Study Paper

on

5G-Key Capabilities & Applications

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Abstract: -

This paper gives a brief overview of the 5G-Key Capabilities & Applications. 5G and its inherent technological capabilities resulting in larger bandwidth, higher reliability and low latency etc are covered in detail. As investments in 5G R&D and its commercial deployments pick up momentum world over, different use case scenarios, applications, and 5G network deployment scenarios are also discussed in this paper. At the end, it was also identified that 5G will provide disruptive capabilities, which will be an economy booster fostering new ways to organize the businesses as well as fostering new business models, supported by advanced ICT.

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1. Introduction

1.1 5G is the fifth generation of cellular mobile communications, with evolutionary and revolutionary services, which succeeds the 4G (LTE-A/ WiMAX), 3G (UMTS) and 2G (GMS) system. 5G being the next generation of mobile networking standards, promises to deliver improved end user experience by offering new applications and services through seamless coverage, high data rate, low latency, and significantly improved performance and reliable communications. It will increase energy efficiency, spectrum efficiency, network efficiency as well as efficiency of other systems. 5G enhances the variety & scope of the use cases that LTE is able to minimally address today, and brings new revenue streams to operators by leveraging new solutions that LTE was not able to serve.

1.2 The commercial deployment of 5G was earlier expected in 2020. However, the completion of the first 5G New Radio (5G NR) standards for a Non – Standalone (**NSA**) solution in December 2017 and for Stand Alone (**SA**) standard in June 2018 has set the stage for the global mobile industry to start full scale development of 5G NR for large scale trials and commercial deployment as early as in 2019. In preparation for the launch of 5G over the years to come, operators have many tasks to accomplish for 5G technology transformation. ITU is continuously developing and updating "IMT for 2020 and beyond", setting the stage for 5G research activities emerging around the world. 5G systems in line with IMT-2020 specifications are expected to provide enhanced device and network-level capabilities, tightly coupled with intended applications. Figure1 shows the 5G development around the world.

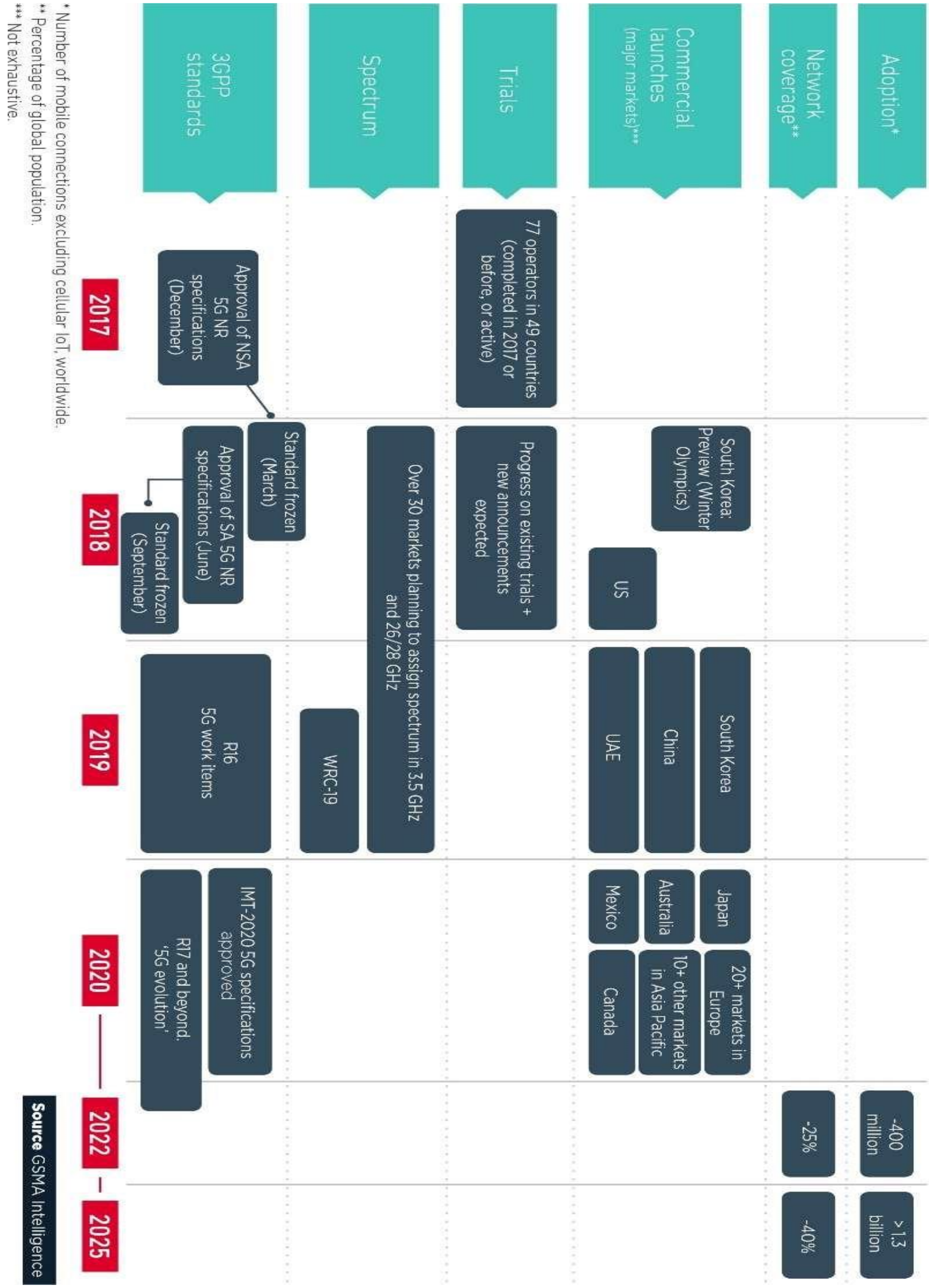


Figure 1: Global 5G development (*source: GSMA*)

2. 5G: Overview and use cases:

International Telecommunication Union (ITU) and other international organizations such as 3GPP are developing 5G standards as well as the use cases of 5G. While the ecosystem for deployment of 5G is yet to be developed, 5G may not be an appropriate consideration across all regions of the world especially in the less developed and developing countries, as of now.

2.1 Overview of 5G:

2.1.1 5G is an opportunity for policy-makers to empower citizens and businesses. 5G will play a key role in supporting governments and policy-makers in transforming their cities into smart cities, allowing citizens and communities to realize and participate in the socio-economic benefits delivered by an advanced, data-intensive, digital economy.

2.1.2 5G promises to deliver improved end-user experience by offering new applications and services through gigabit speeds, and significantly improved performance and reliability. 5G provides an opportunity for wireless operators to move beyond providing connectivity services, to developing rich solutions and services for consumers and industry across a range of sectors.

2.1.3 5G is also expected to increase data rates dramatically and reduce latency to below 1ms, suited to mission-critical services where data are time-sensitive. Its high-speed capability means 5G networks can provide a range of high-speed broadband services and offer an alternative to last-mile access such as FTTH or copper connections.

2.1.4 The 5G standards envisage various types of wireless services - high speed links with peak rates of 2 to 20 Gbps, low speed links with high connection density (1 mn/Km^2) for sensing and actuating devices (like IoT), and a completely new class of links that achieve both low latency (less than 1 ms round trip time) and high connection reliability (link outage of 0.99999). These services put together have the potential of creating revolutionary class of applications. 5G will extend the use of wireless technologies, for the first time, across completely new sectors of the economy. 5G will enable both existing and new wireless service providers to develop novel business models to offer innovative applications to individuals and to different economic verticals from industrial, commercial, educational, healthcare, agricultural, financial and social sectors.

2.2 Role of ITU and 3GPP:

5G is the next generation of mobile standards being defined by the ITU. IMT-2020 (i.e.5G) is the name for the systems, components, and related elements that support enhanced capabilities beyond those offered by IMT-2000 (i.e. 3G) and IMT-Advanced (i.e. 4G) systems. The IMT-2020 standards of ITU-T set the stage for-

- 5G research activities that are emerging around the world
- Defines the framework and overall objectives of the 5G standardization process
- Sets out the roadmap to guide this process to its conclusion by 2020.

ITU in its 'IMT 2020' specification has defined the macro level requirements for 5G. The ITU significantly broadened the concept of mobile networks taking service delivery to new class of endpoints. Detailed timeline and process for ITU-R IMT-2020 is shown in Fig 2.

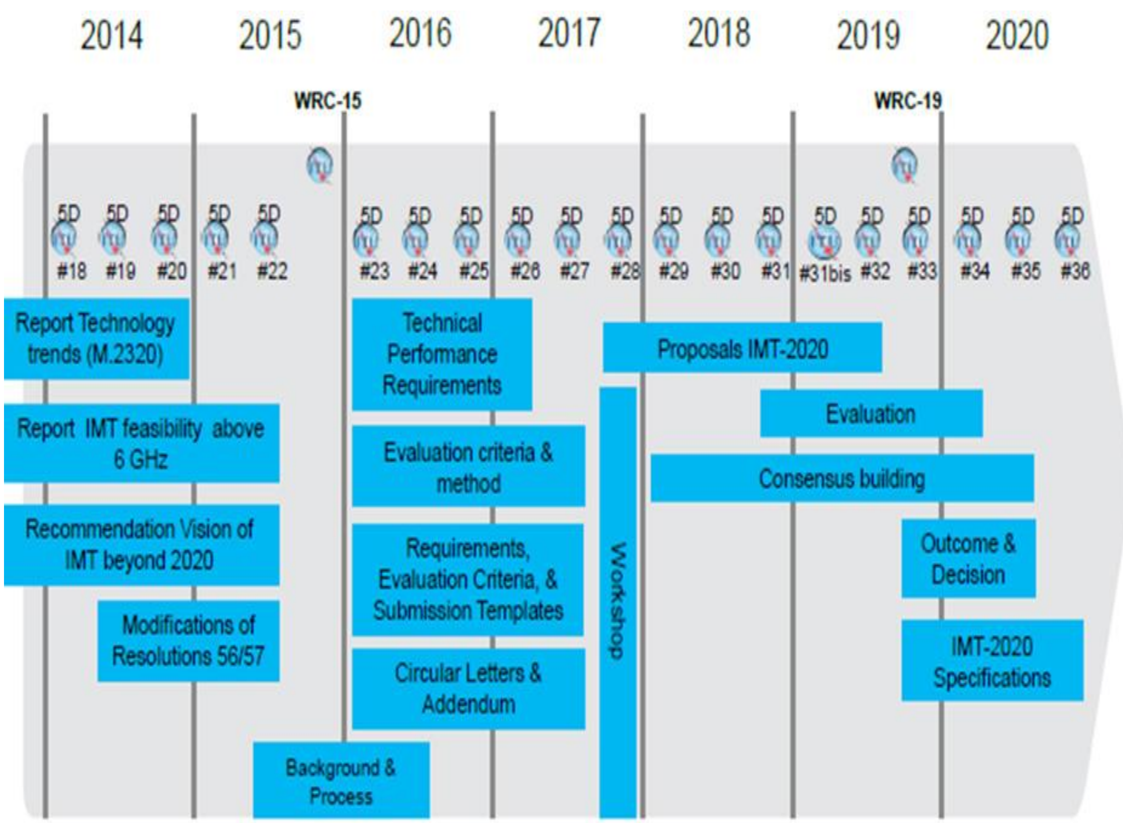


Figure 2: Detailed timeline and process for ITU-R IMT-2020
(Source: https://www.itu.int)

The **3GPP** (3rd Generation Partnership Project), an industry driven standardization body, that has undertaken the standardization of mobile technologies for the past 25 years and is currently developing standards for 5G networks based on the ITU requirements, in a stepwise manner through multiple releases up to the end of 2019. 3GPP has split the 5G standards into two releases:

- Release 15, which corresponds to NR phase 1, and
- Release 16, which corresponds to NR phase 2.

In NR phase 1, there are common elements between LTE and NR, such as both using Orthogonal Frequency Division Multiplexing (OFDM). To truly implement the full version of NR, a massive amount of new hardware must be deployed. To continue using existing hardware, a phased approach has been proposed. There is a non-standalone (NSA) version that will use the LTE core and 5G NR will be deployed in pockets, which means that 5G works along with LTE. The other option is a standalone (SA) version that will use an NR core and be completely independent of the LTE core network which means that 5G will work independent of LTE. 3GPP release timeline is shown in figure 3.

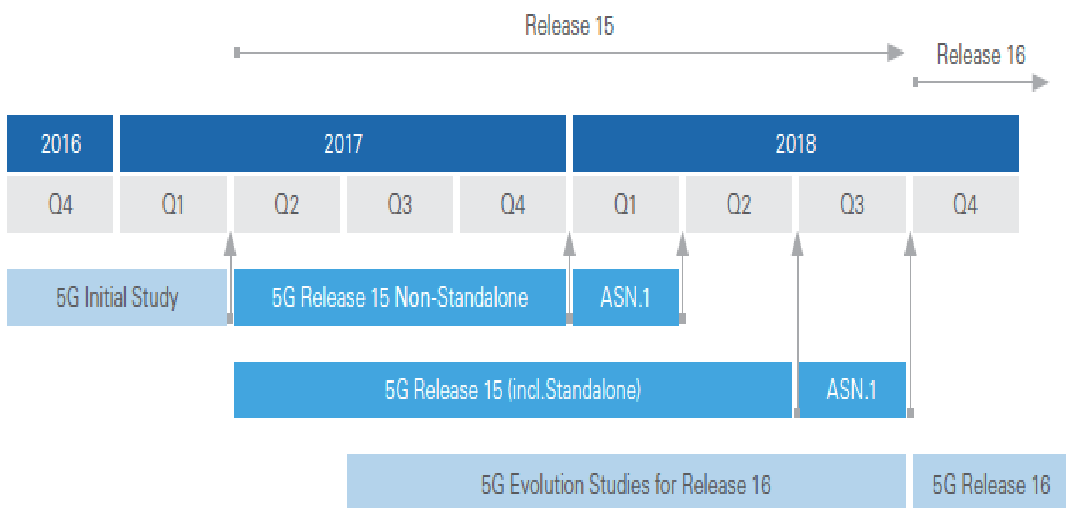


Figure 3: 3GPP release timeline (Source: IEEE Spectrum)

2.3 IMT 2020- key capabilities:

"IMT for 2020 and beyond", is expected to provide far more enhanced capabilities than those provided by IMT Advanced (4G). A broad variety of capabilities, coupled with intended usage scenarios and applications for IMT-2020 is envisioned. Different usage scenarios along with the current and future trends will result in a great diversity/variety of requirements. The key design principles are flexibility and diversity to serve many different use cases and scenarios, for which the capabilities of IMT-2020, described below, will have different relevance and applicability. In addition, the constraints on network energy consumption and the spectrum resource also need to be considered.

The following eight parameters are considered as key capabilities of IMT-2020:

i) **Peak data rate:** It is defined as, maximum achievable data rate under ideal conditions per user/device (in Gbit/s). The peak data rate of IMT-2020 for enhanced Mobile Broadband (eMBB) is expected to reach 10 Gbit/s. However, under certain conditions and scenarios IMT-2020 would support up to 20 Gbit/s peak data rate, as shown in Figure 4.

ii) **User experienced data rate:** It is defined as, achievable data rate that is available across the coverage area to a mobile user/device (in Mbit/s or Gbit/s). IMT-2020 would support different user experienced data rates covering a variety of environments for enhanced Mobile Broadband. For wide area coverage cases, e.g. in urban and sub-urban areas, a user experienced data rate of 100 Mbit/s is expected to be enabled. In hotspot cases, the user experienced data rate is expected to reach higher values (e.g. 1 Gbit/s indoor).

iii) **Latency:** It is defined as the contribution by the radio network to the time, from when the source sends a packet, to when the destination receives it (in ms). IMT-2020 would be able to provide 1 ms over-the-air (OTA) latency, capable of supporting services with very low latency requirements.

iv) **Mobility:** It is defined as the maximum speed at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/-RAT) can be achieved (in km/h). IMT-2020 is also expected to enable high mobility up to 500 km/h with acceptable QoS. This is envisioned in particular for high-speed trains.

v) **Connection density**: It is the total number of connected and/or accessible devices per unit area (per km^2). IMT-2020 is expected to support a connection density of up to $10^6/km^2$, for example in massive machine type communication (mMTC) scenarios.

vi) **Energy efficiency**: Energy efficiency has two aspects:

- On the network side, energy efficiency refers to the quantity of information bits transmitted to/ received from users, per unit of energy consumption of the radio access network (RAN) (in bit/Joule);
- On the device side, energy efficiency refers to quantity of information bits per unit of energy consumption of the communication module (in bit/Joule).

The energy consumption for the radio access network of IMT-2020 should not be greater than IMT networks deployed today, while delivering the enhanced capabilities.

vii) Spectrum efficiency: It is the average data throughput per unit of spectrum resource and per cell (bit/s/Hz). The spectrum efficiency is expected to be three times higher compared to IMT-Advanced for enhanced Mobile Broadband (eMBB). The achievable increase in efficiency from IMT-Advanced will vary between scenarios and could be higher in some scenarios.

viii) Area traffic capacity: It is the total traffic throughput served per geographic area (in Mbit/s/m2). IMT-2020 is expected to support 10 Mbit/s/m2 area traffic capacity, for example in hot spots.

The key capabilities of IMT-2020 are shown in Figure 4, compared with those of IMT-Advanced.

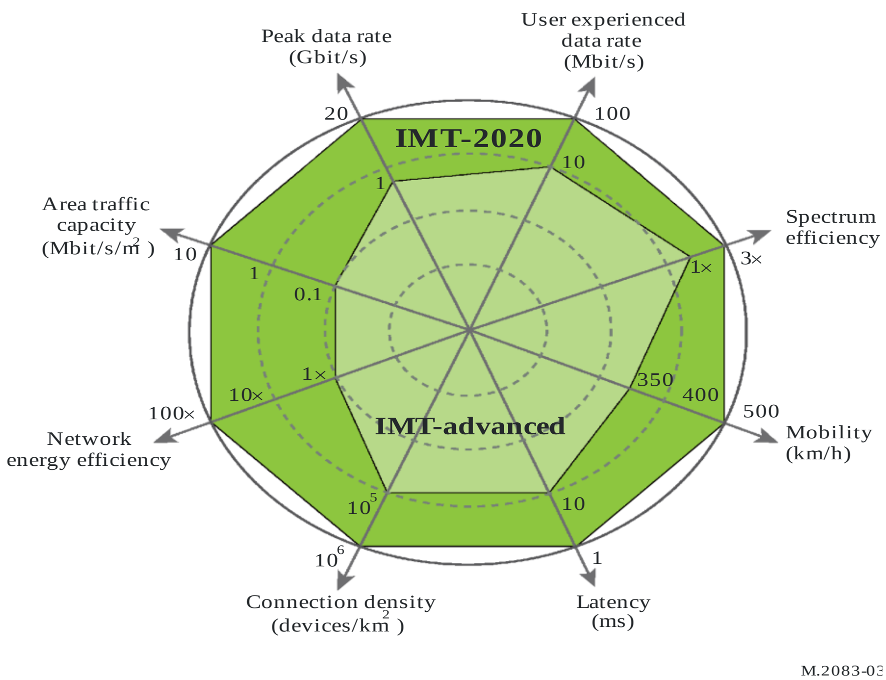


Fig 4: Enhancement of key capabilities from IMT-Advanced to IMT-2020
(*Source: ITU-R M.2083*)

As anticipated above, whilst all key capabilities may to some extent be important for most use cases, the relevance of certain key capabilities may be significantly different, depending on the use cases/scenario. The importance of each key capability for the usage scenarios enhanced Mobile Broadband (eMBB), ultra-reliable and low latency communication

(URLLC) and massive machine-type communication (MMTC) is illustrated in Figure 5. This is done using an indicative scaling in three steps as “high”, “medium” and “low”.

In the enhanced Mobile Broadband (eMBB) scenario, user experienced data rate, area traffic capacity, peak data rate, mobility, energy efficiency and spectrum efficiency all have high importance, but mobility and the user experienced data rate would not have equal importance simultaneously in all use cases. For example, in hotspots, a higher user experienced data rate, but a lower mobility, would be required than in wide area coverage case.

In some ultra-reliable and low latency communications (URLLC) scenarios, low latency is of highest importance, e.g. in order to enable the safety critical applications. Such capability would be required in some high mobility cases as well, e.g. in transportation safety, while, e.g. high data rates could be less important.

In the massive machine type communication (MMTC) scenario, high connection density is needed to support tremendous number of devices in the network that e.g. may transmit only occasionally, at low bit rate and with zero/very low mobility. A low cost device with long operational lifetime is vital for this usage scenario.

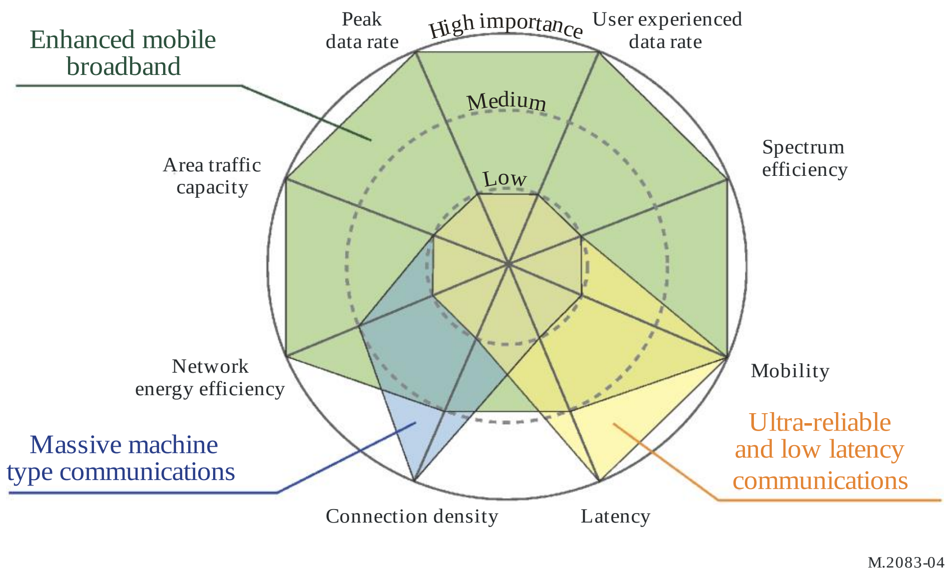


Figure 5: **The importance of key capabilities in different usages scenarios**
(Source: ITU-R M.2083)

Other capabilities may be also required for IMT-2020: - The other capabilities which would make future IMT more flexible, reliable, and secure when providing diverse services in the intended usage scenarios:

ix) **Spectrum and bandwidth flexibility:** Spectrum and bandwidth flexibility refers to the flexibility of the system design to handle different scenarios, and in particular to the capability to operate at different frequency ranges, including higher frequencies and wider channel bandwidths than today.

x) **Reliability:** Reliability relates to the capability to provide a given service with a very high level of availability.

xi) **Resilience:** Resilience is the ability of the network to continue operating correctly during and after a natural or man-made disturbance, such as the loss of mains power.

xii) **Security and privacy:** Security and privacy refers to several areas such as encryption and integrity protection of user data and signaling, as well as end user privacy preventing unauthorized user tracking, and protection of network against hacking, fraud, denial of service, man in the middle attacks, etc.

xiii) **Operational lifetime:** Operational lifetime refers to operation time per stored energy capacity. This is particularly important for machine-type devices requiring a very long battery life (e.g. more than 10 years) whose regular maintenance is difficult due to physical or economic reasons.

2.4 5G Use Cases:

Numerous use cases with a wide variety of applications are on the rise with a highly varied range of performance attributes such as mobility, data speed, latency and reliability. The supporting user data rates could range from a few Kbps for some IoT devices where power consumption will be extremely low, to multiple Gigabits per second used by Augmented Reality (**AR**) and Virtual Reality (**VR**) or high quality multi-media applications. Mobility supported by the use cases could range from fixed wireless high capacity, high data rate applications to high velocity trains or aircraft at speeds of 500 mph. Ultra-low latency, in the order of 0.5 ms, is needed to enable real-time applications like industrial automation and is very different from smart home applications that may be more delay tolerant. Reliability is critical for remote surgery and health care monitoring.

5G use cases can be categorized into three different use case classes namely enhanced Mobile Broadband (eMBB), massive Machine-Type Communication (mMTC), and Ultra-Reliable Low-Latency Communications (UR-LLC). Figure 6 shows the 5G usages scenarios.

i) **Enhanced mobile broadband (eMBB)** – It addressed the human-centric data driven use cases for access to multi-media content, services and data. This usage scenario comes with new application areas such as virtual reality (VR), video monitoring, mobile cloud computing, enhanced indoor and outdoor broadband, enterprise collaboration, augmented and virtual reality (AR/VR).

Requirement: >10 Gb peak data rates for the enhanced Mobile Broadband.

ii) Massive machine-type communications (mMTC) – This use case is characterized by a large number of connected devices typically transmitting a relatively low volume of non-delay sensitive data. Devices are to be low cost and have a very long battery life. **This use cases covers IoT, asset tracking, smart agriculture, smart cities, energy monitoring, smart home, remote monitoring etc.**

Requirement: >1 Mn/Km^2 connection (> 1 million devices per square kilometer) for Massive Machine Type Communications.

iii) Ultra-reliable and low-latency communications (URLLC) – this use case has stringent requirements for capabilities such as throughput, latency and availability to support the delivery of critical communications. Some examples include **autonomous vehicles, smart grids, remote patient monitoring and telehealth, industrial automation etc.**

Requirement: < 1 ms latency for Ultra-Reliable Low-Latency Communications.

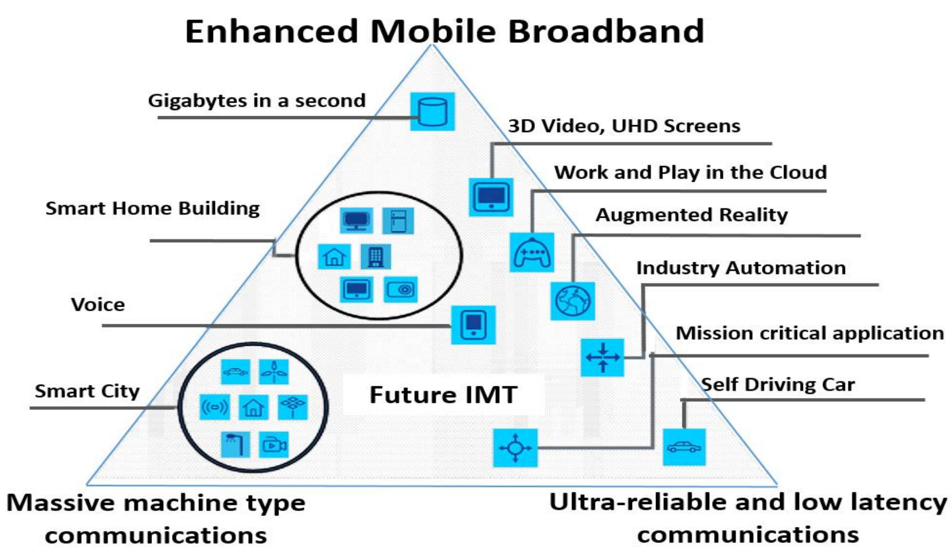


Figure 6: 5G-usage scenario (*Source: ITU*)

eMBB is expected to be the primary use case for 5G in its early deployments. eMBB will bring high-speed mobile broadband to crowded areas, enable consumers to enjoy high-speed streaming for in-home, screen and mobile devices on demand, and will allow enterprise collaboration services to evolve. **Some operators may also consider eMBB as the last-mile solution in those areas lacking copper or fiber connections to homes.**

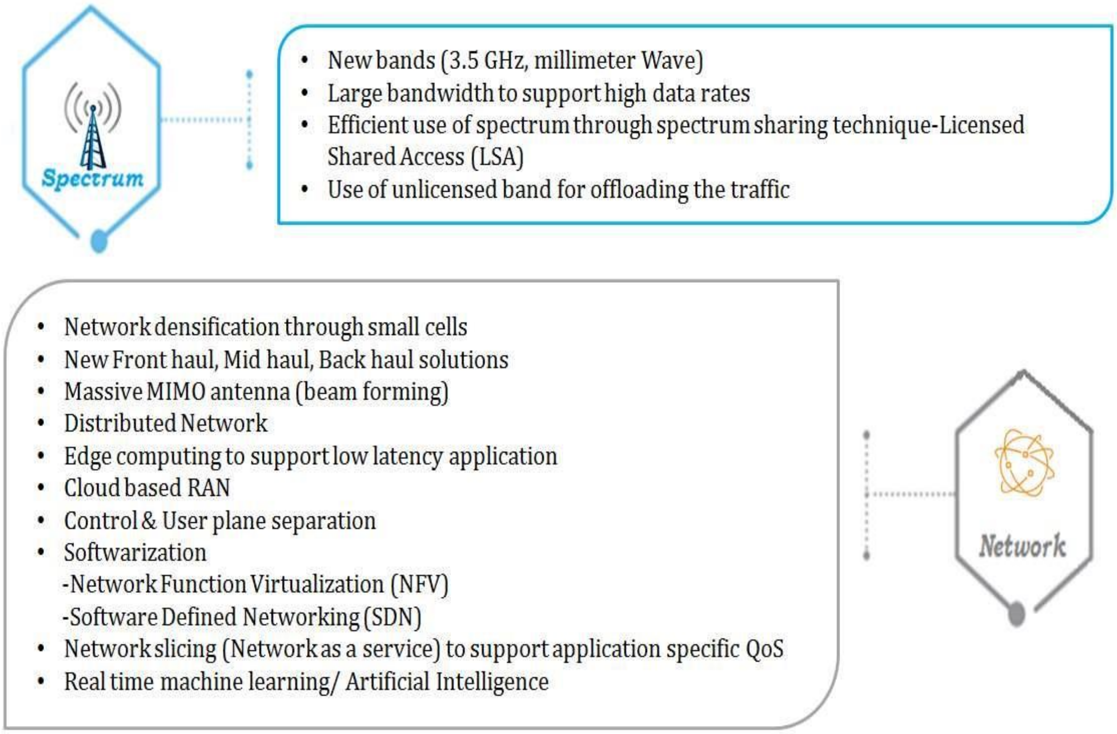
5G is also expected to drive the evolution of smart cities and IoT through the deployment of a considerable number of low-power sensor networks in cities and rural areas.

The security and robustness built into 5G will make it suitable for **public safety** as well as for use in mission-critical services, such as smart grids, police and security services, energy and water utilities, and healthcare. Its low latency performance characteristics make it suitable for remote surgery, factory automation and the control of real-time processes.

5G's low latency and safety characteristics will play well in the evolution of intelligent transport systems (ITS), enabling smart vehicles to communicate with each other, and creating opportunities for connected, autonomous cars and trucks. For example, an autonomous vehicle (AV) operated via a cloud-based, autonomous driving system must be able to stop, accelerate or turn when told to do so.

2.5 Key Enablers:

2.5.1 Communication networks are undergoing their next evolutionary step towards 5G. The 5G networks are envisioned to provide a flexible, scalable, agile and programmable network platform over which different services with varying requirements can be deployed and managed within strict performance bounds. In order to support different services with varying requirements, **a paradigm shift is taking place in the technologies that drive the networks, and thus their architecture.** Innovative techniques as shown in Figure 7, are being developed to power the next generation mobile networks. Mobile network functions are being split-up, distributed and virtualized to provide the best combination of latency, throughput and cost effectiveness for various potential applications.



(Source: TRAI)

Figure 7: Enablers of 5G

2.5.2 At the heart of this development lie Network Function Virtualization (NFV) and Software Defined Networking (SDN) technologies which are now recognized as being two of the key technology enablers for realizing 5G networks, and which have introduced a major change in the way network services are deployed and operated. These technologies-based network enables "network slice "for different vertical markets which provide customized Quality of Service (QoS) and specific functional requirements. Cloud Radio Access Network (Cloud RAN) reduces operators' Total Cost of Ownership (TCO) and facilitates efficient allocation of resources. Deployment of Small Cells increases network capacity and spectrum reuse. New backhaul solutions support the implementation of both traditional and distributed RAN network. Use of edge computing for local analysis and processing of data provides users faster higher-quality experiences with ever-improving visual, audio and potentially tactile interfaces. Massive Multiple Input Multiple Output (MIMO) implementations increase user data speeds and system capacity to meet 5G standards by dynamically transmitting data as highly-focused beams and exploiting multipath propagation and spatial multiplexing to simultaneously send and receive more than one data signal over the same radio channel.

2.5.3 High frequency bands are best suited for technologies such as massive MIMO, super-dense meshed cells and macro-assisted small cells. Furthermore, substantially more bandwidth is available in high frequency bands than in the bands below 1GHz, which is beneficial for providing much wider channels and higher speeds. Use of spectrum within three different frequency range (sub 1 GHz, 1-6 GHz, above 6 GHz) support-varying requirements of all use cases. Spectrum sharing technique such as Licensed Shared Access (LSA) improves spectrum utilization. In addition, unlicensed spectrum coupled with licensed spectrum increase the access network capacity and improves users' wireless experience.

2.6 5G initiatives in India

2.6.1 A 5G High Level Forum (5H HLF) was set up by the Government in September 2017 to articulate the vision for 5G in India and to recommend policy initiatives & action plan to realize this vision. The 5G HLF has released a report in August 2018 titled "Making India 5G ready" suggesting measures in the area of Spectrum Policy, Regulatory Policy, Education and Awareness Promotion Program, Application & Use Cases Labs, Development of Application Layer Standards, Major Trials and Technology Demonstration and Participation in International Standards.

2.6.2 Government has launched a program titled 'Building an End-to-End 5G Test Bed' to advance innovation and research in 5G. This three-year program began in March 2018, with a budget authorization of Rs 224 crores. The program has been awarded to IIT Madras, IIT Hyderabad, IIT Delhi, IIT Kanpur, CEWIT, SAMEER and Indian Institute of Science (IISc), Bangalore. The program envisages close collaboration between the universities and small technology companies. The goal of the program is to build proof-of-concept 5G prototypes that are broadly compliant with the 3GPP standards. Several smaller academic R&D programs around 5G themes have also been funded by DST and MEITY.

Ericsson has installed the first public access 5G test bed at IIT Delhi in July 2018 for developing applications in the broadband and low latency areas providing access to the industry and institutions to work on India specific usage scenarios and applications. The industry is encouraged to take lead and establish more public test beds in the country.

2.6.3 On the standards front, India have been successful in getting the Low Mobility Large Cell (**LMLC**) use case accepted in the IMT 2020 requirements. LMLC reflects the needs of rural India and other similar countries.

2.6.4 The National Digital Communication Policy-2018 (**NDCP-2018**), released on 26th September 2018, envisages the following with respect to the rollout of 5G services: -

"2.2 … (d) Enabling Hi-speed internet, Internet of Things and M2M by rollout of 5G technologies:

i) Implementing an action plan for rollout of 5G applications and services
ii) Enhancing the backhaul capacity to support the development of next generation networks like 5G
iii) Ensuring availability of spectrum for 5G in 6 GHz bands
iv) Reviewing industry practices with respect to traffic prioritization to provide 5G enabled applications and services
v) Developing framework for accelerated deployment of M2M services while safeguarding security and interception for M2M devices
vi) Defining policy for EMF radiation for M2M devices, with accompanying institutional framework to coordinate government-funded and India specific research in this regard"

2.7 5G deployment and Timeline:

The vendor eco-system for 5G is maturing. Nokia, Ericsson, Huawei and ZTE have production ready equipment in trials based on 5G-NR standard. China Telecom is doing a pilot deployment in six cities ahead of the full 5G commercial launch in 2020. Several other countries have announced deployment schedules.

5G deployment can be classified into three phases.

- **Phase 1** – Fixed Wireless Access services in the millimeter-band with 0.5 to 1 Gbps links by 2019. And mobile services in the < 3 GHz band by 2020. By 2021, many countries across the world will have deployed 5G broadband services.
- **Phase 2** – 5G based IoT technology is expected to begin around 2021. While small IOT networks built around earlier technologies like NB-IoT, LoRA and Cat M have been deployed, the entry of 5G IoT will accelerate these trends.
- **Phase 3** – Low latency and highly reliable wireless services will debut in 2022 and offer new applications like car platooning (a fleet of close coordinating self-driving vehicles), remote machinery control, drone navigation, and tele-surgery.

In India, 5G deployment strategy may have different scenario. If early deployment is adopted, the equipment is likely to be more expensive and being early, it will also be glitchy needing costly maturing. On the other hand, early adoption will fast track the country's embrace of 5G's benefits and increase opportunities to develop innovative use cases that support Indian needs. Balancing these scenarios needs study, by the industry experts.

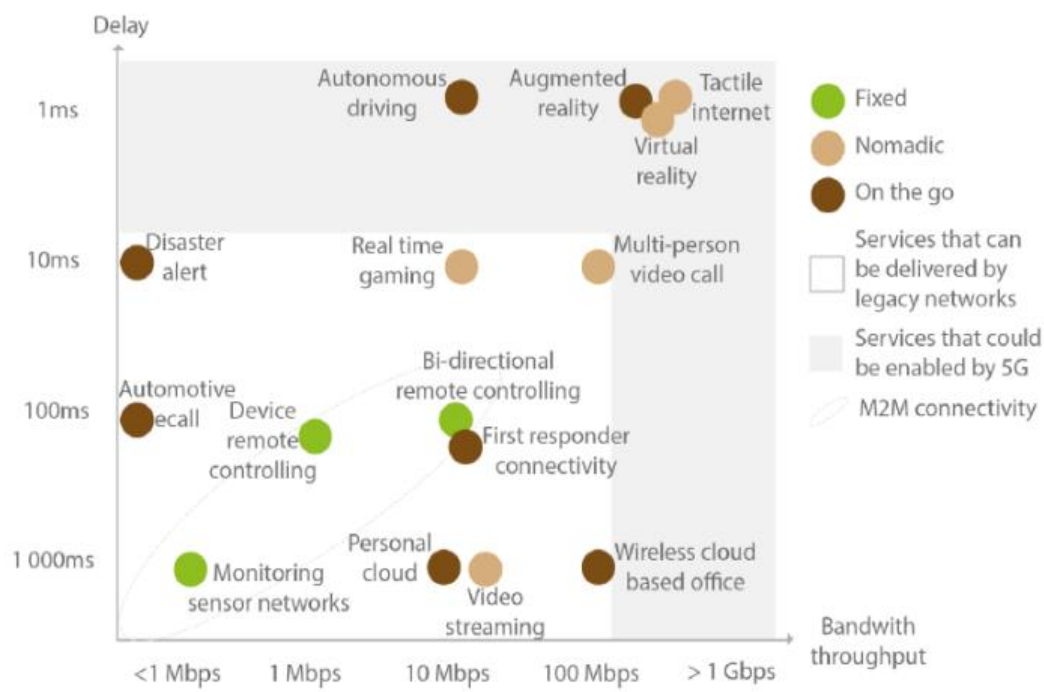
It is also important to note that even after the entry of 5G into the Indian networks, the earlier generation mobile technologies - 2G, 3G and 4G, will continue to remain in use and it may take 10 or more years to phase out.

3. 5G technology and spectrum requirements:

Radio spectrum, backhaul, softwarization of core networks and radio access networks will be vital in early deployment of 5G networks particularly where enhanced mobile broadband is concerned.

3.1 Radio Access Networks

Most outdoor 4G mobile network deployments are currently based on macro-cells. However, macro-cells that cover large geographical areas may struggle to deliver the dense coverage, low latency and high bandwidth required by some 5G applications (as shown in Fig 8)



Source: GSMA Intelligence, 2015.

Figure 8: Bandwidth and latency requirements for 5G applications

To deliver the dense coverage and high capacity network required by 5G, wireless operators are now investing in the densification of their 4G radio access network (RAN) – particularly in densely populated urban areas – by deploying small cells. Small cells, while serving a much smaller geographical area than a macro cell, increase network coverage, capacity and quality of service.

The deployment of small cells is one way of boosting the capacity and quality of existing 4G networks while laying the foundation for commercial 5G networks and early eMBB services. Small cells are already being used by some wireless operators to boost the capacity and coverage of their existing 4G networks particularly in a dense urban setting.

Small cells boost network capacity without the need for additional spectrum, making them attractive to operators with a low spectrum holding or where spectrum is scarce. Furthermore, the industry view is that the deployment of small cells in dense urban to boost existing 4G network quality is likely to support the anticipated high capacity requirements of 5G networks and early eMBB services.

Due to the dense coverage that small cells need to provide, small cell antennae need to be installed onto street furniture like – bus shelters, lampposts, traffic lights, etc. These are often accompanied by a street cabinet to accommodate the operator radio equipment, power and site connectivity.

Massive MIMO (multiple input, multiple output) scales up to hundreds or even thousands of antennae, increasing data rates and supporting beamforming, essential for efficient power transmission. Massive MIMO increases spectral efficiency and in conjunction with dense small cell deployment, will help operators to meet the challenging capacity requirement of 5G.

3.2 Core networks

End-to-end flexibility will be one of the defining features of 5G networks. This flexibility will result in large part from the introduction of network softwarization where the core network hardware and the software functions are separated. Network softwarization – through network functional virtualization (NFV), software defined networking (SDN), network slicing and Cloud-RAN (C-RAN) – aims to increase both the pace of innovation and the pace at which mobile networks can be transformed.

- **NFV** – replaces network functions on dedicated appliances – such as routers, load balancers, and firewalls, with virtualized instances running on commercial off-the-shelf hardware, reducing the cost of network changes and upgrades.
- **SDN** – allows the dynamic reconfiguration of network elements in real-time, enabling 5G networks to be controlled by software rather than hardware, improving network resilience, performance and quality of service.

- **Network slicing** – permits a physical network to be separated into multiple virtual networks (logical segments) that can support different RANs or several types of services for certain customer segments, greatly reducing network construction costs by using communication channels more efficiently.
- **Cloud RAN (C-RAN)** – is presented as a key disruptive technology, vital to the realization of 5G networks. It is a cloud-based radio network architecture that uses virtualization techniques combined with centralized processing units, replacing the distributed signal processing units at mobile base stations and reducing the cost of deploying dense mobile networks based on small cells.

Other technology enhancements being considered include signal-coding techniques, which provide improved spectral efficiency and the high-speed performance required by 5G. In addition, edge computing is increasingly important for real-time and very latency-sensitive applications. Edge computing brings data closer to end-user devices, providing computing power with very low latency for demanding applications. This speeds up the delivery of actionable data, cuts down on transport costs and optimizes traffic routes.

3.3 Backhaul:

Backhaul networks connect the radio network (RAN) to the core network. The ultra-high capacity, fast speeds and low latency requirements of 5G require a backhaul network capable of meeting these high demands. Fiber is often considered the most suitable type of backhaul by mobile operators due to its longevity, high capacity, high reliability and ability to support very high capacity traffic. However, pulling fiber to every cell site is practically not feasible due to cost, time and logistical challenges. In this case, a portfolio of wireless backhaul technologies should be considered in addition to fiber, including point-to-multipoint (PMP) microwave and millimeter wave (mmWave). PMP is capable of downstream throughput of 1Gbit/s and latency of less than 1ms per hop over a 2-4 km distance. MmWave has significantly lower latency and is capable of higher throughput speeds (1-10 Gbps). In comparison to fiber, microwave is cheaper, scalable option and can be deployed quickly.

While most focus is being given to terrestrial technology, there is also a role for high altitude platform systems (HAPS) and satellite technology in 5G. HAPS and satellite systems (including non-geostationnary constellations) can deliver very high data rates (>

100 Mbit/s – 1 Gbit/s) to complement fixed or terrestrial wireless backhaul networks outside major urban / suburban areas (remote areas) and can deliver video transmission to fixed locations. HAPS and satellites may be integrated with other networks rather than function as a standalone network to provide 5G, thereby augmenting the 5G service capability and addressing some of the major challenges regarding the support of multimedia traffic growth, ubiquitous coverage, machine-to-machine communications and critical telecom missions.

In summary, a realistic 5G backhaul strategy is likely to consist of a portfolio of technologies. Each approach should be considered on its own merits in light of the performance needs, available infrastructure and viability on investment.

3.4 Front haul

Conventionally in a 4G wireless network, the fronthaul link exists between radio frequency (RF) function and the remaining layer 1, 2 and 3 (L1/L2/L3) functions. Recommendation ITU-T Y.3100 defines fronthaul as "a network path between centralized radio controllers and remote radio units (RRU) of a base station function". This architecture allows for the centralization of all high layer processing functions at the expense of the most stringent fronthaul latency and bandwidth requirements. The increase in data rates in 5G makes it impractical to continue with the conventional Common Public Radio Interface (CPRI) fronthaul implementation. Allocating more processing function to RRU would relax the latency and bandwidth requirements – but fewer processing functions can then be centralized. It is thus critical that the new functional-split architecture take into account technical and cost-effective tradeoffs between throughput, latency, and functional centralization.

3.5 Spectrum for 5G

3.5.1 Spectrum is the lifeline for any wireless communications. More spectrum bandwidth will be required to deploy 5G networks (than 4G) to the high capacity requirements, increasing the need for spectrum. In consequence, the industry is making concerted efforts to harmonize 5G spectrum. ITU-R is coordinating the international harmonization of additional spectrum for 5G mobile systems development. ITU's Standardization Sector (ITU-T) is playing a key role in producing the standards for the technologies and architectures of the wireline elements of 5G systems.

3.5.2 5G use cases could potentially be met by a variety of spectrum frequencies. For example, low-latency and short-range applications (suited to dense urban areas) are likely to be suitable for mmWave frequency (above 24 GHz). Long-range, low-bandwidth applications (more suited to rural areas) are likely to be suitable for sub-1 GHz frequencies. While the lower frequencies have better propagation characteristics for better coverage, the higher frequencies support higher bandwidths due to the large spectrum availability at mmWave bands. The three key spectrum frequency ranges required for 5G can be summarized as shown in figure 9.

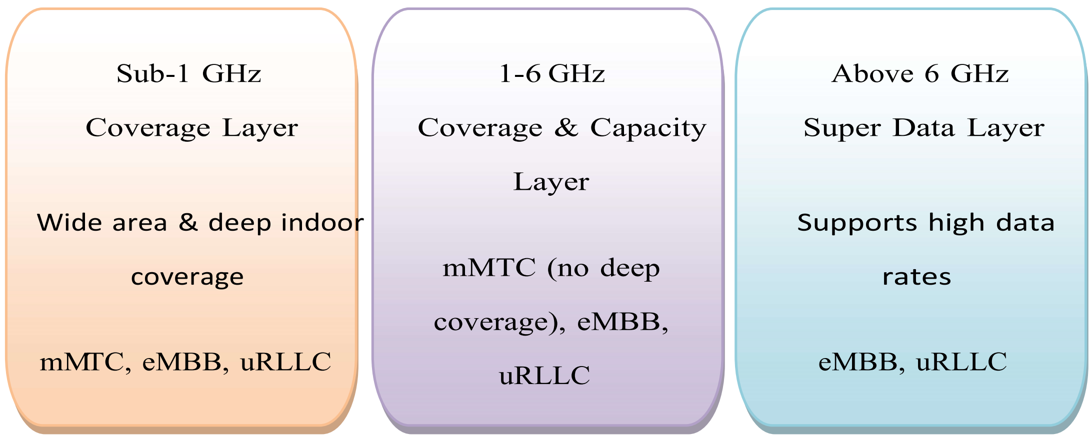


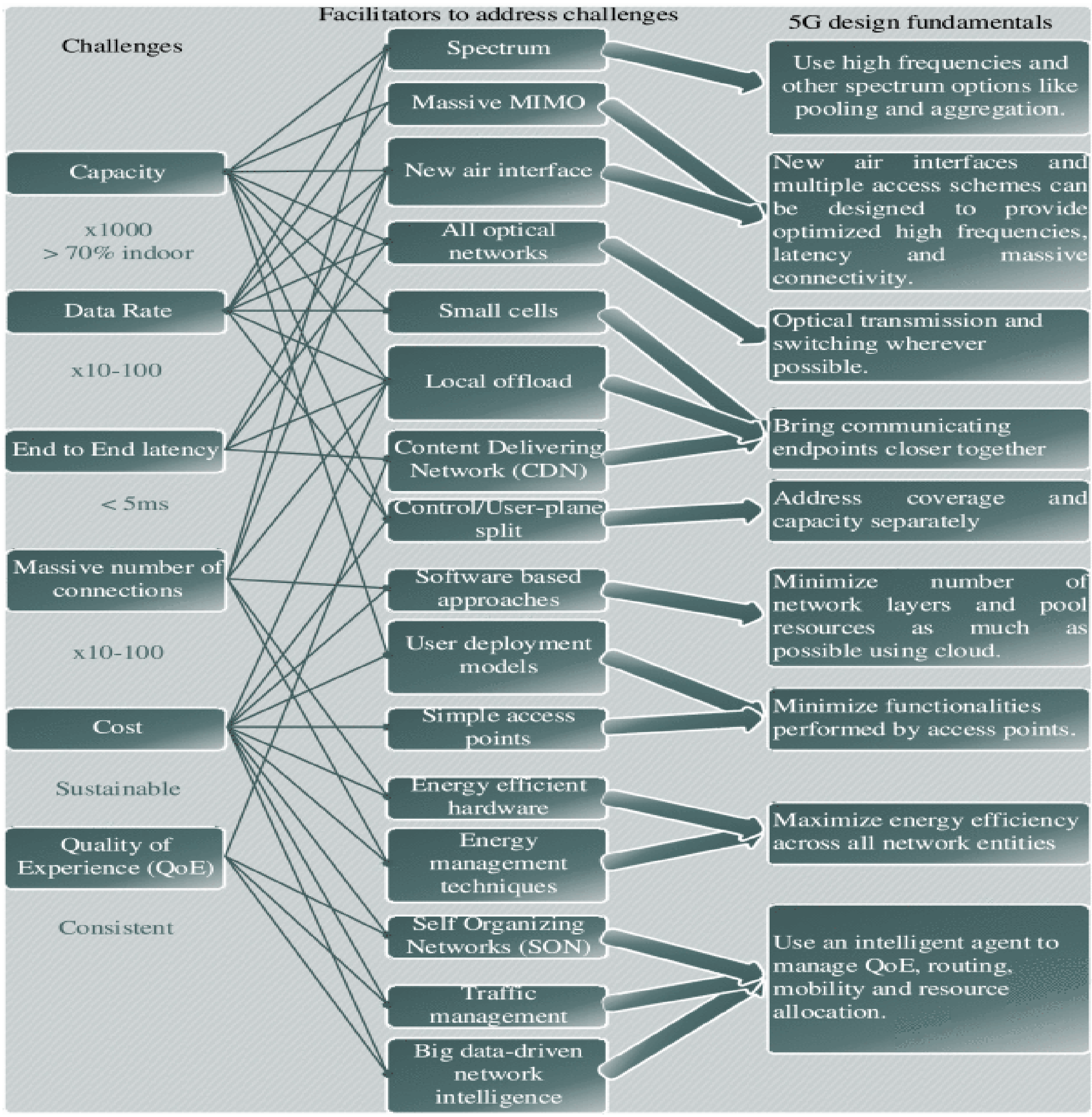
Figure 9: Spectrum for 5G

3.5.3 The challenge will be to select globally harmonized spectrum bands for 5G. The best way to achieve this goal will be to take into account the WRC-19 relevant decisions for higher bands, as well as WRC-07 and WRC-15 decisions for lower bands.

4. Key Challenges:

For any new technology to be of practical use, it must not be prohibitively expensive. The mass adoption of 5G might face some initial roadblocks regarding this. For starters, the initial subscription plans are likely to be more expensive than the ones currently available. The annual investments required for upgrading to 5G might very high – raising questions over the justifications of actually switching over from 4G to 5G. In addition, carriers will also have to incur heavy expenses for upgrading their existing infrastructure to accommodate the new devices and antennas required by 5G systems. It is going to be a full-blown overhaul, and it is not going to be cheap.

In some countries, regulation and local authority policy have slowed the development of small cells through excessive administrative and financial obligations on operators, thus blocking investment. The allocation and identification of globally harmonized spectrum across a range of frequencies requires coordination among the global community, regional telecommunication organizations and National Regulatory Authorities (NRAs). This represents one of the largest challenges for NRAs in the successful deployment of 5G networks.



Source: https://ieeexplore.ieee.org/document/7169508

Figure 10: Key challenges to 5G and their facilitators

Any network latency or loss in signal coverage preventing the message from being delivered could result in catastrophic consequences.

Digital divide: Studies and experience of previous technologies such as 3G, 4G, indicating that initial deployment of 5G networks will be in dense urban areas and will offer services such as enhanced mobile broadband (eMBB) – it will be commercially challenging to deploy 5G networks in rural areas where demand tends to be lower – consequently, rural areas may be left behind, thereby increasing the digital divide.

Key challenges for 5G and their facilitator are shown in Figure 10.

5. Conclusion:

5G technology promises to be revolutionary which is expected to play a key role in digital economies, improving economic growth, enhancing citizens' life experiences and creating new business opportunities. Larger bandwidth and low latency times will allow the development of new services and the improvement of existing ones.

A 5G investment decision must be backed by a sound business case, as deployment of 5G network will require substantial investment in the core, Radio Network and Spectrum. However, the 5G services will open-up many new revenue generating streams also as it will cater to variety of solutions to new verticals besides enhanced mobile broadband solutions. 5G will provide disruptive capabilities, which will be an economy booster by fostering new ways to organize the business sector as well as fostering new business models supported by advanced ICT.

Abbreviations:

3GPP:	3rd Generation Partnership Project
5G:	5th Generation of Wireless technology
C-RAN:	Cloud Radio Access Network
eMBB:	Enhanced Mobile Broadband
GSM:	Global System for Mobile Communications
GSMA:	GSM Association
HLF:	High Level Forum
IMT:	International Mobile Telecommunications
IoT:	Internet of Things
LSA:	Licensed Shared Access
LMLC:	Low Mobility Large Cell
LTE:	Long Term Evolution
M2M:	Machine to Machine
MIMO:	Multiple Input Multiple Output
mMTC:	Massive Machine Type Communication
NDCP:	National Digital Communication Policy
NFV:	Network Function Virtualization
NR:	New Radio
NSA:	Non-Stand Alone
OFDMA:	Orthogonal Frequency Division Multiple
QoS:	Quality of Services
RAN:	Radio Access Network
SA:	Stand Alone
SDN:	Software Defined Networking
TCO:	Total Cost of Ownership
TRAI:	Telecom Regulatory Authority of India
URLLC:	Ultra Reliable and Low Latency Communication

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