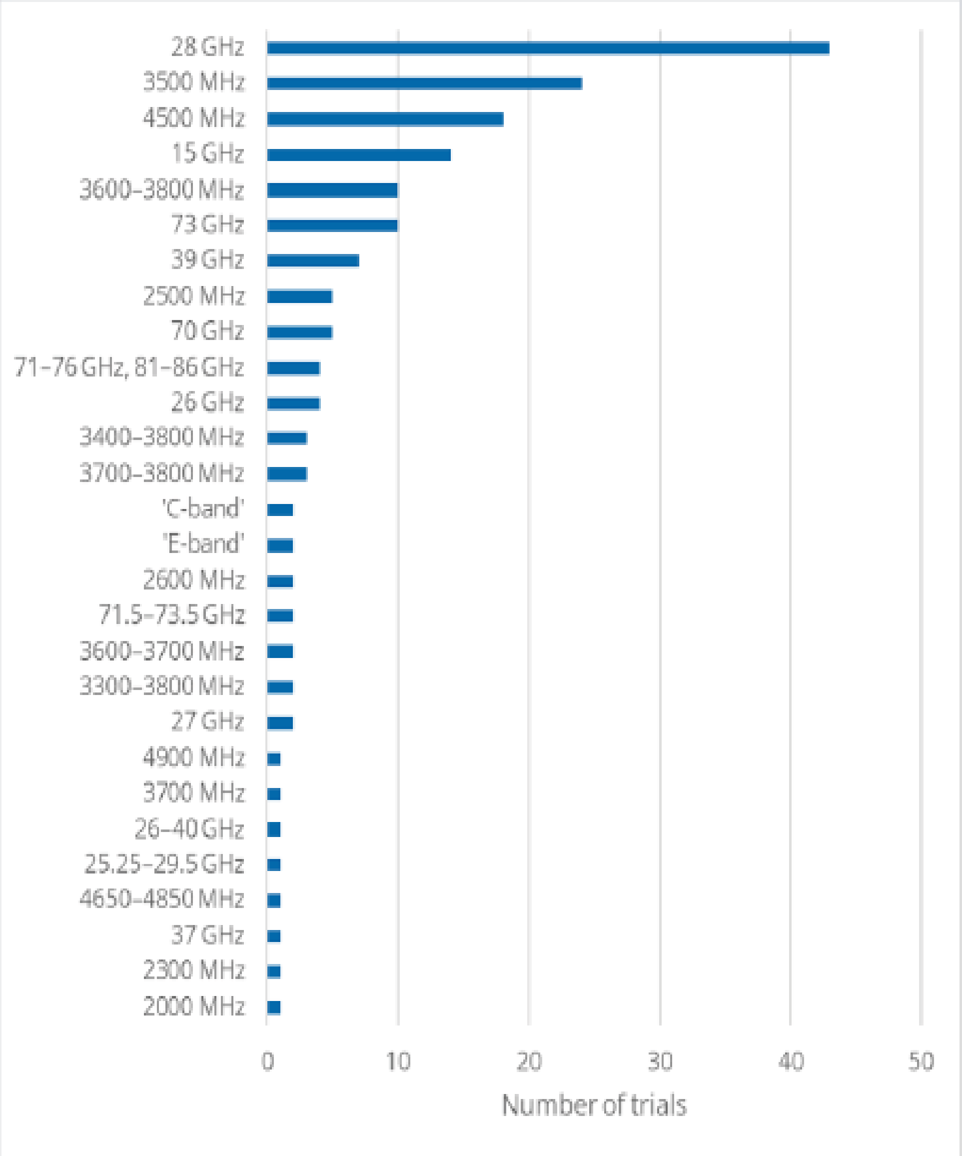
- Suitable for rendering eMBB and Fixed Wireless Access services.
- Availability should be in excess of 1 GHz per operator.
- 28 GHz band has globally emerged as the most popular spectrum choices for initial 5G trials.

5G Spectrum – Global Trend

- Regulators across the world are yet to freeze spectrum bands to utilise for 5G.
- Spectrum bands used by operators in 172 demonstrations/trials published by GSA are shown in the adjoining chart.
- The focus of trials has largely been on extremely high data rates serving eMBB use cases.
- Trends indicate that sub 6 GHz spectrum range comprising primarily from mid 3 GHz bands has emerged as the most popular spectrum range as shown in the pie-chart below.



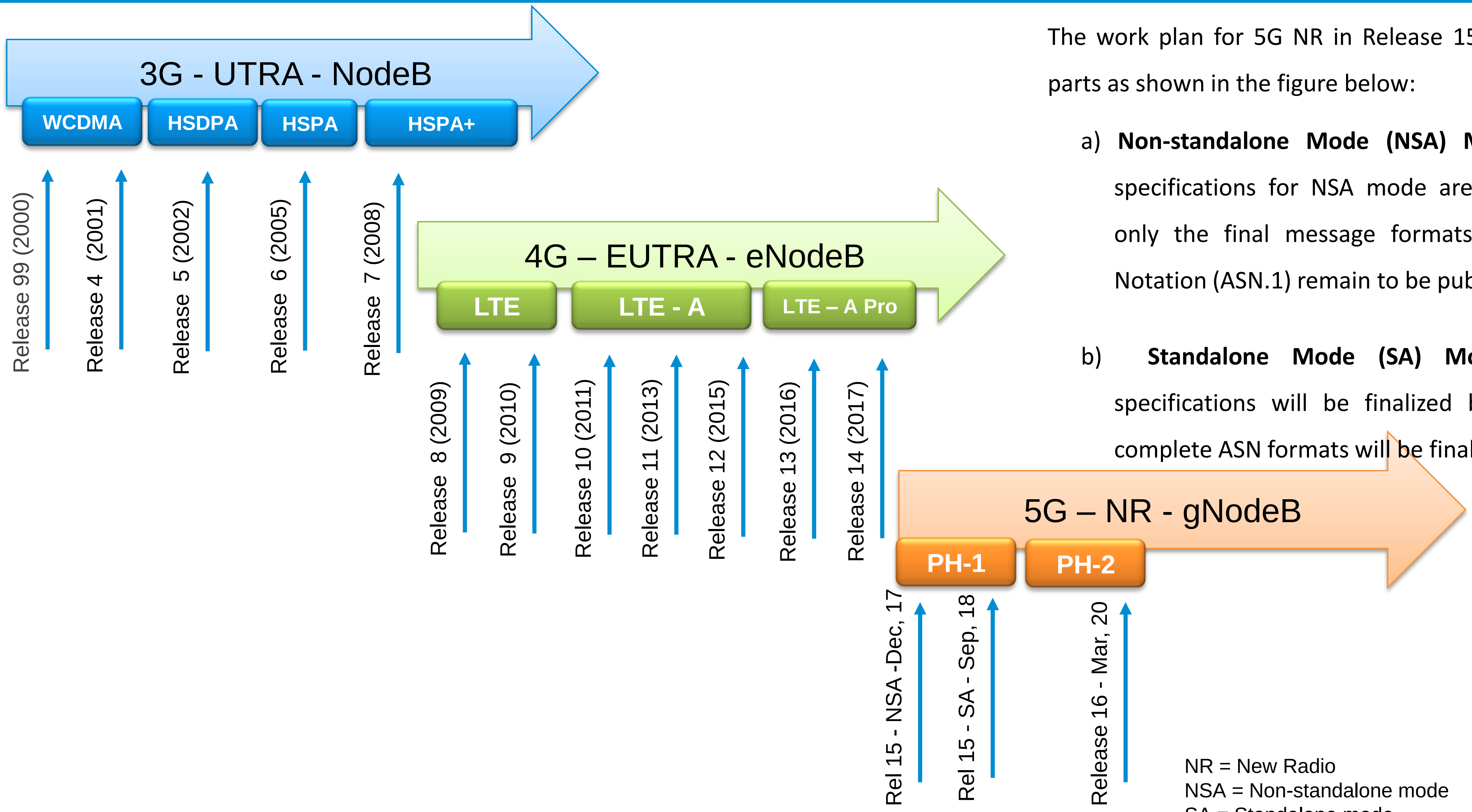
- The next popular band after 3.5 GHz is the 28 GHz TDD band. These two bands being most likely to be used widely across the globe, will drive economies of scale for equipment and Devices.



Source : GSA

Technology Aspects

Technology Progression



The work plan for 5G NR in Release 15 is divided into two parts as shown in the figure below:

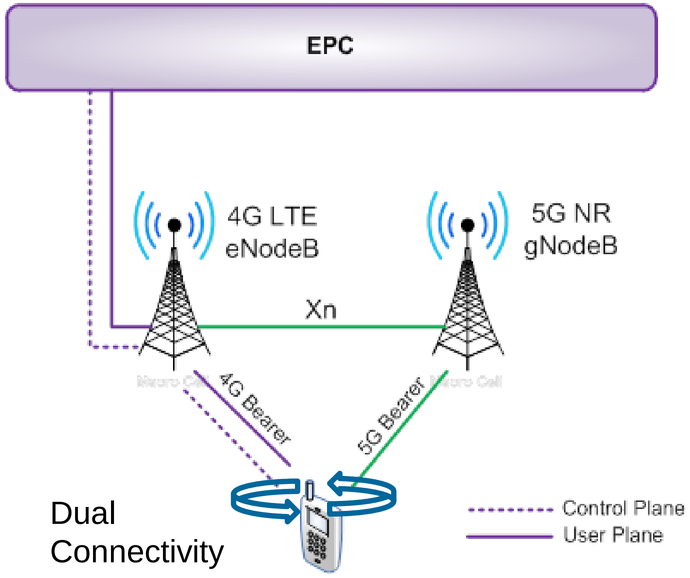
a) **Non-standalone Mode (NSA) Mode:** The Stage 3 specifications for NSA mode are now complete and only the final message formats in Abstract Syntax Notation (ASN.1) remain to be published.

b) **Standalone Mode (SA) Mode:** The Stage 3 specifications will be finalized by Q2 whereas the complete ASN formats will be finalized by Q3 of 2018

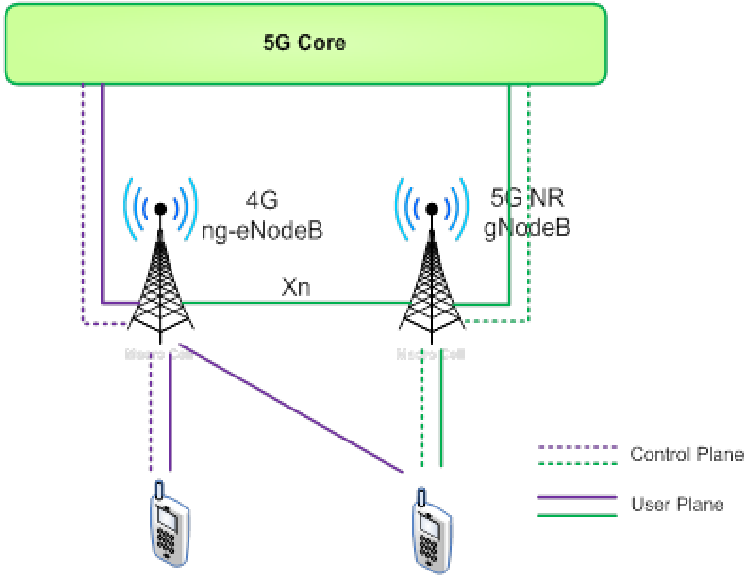
NR = New Radio
NSA = Non-standalone mode
SA = Standalone mode

5G Network Architecture Options

- Radio Interface has been completely redefined and is termed as ‘New Radio’ (NR), with gNodeB being equivalent of eNodeB in LTE.
- 3GPP has created the specifications to allow phased deployments of 5G - starting with Non-Standalone (NSA) mode.
- In NSA mode, gNodeB will integrate with the existing LTE EPC. Therefore even as the gNodeBs are installed, they can be connected to the existing EPCs. The NSA mode is depicted in the Left figure below. The gNodeB is shown to be connected to a neighboring or co-located 4G eNodeB which in turn connects to the EPC.
- The second phase is to move towards Standalone (SA) deployment of gNodeBs with the 5G Core (Next Generation Core – NGC) which will be the 5G counterpart of the current EPC.
- The 4G LTE eNodeB will also have to evolve to ng-eNodeB to integrate with 5G Core.



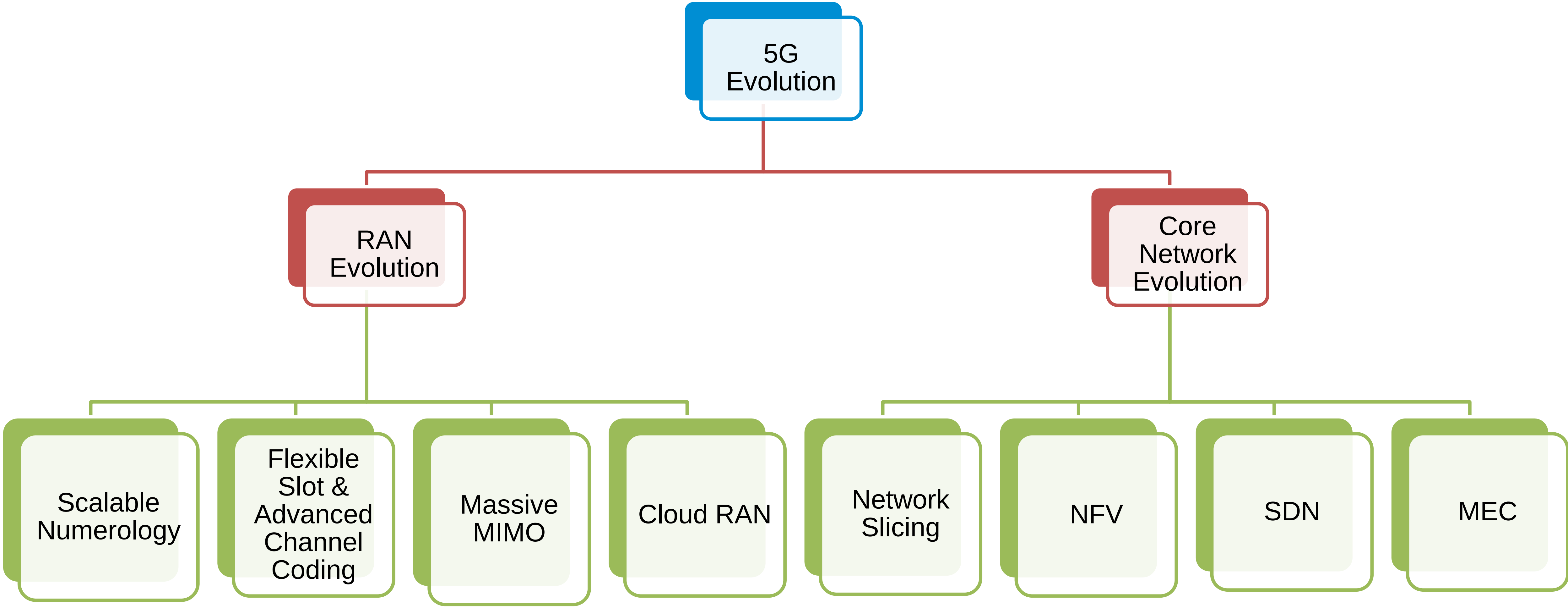
Non-Standalone (NSA) mode with LTE via EPC as master



Standalone (SA) mode with NR via 5GC as master

5G Technology Evolution

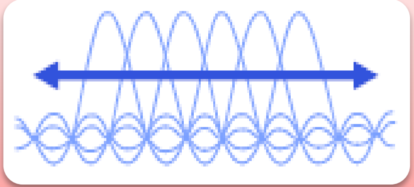
5G embodies significant new technological innovations in both Radio Access Network (RAN) as well Core Network which enables scalability and flexibility to serve a vast number of use-cases through a single common network.



5G Technology - New Radio Overview

5G is the next frontier for entire mobile industry. The radio interface defined in 5G is termed as 'New Radio' (NR). For enhanced mobile broadband and to support diverse set of services, NR is designed as follows:

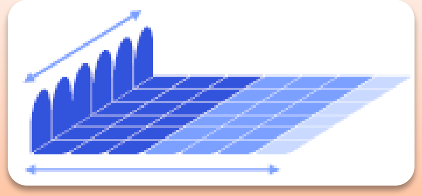
Scalability



Scalable OFDM Technology

(Sub Carrier Spacing of 15, 30, 60, 120 and 240 KHz for diverse deployments and services)

Low Latency Flexibility



Flexible Slot Structure

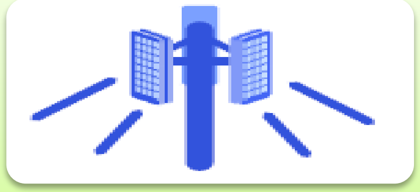
(Symbol Level TDD Formats providing low latency to meet URLLC requirements)

High Reliability

Advanced Channel Coding

(Low Density Parity Check Codes for high reliability)

High Data Capacity

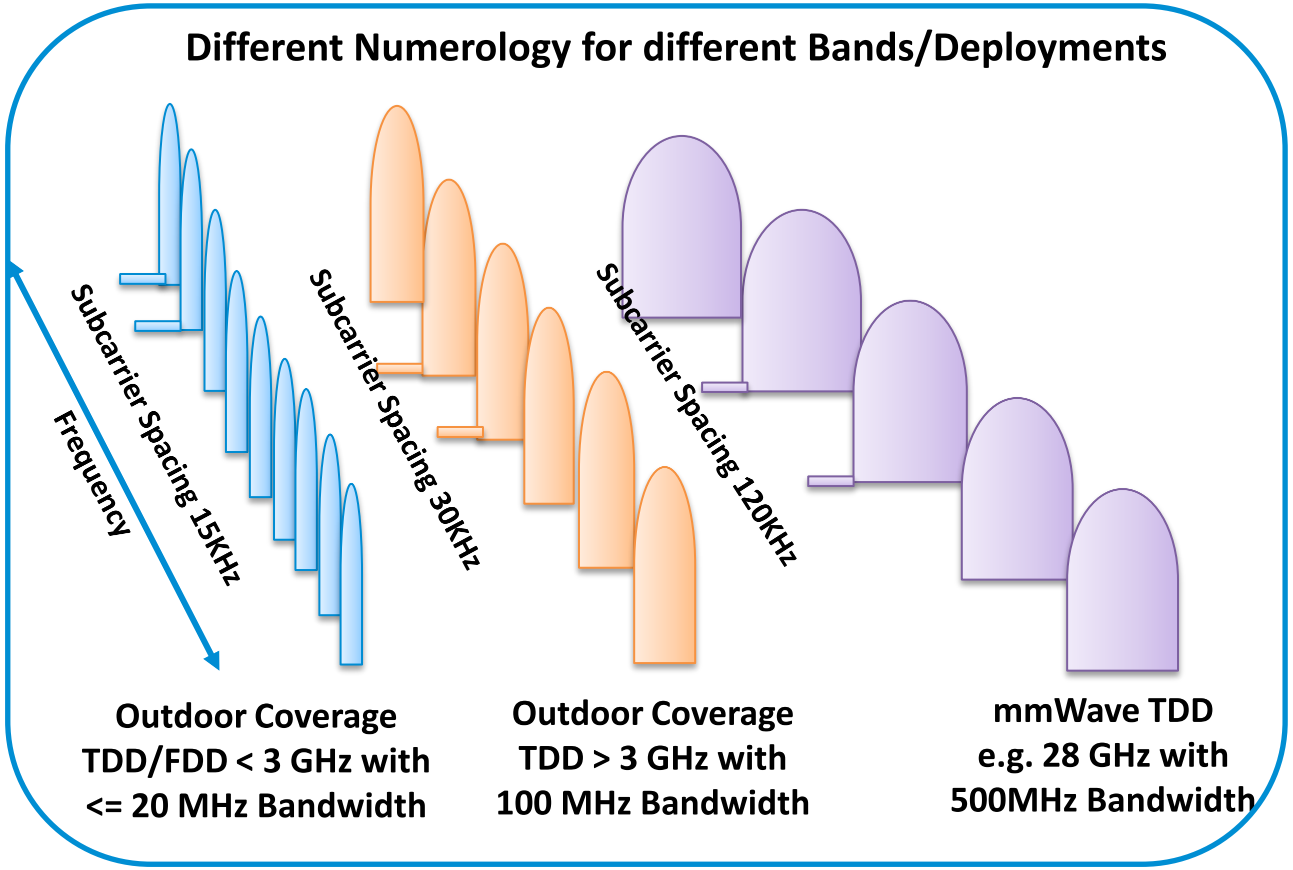


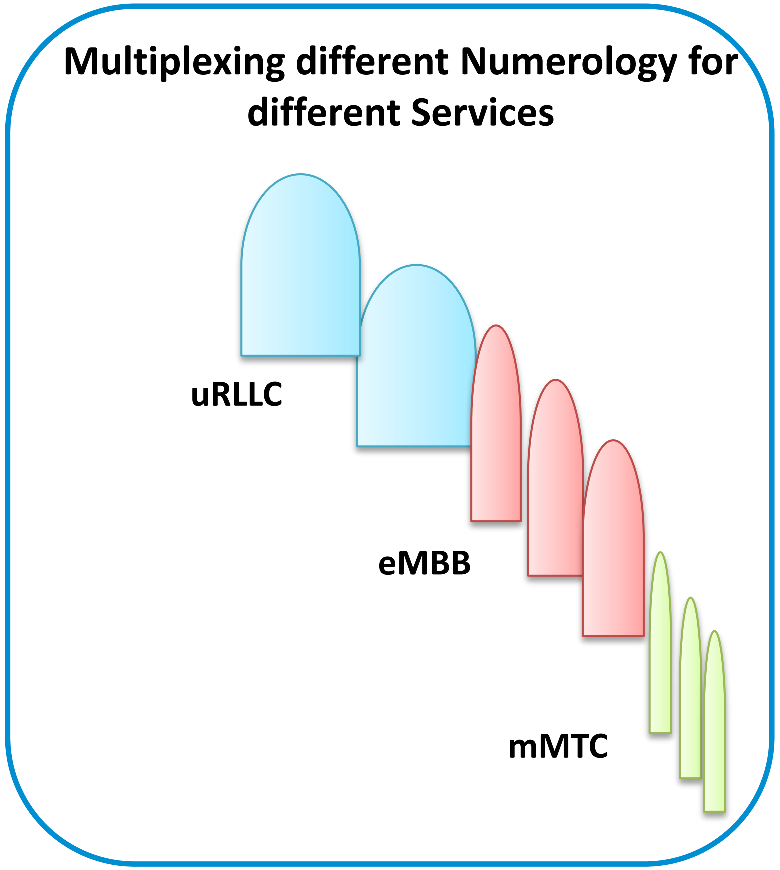
Massive MIMO

(Beamforming with more than 128 active antenna array for high capacity gains)

5G Technology – Scalable Numerology

Unlike LTE with almost fixed OFDM numerology (15 kHz subcarrier spacing), 5G NR introduced scalable OFDM numerology to support diverse spectrum bands, services and deployment models. For example, mmWave bands have wider channel bandwidths (e.g. 100s of MHz) and it is critical that the OFDM subcarrier spacing is able to scale with the channel bandwidth such that processing complexity (FFT size) does not increase exponentially for wider bandwidths.

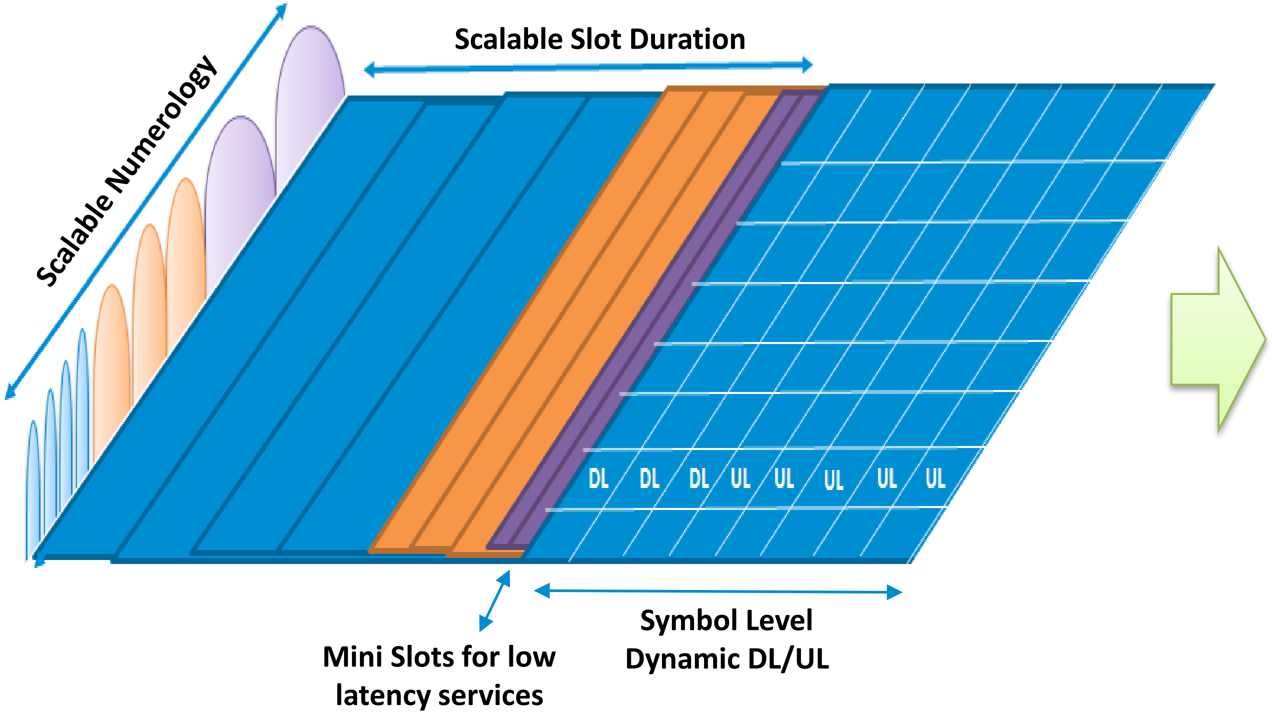


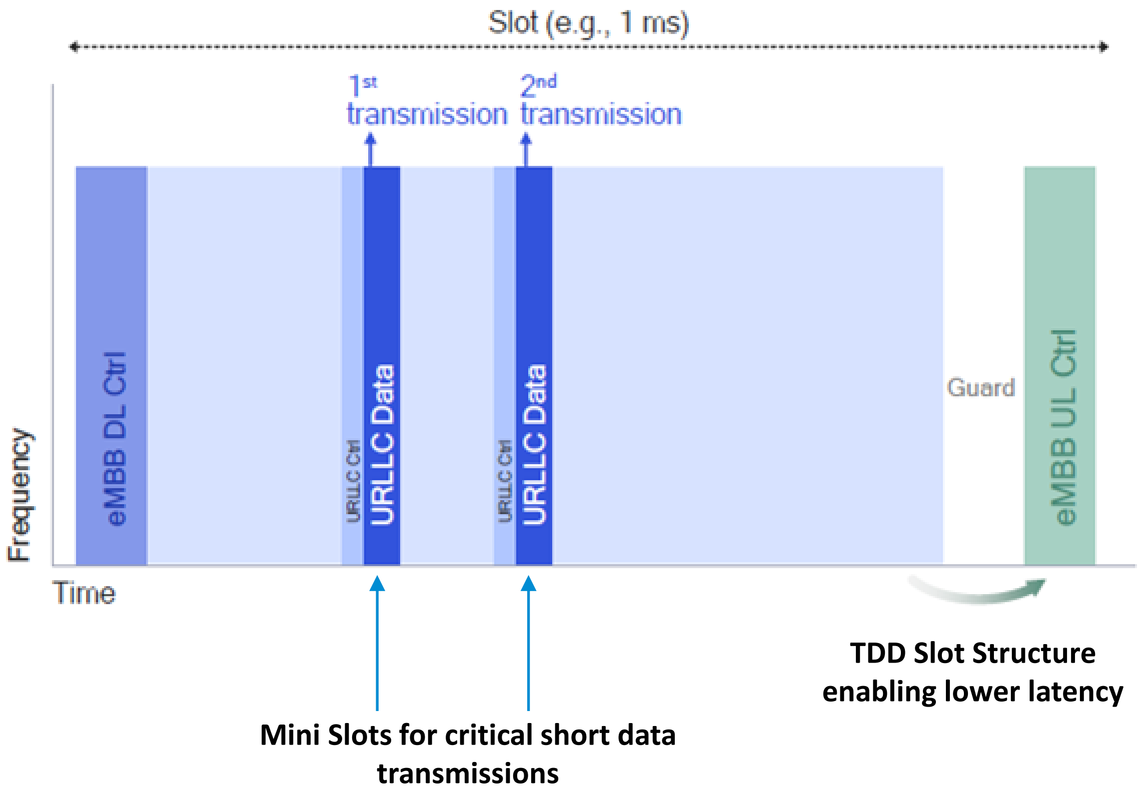


Numerology	Sub carrier spacing (KHz)
0	15
1	30
2	60
3	120
4	240

5G Technology – Flexible Slot Structure

5G NR is designed with a flexible frame structure to efficiently multiplex diverse 5G services and provide forward compatibility for future ones. Symbol Level TDD Formats providing low latency are defined to meet URLLC requirements



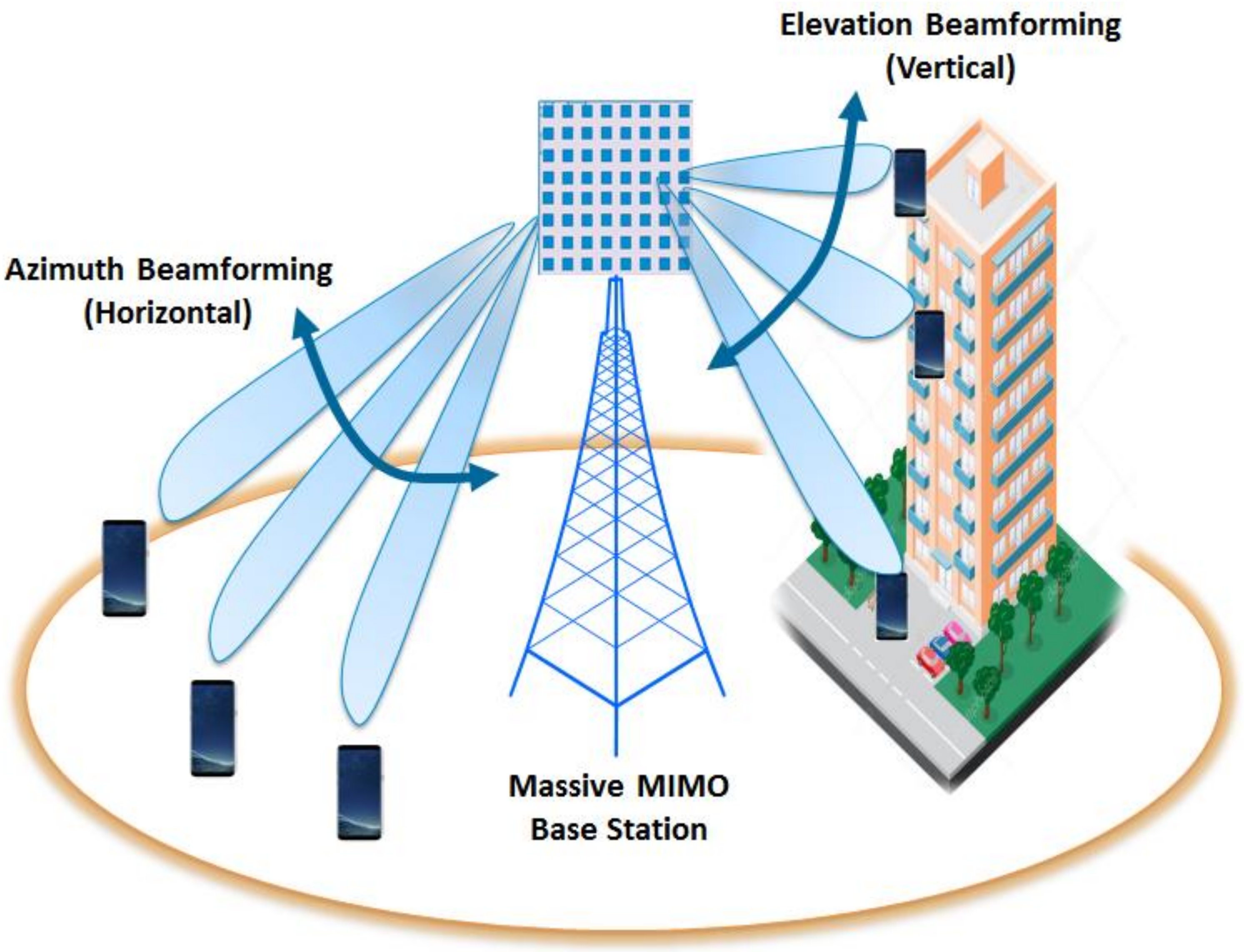


5G Technology – Massive MIMO

Massive MIMO involves an array of antenna elements which allow narrow RF beams to be directed to individual active UEs in the sector – both in the Horizontal (Azimuth) as well as Vertical (Elevation) planes – enable good coverage everywhere. Apart from capacity gains, there is also improved penetration of RF beams to enhance the SINR and indoor coverage. 5G uses Massive MIMO with large number of antenna elements (up to 256).

This technology benefits 5G as follows:

- Significantly increases Data Throughput
- High Capacity
- Good Cell Edge performance



5G Technology – Cloud RAN

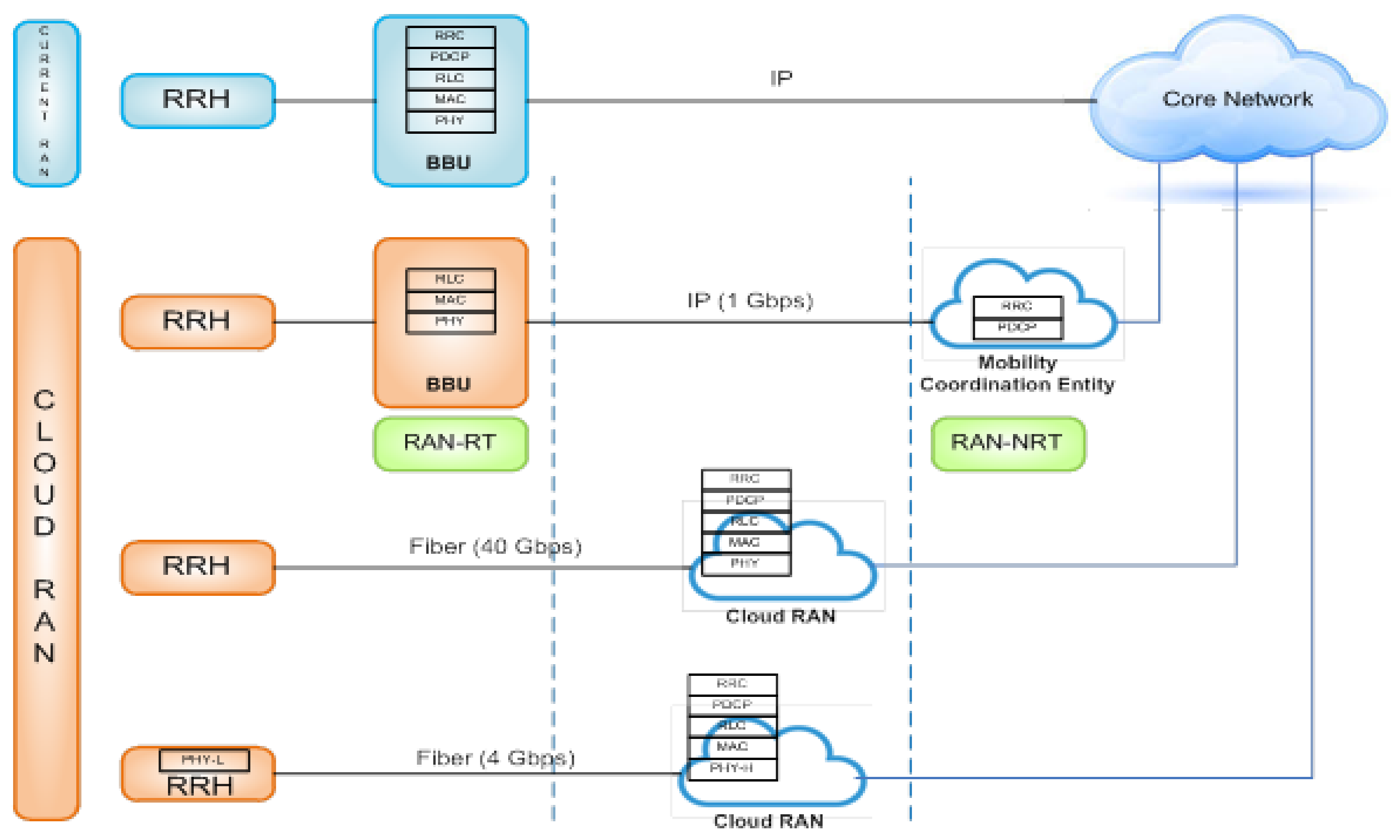
- Deployment flexibility is built-in from the inception in 5G to host relevant RAN, Core Network (CN) and application functions close together at the edges of the network to enable context aware service delivery and low latency services.

- Legacy RAN architecture has both RRH and BBU deployed at the local cell site as shown in adjoining figure.

- 5G provides an option to segregate real-time components of RAN (RAN-RT) and non-real time components (RAN-NRT) of BBU using NFV and SDN allowing quick turnaround for delay-sensitive services and better management of non-delay critical aspects like interference management and SON.

- Another option is to use shift BBU entirely to Cloud referred as Cloud RAN.

- Cloud RAN facilitates on-demand resource processing, storage and network capacity.



5G Technology – Mobile Edge Computing

- Mobile Edge Computing or Multi-Access Edge Computing (MEC) architecture pushes cloud-computing capabilities at the edge of the mobile network, within the Radio Access Network (RAN) in close proximity to mobile subscribers for delivery of time-critical services.

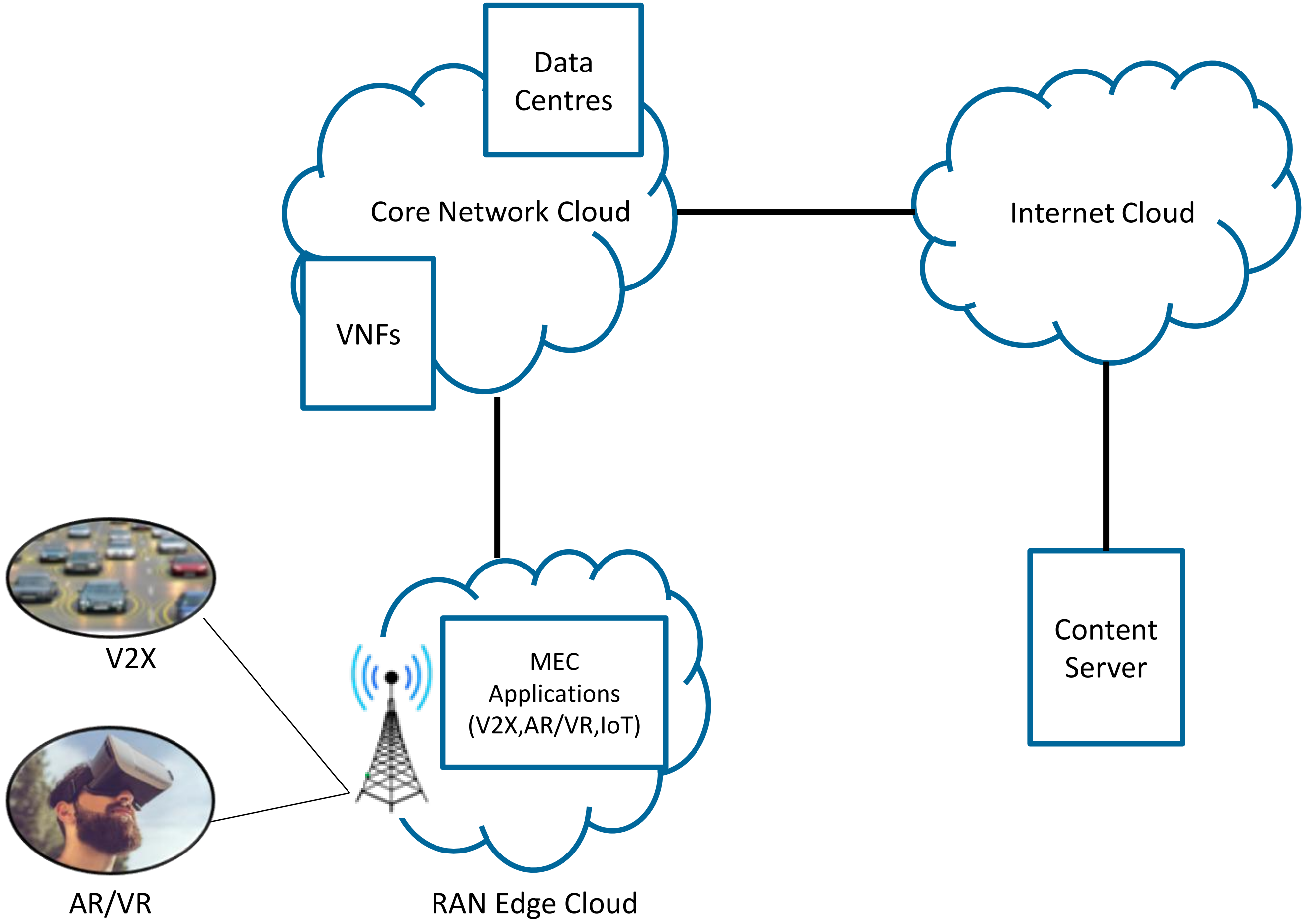
- MEC will enable applications and services to be hosted 'on top' of the mobile network elements i.e. above the network layer.

- MEC is based on a virtualized platform using NFV technology to enable application centric processing capabilities at RAN edge.

- MEC platform can be hosted with the BBU and use CRAN deployment models as per specific service requirement.

- URLLC services such as V2X and Real time immersive technology such as AR/VR can benefit from reduced latency offering an improved user experience.

- MEC provides on-edge video optimization support using local content-caching and adaptive content delivery based on radio network context feedback.

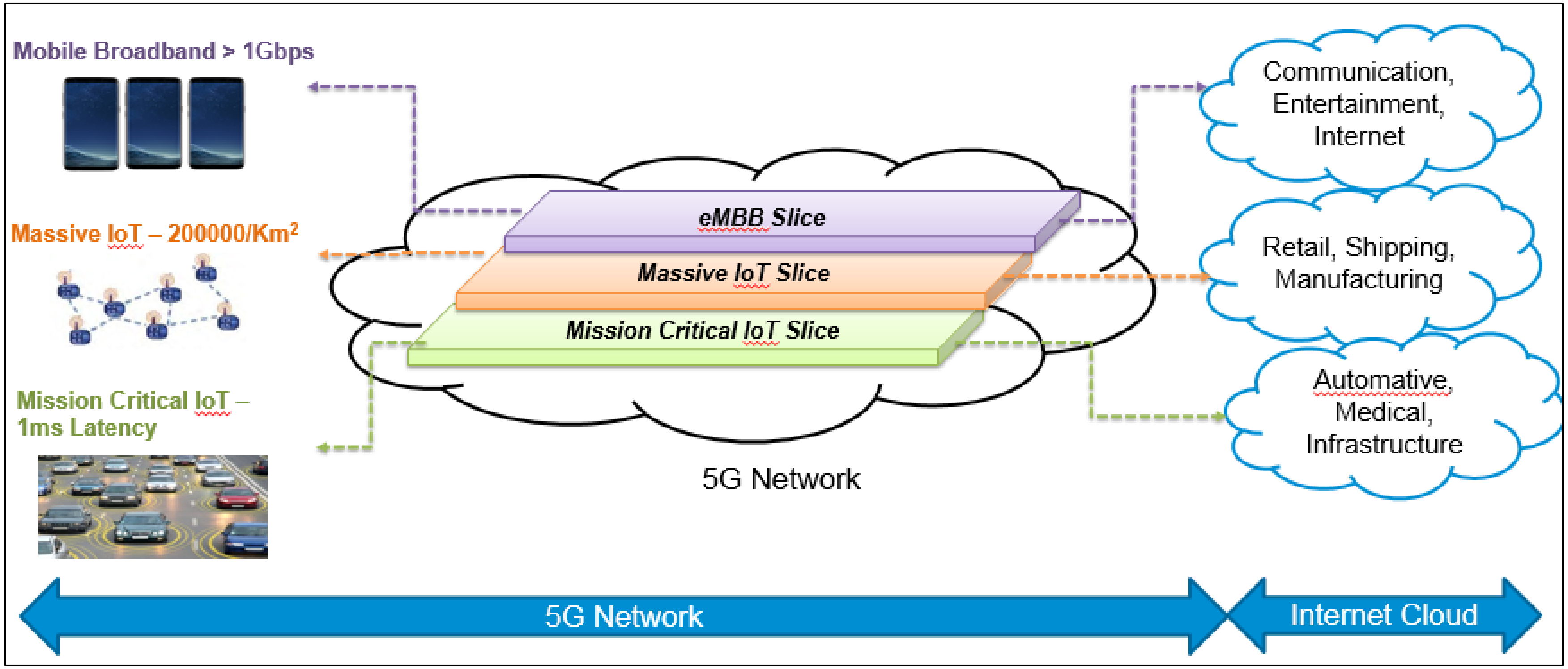


5G Technology – Network Slicing

- 5G has imbibed virtualization at its core in form of Network Slicing using Network Function Virtualization (NFV) and Software Defined Network (SDN) technologies. NFV allows flexibility and scalability to deploy virtual Network Functions (NF) that can be deployed in any physical hardware while SDN plays the role of separating Control and User plane for independent scalability.

- Network Slicing enables operators to create multiple logical instances on the same underlying network for serving different services such as eMBB, Massive IOT or URLCC with varying network resource requirements.

- As shown in the figure below, slicing enables the operator to provide customised networks to specific users having different set of requirements (e.g. priority, charging, policy control, security, and mobility).



5G Technology – NFV/SDN

To implement network slicing as explained before, NFV is a prerequisite. Instead of dedicated network equipment for each network entity, NFV architecture allows to install Network Function S/W (i.e., MME, S/P-GW and PCRF in Packet Core, and DU in RAN) all onto Virtual Machines (VMs) deployed on servers. SDN Controller performs provisioning of the G/W routers to create **SDN tunnels** between each VM.