Advent of 5G: Opportunities and Challenges

Manjit Singh
B-54, Sector 14, Noida 201301 UP India
manjit.davinder@gmail.com

Abstract : **During the next few years, the Internet of things (IoT) is expected to explode and place new requirements on mobile network that will not be able to be handled with the evolution of the 4G LTE network. The popularity of IoT devices is expected to drive device connection density to extreme, eventually reaching 200,000 connections per km^2. It is expected that the high density of IoT connections will also add excessive signaling to the network. In parallel, other services and applications will place other pressures on the 4G network leading to new requirements of reduced latency, improved reliability, longer battery life for devices.**

Many international bodies like ITU, European Commission are working on features and specification for 5G systems. Many European and Korean and Chinese vendors have already started developing the product, some of the well-known vendors are Nokia, Huawei and Samsung. Next Generation Mobile Network (NGMN) is a group of operators who have has started working with input from vendors on the features for 5G. Korea has target to use 5G technologies in 2018 for Winter Olympics and Japan will use it in 2020 for Summer Games.

The set of requirements for 5G is not economically or technically achievable with the evolution of 4G. NGMN Vision is "5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models."

Keywords: 5G, LTE, Next Generation Mobile Networks, Internet of Things, Internet Traffic, Network Traffic Growth, Software-Defined Networking,

I. INTRODUCTION

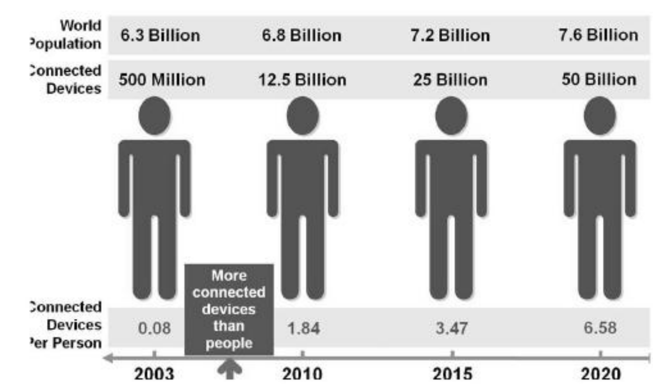
IT's no secret that we live in a connected world and that it's becoming more and more connected every day. The numbers of mobile users worldwide are expected to almost double from 2010 to 2020, increasing from 5.3 billion to 9 billion. China had just over 1.2 billion mobile connections in 2014, while India reached almost one billion. By 2019, China is predicted to reach 1.4 billion mobile connections and India almost 1.1 billion.

The number of mobile devices in use is also increasing. The number of mobile devices in use will increase by over 57% between 2014 and 2018, reaching 12.2 billion in 2018. The number of devices per user is also going up.

The number of people using and downloading mobile apps is also increasing each year. The number of mobile app users will increase from 1.2 billion in 2012 to 4.4 billion in 2017. This is more than a 3-fold increase in 5 years. They also predict that the number of mobile app downloads per year will increase over 4 times, growing from 46 billion to 200 billion during the same period.

Moreover, machines are not just making mobile connections by people, but increasingly range from lower level machines, such as sensors and meters, to IoT devices with embedded electronics, software and sensors that can collect and transfer data over a network. Examples of IoT devices include implantable or wearable health and fitness devices, smart thermostats, smart streetlights as well as manufacturing maintenance and repair sensors. IDC predicts that the IoT installed base will climb from 9.1 billion in 2013 to 50 billion in 2020.

The net result of more devices, more device types, more connections and more mobile applications is more mobile data traffic with a greater diversity of requirements. Statista* forecasts that mobile data traffic will increase from 2.5 exabytes/month in 2014 to 24.3 exabytes/month in 2019. This is an increase of almost 10 times in five years.
(*Statistical data for Market Research)



II. 1G TO 4G

As can be seen from the table below, First generation was amplitude modulated AMPS technology and primarily for voice calls. It lacked in Secrecy and spectral efficiency. 2nd Generation was basically an effort of European standards body ETSI and European equipment suppliers called GSM. It is digital and provided voice and SMS service. When Internet was opened to public in 1995, a need was felt for using internet based services. 3rd Generation system was formulated under the

ITU flag called IMT 2000. Since 3rd generation came in around 2000, but to meet immediate needs of customers and use the existing infra, 2.5 (EDGE) and 2.75(GPRS) were incorporated in existing network. 3G lacked speed of Internet and was not acceptable to users. Also at that time 4G was born and operators waited for 4G technologies to mature for implementation. 4G implementation came in 2012 onwards.

Presently, In India, 4G service is being implemented and services are being provided. 4G network (LTE) promised a network speed of 100 Mbps. The 4G technologies could not provide this speed and now LTE advanced has been implemented to give a speed of 100-150 Mbps.

TABLE 1
COMPARISON OF MOBILE SERVICES

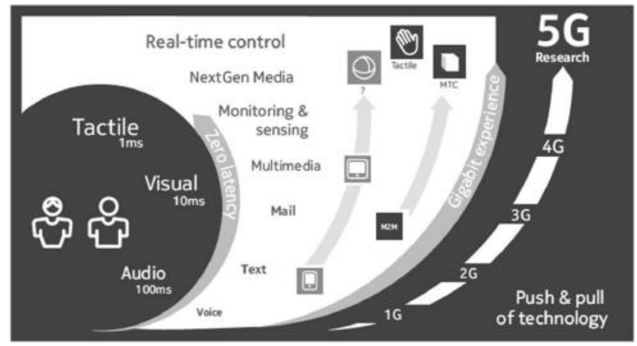
Generation	Primary Service	Key Differentiator	Weakness
1G	Analogue phone calls	Mobility	Poor spectral efficiency, major security issues
2G	Digital phone calls and messaging	Secure, mass adoption	Limited data rates – difficult to support demand for internet/e-mail
3G	Phone calls, messaging, data	Better internet experience	Real performance failed to match hype, failure of WAP for internet access
4G	All-IP services (including voice, messaging)	Faster broadband internet, latency	Meeting Future needs of High traffic and low latency

- 1G – Voice services
- 2G – Improved voice and text messaging
- 3G – Integrated voice and affordable mobile Internet
- 4G – High capacity mobile multimedia.

A new mobile generation has appeared approximately every 10th year since the first 1G system, Nordic Mobile System was introduced in 1981. The first 2G system started to roll out in 1991, the first 3G system first appeared in 2001 and 4G systems fully compliant with IMT Advanced were standardized in 2012. The development of the 2G (GSM) and 3G (IMT-2000 and UMTS) standards took about 10 years from the official start of the R&D projects, and development of 4G systems started in 2001 or 2002.

Now we are talking about Next Generation 5G-in 2020

The figure below gives the features of Generations 1G to 5G



III. TRENDS AND ANALYSIS OF INTERNET TRAFFIC

With the anticipated growth of Internet of Things (IoT) during the next few years, there will be more users, more devices and a more diverse range of device types than ever before. Additionally, other new services and applications will require reduced latency, improved reliability, longer battery life for devices and more consistent user bit rates. 4G LTE, with all its evolution, will not be enough to handle this new wave of heterogeneous data traffic.

Cisco has carried out studies on Network traffic growth with the increase in number of devices and change in traffic pattern of customers in different regions of the world. These findings are summarized in the table below. It is quite alarming to see growth intraffic 2.5 times in next five years from 2015 to 2020. The number of devices connected will also go up from 25 billion to 50 billion. This is all due to connecting devices 'THINGS' to the network. Internet of Things is catching up and by 2020, it will be necessary to have a system that will make presence in all areas. About 200,000 devices per km^2 of area will put pressure on the wireless network.

TABLE 2
NETWORK TRAFFIC GROWTH

- Monthly IP traffic per capita will be 25 GB in 2020 from 10 GB in 2015
- BH traffic will increase by 51% as compared to average traffic growth of 29% in 2015
- Smart phone traffic will exceed PC traffic in 2020. Smart phone traffic will grow @58% and M2M will grow @ 44%
- Wi-Fi traffic in 2015 was 66% , Mobile traffic was 34%
- Internet Video traffic grows @ 82% annually
- Video surveillance traffic doubled in 2015
- Video gaming will grow seven fold from 2015 to 2020
- IP Traffic is growing fastest in Middle East and Africa @ 41%

IV. NEED FOR 5G

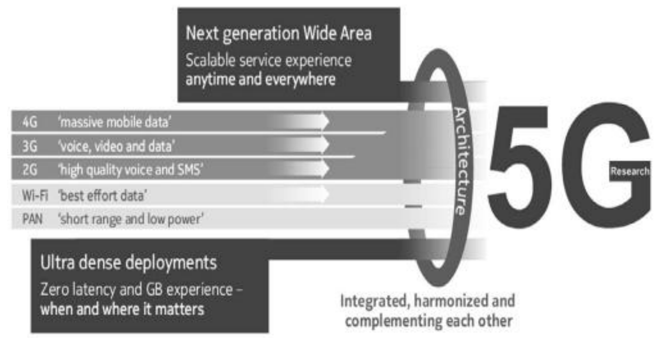
LTE evolved as a versatile system with features comparable to any other good system such as:

- LTE radio interface improvements, such as 3D Multiple Input Multiple Output (MIMO) and wider Carrier Aggregation (CA)
- Deployment of LTE carriers in unlicensed and shared spectrum
- Heterogeneous Network (HetNet) improvement with Dual Connectivity (DC) and Coordinated MultiPoint (CoMP) Antennae
- Enhanced interworking solutions for Multiple Radio Access Technologies (Multi-RAT), especially between LTE and WLAN
- Improved coverage with in-band support for machine-type communications with new LTE Category 0 and M profiles and to support the ongoing work on narrowband IoT.

With all these new features, why can't we simply evolve LTE? The answer is simple. The set of requirements for 5G is not economically or technically achievable with the evolution of 4G.

Some of the main challenges include:

- Advanced mission critical services and immersive virtual reality will eventually require extremely low end-to-end service latency of less than 1 millisecond. This will challenge the basis of the LTE framework and the hybrid retransmission approach used to handle error correction, which effectively limits latency to approximately 10 milliseconds.
- With widespread adoption of IoT devices, the RAN will need to handle extreme device connection density, up to 200,000 devices per km^2. Because LTE is connection-oriented, the signaling overhead will become a major issue as soon as the device density increases. What is required is a connectionless service coupled with a new contention access mode.
- Desire by mobile operators to offer a more consistent Quality of Experience (QoE) rather than simply promoting raw peak bit rates will push the RAN to support a more flexible optimization for a more uniform delivered bit rate.
- The need to optimize the radio interface to simultaneously meet a wider range of user cases will drive the need for a more adaptable radio and core network solution than LTE/EPC.
- Ongoing traffic growth in high density zones will eventually exceed what can be supported in the spectrum bands in which LTE was designed to operate, leading to a need for new radio access technologies optimized for new spectrum bands above 20 GHz.
- The need to evolve the security infrastructure to handle a significantly large number of attached devices will encourage the adoption of more distributed solutions based on chain of trust using verifiable credentials.



IV. NEXT GENERATION MOBILE NETWORK (NGMN) is a body of operators working with selected vendors for the development of 5G. NGMN defines the basic requirements of future 5G systems to meet the needs of the future networks to meet the following parameters.

1. Data rates of tens of megabits per second should be supported for tens of thousands of users
2. 1 gigabit per second to be offered simultaneously to many workers on the same office floor
3. Several hundreds of thousands of simultaneous connections to be supported for massive sensor deployments
4. Spectral efficiency should be significantly enhanced compared to 4G
5. Coverage should be improved
6. Signalling efficiency should be enhanced
7. Latency should be reduced significantly compared to LTE.

V. TECHNOLOGIES FOR 5G

When the baseline 4G system (which here is considered to be 3GPP Release-12) is compared against the 5G requirements, improvements are needed in three dimensions, namely, network capabilities, enablers for operational sustainability, and enablers for business agility. Existing systems (*e.g.*, 3GPP Release-12, IEEE 802.11) are continuously evolving in terms of standardization, implementation and deployment. Several ongoing trends are identified in the accompanying Figure below. These are expected to help the existing systems to improve in the three dimensions. Nevertheless, incremental evolution of 4G systems alone is not expected to be sufficient to address all the shortfalls. Thus, a 5G system is required that introduces some fundamentally new technologies and paradigms to complement ongoing evolutionary trends.

These ongoing trends are shown in the figure below:

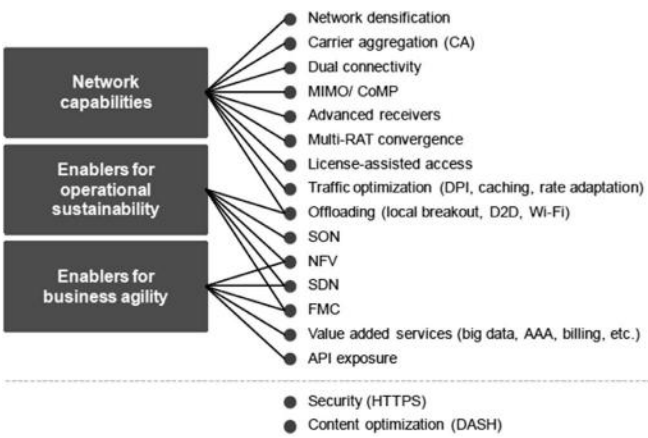


Figure : Trends in Technology.

Some of the technologies depicted in Figure are expected to be at an advanced stage of maturity before 5G deployments. Thus, 5G networks should be designed to leverage them. Besides these, new technologies currently in their early stages of development, such as (but not limited to) massive MIMO and full duplex, should be considered. and foreseen issues to be investigated. These technologies together could potentially address the majority of the requirements. Nevertheless, the extent and the degree to which they will address the requirements need to be carefully studied by NGMN operators jointly with the industry.

These new requirements for the mobile network suggest that a new 5G radio interface is necessary and that it should be able to operate over a wide range of frequencies, from less than 1 GHz up to and beyond 40 GHz. To provide wide area coverage of new services for all devices and device types, 5G will need to be operated in bands similar to existing cellular networks, most likely in frequencies below 2 GHz. Secondly, to provide massive broadband capacity, it will be necessary to complement this new 5G coverage layer with additional 5G carriers in new bands below 6 GHz along with existing LTE and WLAN carriers on both the macro and small cell layers. Eventually, these carriers will be complemented by additional 5G carriers in new higher frequency bands (*e.g.,* millimeter Wave or mmWave) on small cells to augment capacity in high density urban areas.

Evolutionary

5G is expected to start being deployed in 2020. By then, most major operators will have completed the rollout of their LTE networks over multiple carriers mixing licensed and unlicensed spectrum tied together with carrier aggregation. Use of dual connectivity to link the macro and small cell layers would also be in place and operators would have started deploying NFV and SDN based technologies enabling the introduction of new virtual RAN sites in major cities as well as a virtualized core network.

By 2020, the penetration of smart phones in developed markets will have stabilized. New connections will mostly be for second and third personal devices along with machines and sensors leading to a rise in short bursty traffic. This rise will burden the LTE network with increased signaling traffic.

At this point, ongoing capacity demands in dense urban areas and continued IoT traffic growth will demand higher capacity and a more efficient and cost-effective solution than that offered by any further evolution of the LTE network. Additionally, operators will want to launch new revenue-generating services such as those outlined in NGMN 5G use cases. Taken together, these different triggers will encourage operators to deploy 5G radio technologies.

5G will not only be an evolution of mobile broadband networks. It will bring new unique network and service capabilities. Firstly, it will ensure user experience continuity in challenging situations such as high mobility (*e.g.* in trains), very dense or sparsely populated areas, and journeys covered by heterogeneous technologies. In addition, 5G will be a key enabler for the Internet of Things by providing a platform to connect a massive number of sensors, rendering devices and actuators with stringent energy and transmission constraints. Furthermore, mission critical services requiring very high reliability, global coverage and/or very low latency, which are up to now handled by specific networks, typically public safety, will become natively supported by the 5G infrastructure.

5G will integrate networking, computing and storage resources into one programmable and unified infrastructure. This unification will allow for an optimized and more dynamic usage of all distributed resources, and the convergence of fixed, mobile and broadcastservices. In addition, 5G will support munti tenancy models, enabling operators and other players to collaborate in new ways.

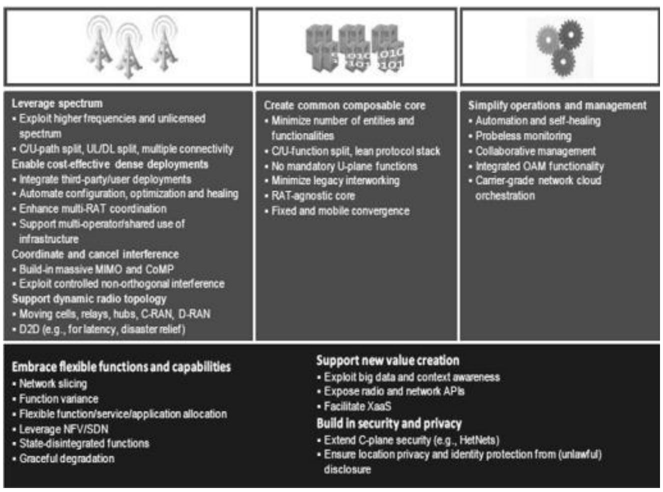
At this point, ongoing capacity demands in dense urban areas and continued IoT traffic growth will demand higher capacity and a more efficient and cost-effective solution than that offered by any further evolution of the LTE network. Additionally, operators will want to launch new revenue-generating services such as those outlined in NGMN 5G use cases. Taken together, these different triggers will encourage operators to deploy 5G radio technologies.

As 5G is deployed, operators will also maintain access to their 4G LTE capacity by using carrier aggregation and dual connectivity between 5G and 4G carriers, minimize the need for inter-generational handovers. This represents a paradigm shift in the mobile industry as it will be the first time a new generation will be designed to reuse rather than replace the capacity of the previous generation.

VI. 5G DESIGN PRINCIPLES

Given the requirements stipulated earlier, and considering emerging technology trends, NGMN believes that the 5G system should be designed based on the design principles illustrated in Figure below.

Radio Network Operation and Maintenance



5G Design Principles

Radio

Leverage spectrum – Higher frequencies (*e.g.,*centimetre and millimetre waves) and licence-exempt spectrum should be exploited to complement endeavours to use any spare bandwidth at lower frequencies and as a complement to the available exclusively licensed mobile spectrum resource. Due to different properties of different spectrum, concepts such as C/U-plane path split and UL/DL split should be employed to optimize the use of various spectra. This implies that simultaneous connections to multiple access points need to be supported.

To optimize the spectrum use depending on the traffic demand, flexible duplex should be facilitated by design, *e.g.*, via a unified frame structure. In addition, full duplex should be applied where feasible, to resolve issues around FDD (*e.g.,* guard bands) and TDD (*e.g.*, guard time, synchronization). Even if implementation technologies limit the achievable performance by 2020, protocols should be designed to support flexible and full duplex from the beginning, if advances in implementation technologies are foreseen.

In addition, the RF capabilities of devices must be improved to take full advantage of different spectrum opportunities whilst maintaining power-efficient large bandwidth operation without desensitization.

Massive MIMO and CoMP will be essential to improve the achievable SNR in the system, thereby improving QoS consistency and overall spectrum efficiency.

The 5G network must also be designed to exploit any feasible interference cancellation methods such as non orthogonal multiple access (NOMA) with advanced receivers where they offer useful performance benefits.

Devices should be connected through topologies that minimize battery consumption and signaling without limiting their visibility and reachability by the network. Wearable devices may also connect through a smart phone as well as directly to the network if the smart phone battery runs out.

Core Network

Create common composable core – To support the diversity of use cases and requirements in a cost-effective manner, the system design should move away from the 4G monolithic design optimized for mobile broadband. In this regard, a rethink of models such as bearers, APNs, extensive tunnel aggregation and gateways is needed. In addition, the UE state machine and entities which store UE context should be revisited and redesigned. Mandatory functions should be stripped down to an absolute minimum, and C/U-plane functions should be clearly separated with open interfaces defined between them, so that they can be employed on demand.

To provide further simplification, legacy interworking must also be minimized, for example towards circuit switched domain in the 2G and 3G networks. A converged access-agnostic core (*i.e.,* where identity, mobility, security, etc. are decoupled from the access technology), which integrates fixed and mobile core on an IP basis, should be the design goal.

Network/ device functions and RAT configuration should be tailored for each use case, leveraging the NFV and SDN concepts. Thus, the network should support flexible composition of network functions, as well as, their flexible allocation and location. The network functions should be scalable such that capacity is provided when and where needed. Even when particular functions or nodes become unavailable, *e.g.,* due to disaster events, the system should support graceful degradation instead of complete service interruption. To improve such robustness, state information should be split from functions and nodes, so that contexts could be easily relocated and restored even in failure events.

5G should aim to virtualize as many functions as possible, including the radio baseband processing. Although some functions may still run on non-virtualized platforms, *e.g.,* to meet state-of-the-art performance targets, they should be programmable and configurable using C-plane functions according to SDN principles.

Operations and Maintenance

5G should make it possible to exploit the network to quickly and efficiently create new value added services and explore different business models and opportunities. For instance, big data and context awareness can be used to create new values for third-party and social use, *e.g.,* for marketing, optimizing public transport, and city planning. Thus, the network design must make the collection, storage and processing of the necessary data simple and efficient.

To further benefit from a programmable network platform, appropriate APIs to various parts of the network should be exposed and standardized. This enables access by third-parties and fosters the realization of different XaaS business models. For example, the APIs could allow third-party access to agile service creation, network measurements, network traces and full configuration control of network functions to enable seamless configuration changes in real-time.

Security is an essential value proposition of the 5G system and must be a fundamental part of the system design despite paradigm shifts like extreme densification, dynamic radio topology, and flexible function allocation. In particular, user location and identity must be protected from unlawful disclosure. Some 5G use cases require extremely low latency – including the latency of initiating communications. For these use cases, multiple-hop security, where intermediate nodes need to decrypt and re-encrypt data, should be avoided.

It should be noted that end-to-end security methods (*e.g.*, SSL, VPN and HTTP 2.0) are increasingly prevalent and these provide the added benefit of protection outside of the 5G operator domain. This could give rise to unfortunate duplication of security functions.

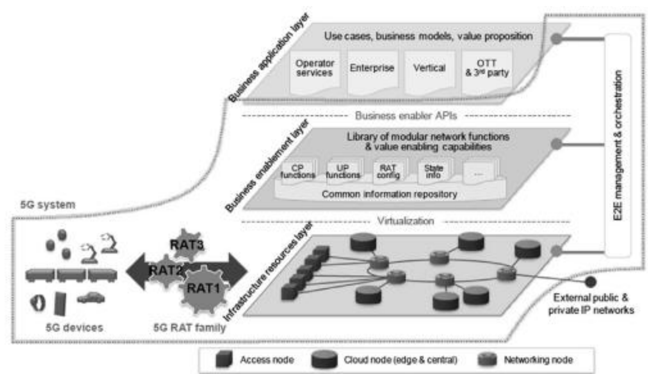
5G will be driven by software

Network functions virtualization (NFV) and software-defined networking (SDN) provide examples for possible new design principles to allow more flexibility and tighter integration with infrastructure layers, though performance and scalability need further investigation. Both approaches stem from the IT realm: NFV leverages recent advances in server virtualization and enterprise IT virtualization; SDN proposes logical centralization of control functions and relies on advances in server scale out and cloud technologies. However, none of those is essentially a networking technology, as the network is assumed to be there, before NFV or SDN can be even used.

Hence, 5G will provide a unified control for multi-tenant networks and services through functional architectures deployment across many operators' frameworks, giving service providers, and ultimately consumers, the perception of a convergence across many underlying wireless, optical, network and media technologies. 5G will make possible the fundamental shift in paradigm from the current "service provisioning through controlled ownership of infrastructures" to a "unified control framework through virtualization and programmability of multi-tenant networks and services".

VII. NETWORK ARCHITECTURE

Based on the design principles, NGMN envisions an architecture that leverages the structural separation of hardware and software, as well as the programmability offered by SDN and NFV. As such, the 5G architecture is a native SDN/ NFV architecture covering aspects ranging from devices, (mobile/ fixed) infrastructure, network functions, value enabling capabilities and all the management functions to orchestrate the 5G system. APIs are provided on the relevant reference points to support multiple use cases, value creation and business models. This architecture is illustrated in Figure below:



The architecture comprises three layers and an E2E management and orchestration entity.

The *infrastructure resource layer* consists of the physical resources of a fixed-mobile converged network, comprising access nodes, cloud nodes (which can be processing or storage resources), 5G devices (in the form of (smart) phones, wearables, CPEs, machine type modules and others), networking nodes and associated links. 5G devices may have multiple configurable capabilities and may act as a relay/ hub or a computing/ storage resource, depending on the context. Hence, 5G devices are also considered as part of the configurable infrastructure resource. The resources are exposed to higher layers and to the end-to-end management and orchestration entity through relevant APIs. Performance and status monitoring as well as configurations are intrinsic part of such an API.

The *business enablement layer* is a library of all functions required within a converged network in the form of modular architecture building blocks, including functions realized by software modules that can be retrieved from the repository to the desired location, and a set of configuration parameters for certain parts of the network, *e.g.*, radio access. The functions and capabilities are called upon request by the orchestration entity, through relevant APIs. For certain functions, multiple variants might exist, *e.g.,* different implementations of the same functionality which have different performance or characteristics. The different levels of performance and capabilities offered could be utilized to differentiate the network functionality much more than in today's networks (*e.g.,* to offer as mobility function nomadic mobility, vehicular mobility, or aviation mobility, depending on specific needs).

The *business application layer* contains specific applications and services of the operatorenterprise, verticals or third parties that utilize the 5G network. The interface to the end-to-end management and orchestration entity allows, for example, to build dedicated network slices for an application, or to map an application to existing network slices.

The *E2E management and orchestration entity* is the contact point to translate the use cases and business models into actual network functions and slices. It defines the network slices for a given application scenario, chains the relevant modular network functions, assigns the relevant performance configurations, and finally maps all of this onto the infrastructure resources. It also manages scaling of the capacity of those functions as well as their geographic distribution. In certain business models, it could also possess capabilities to allow for third parties (*e.g.,* MVNOs and verticals) to create and manage their own network slices, through APIs and XaaS principles. Due to the various tasks of the management and orchestration entity, it will not be a monolithic piece of functionality. Rather it will be realized as a collection of modular functions that integrates advances made in different domains like NFV, SDN or SON. Furthermore, it will use data-aided intelligence to optimize all aspects of service composition and delivery

VIII. TIME LINE TO 5G

Research work on 5G started about five years ago with significant research projects in Europe, China, Korea, and Japan. At the same time, ITU-R started working on setting the fundamental requirements for 5G, followed more recently by the NGMN, an operator pre-standards organization, with the release of its 5G White Paper at Mobile World Congress (MWC) 2015.

Moving forward, the 3GPP will start working on a more detailed set of standards for 5G. Their initial focus will be on setting requirements, followed by formal study items to baseline the architecture and radio technologies. This will lead to work between 2016 and 2019 to define the complete 5G specifications, which will result in the first release as part of 3GPP Release 15 in 2018, followed by a more complete specification in Release 16 in 2019.

In parallel ITU-R is expected to launch a formal call for candidate radio technologies for its IMT-2020 project and prepare for the critical World Radio Conference (WRC) in 2019 where new radio bands above 20 GHz are expected to be identified.

Mobile Network.

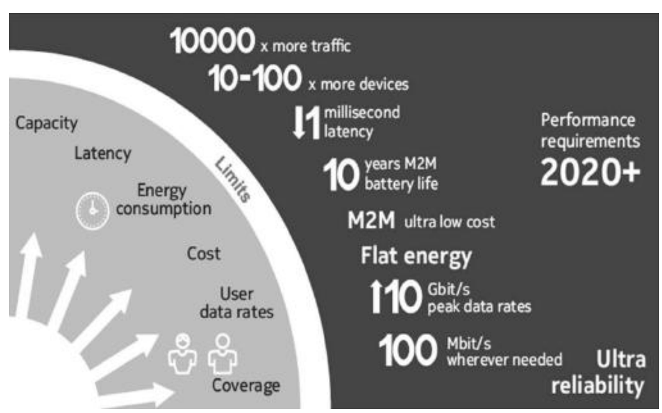
TABLE 3
TIME LINE FOR 5G

YEAR	ITU-R	3GPP	MNOS
2015	• IMT-2020 vision • WRC-15	Requirements	Requirements (NGMN)
2016		• Requirements • Study items (Rel-14)	
2017	Call for radio technologies	• Architecture evolution • Radio technology selection	
2018	Start of evaluation process	• Stage 2 (Rel-15) • ITU-R submission	Technology trials
2019	WRC-19	Stage 3 (Rel-15)	Limited customer trials (Korea)
2020	IMT-2020 recommendations	5G enhancements (Rel-16)	Start of commercial service (Japan, Korea)
2021			Wider deployment
2022			mmWave carriers on small cells

The move to 5G is quickly gaining momentum, with leading mobile operators in Asia Pacific and North America racing to announce initiatives and trials with vendors as well as ambitious launch targets. But the first official release of a 5G standard isn't expected until mid-2018, with phase two following by the end of 2019 – so the consensus is that 5G launches won't start until 2020. Widespread deployments of 5G aren't expected to come until 2022 or later.

IX. SUMMARY

The 5G network capabilities as envisioned by NGMN and other bodies can be summarised in the figure below. It shows different parameters such as coverage capacity, speed, latency etc.



Various administrations are preparing for the deployment of 5G network, the leaders being USA, Korea and Japan. Some representative actions taken by government bodies are: In the US Samsung is partnering with Verizon, via the recently set up 5G Open Trial Specification Alliance. Other operator members are NTT Docomo, SK Telecom (SKT) and KT. Verizon announced plans last year to work with a number of vendors on outdoor 5G tests and trials over the summer. Its focus is on fixed wireless and aims to have an initial fixed wireless pilot starting in 2017.

US operators have the full backing of the government, with FCC allotting vast amounts" of suitable spectrum, with the intention of giving the US a headstart in creating applications for 5G.

Samsung can also look to its home market, where operators have announced plans to launch some form of 5G technologyfor the Winter Olympics in February 2018.

Elsewhere, over in Europe, the European Commission has decided to open a consultation on what the industry reckons 5G should be. It is running a survey to get some ideas together, to at least suggest it is making something resembling progress, which closes three days before the FCC intends to make its 5G plans concrete.

SKT said it tested its 5G system at 28GHz in the outdoor environment and has been working on millimetre wave 5G systems since last year with Samsung. The operator also opened up a 5G Global Innovation Centre earlier in the year with a 5G test-bed.

On January 29, 2016, Google revealed that they are developing a 5G network called Sky Bender. They planned to distribute this connection through sun-powered drones.

In mid-March 2016, the UK government confirmed plans to make the UK a world leader in 5G. Plans for 5G are little more than a footnote in the country's 2016 budget, but it seems the UK government wants it to be a big focus going forward.

It is also important, however, to recognise that 5G technology will be in constant evolution. It would be a mistake to think 5G can be frozen in a snapshot; it is more like a video with many new scenes, all building on each other. The systems and standards of 5G will be continually improving and evolving.

X. REFERENCES

[1]. NGMN Alliance, "5G White Paper – Executive Version," 22 December 2014.
[2]. Understanding 5G-GSMA Intelligence.
[3]. Analysis Mason, "Wireless network traffic worldwide: forecasts and analysis 2014–2019," October 2014.
[4]. Cisco, "The Zettabyte Era: Trends and Analysis," White Paper, June 2014.
[5]. Ofcom call for input, "Spectrum above 6 GHz for future mobile communications," 16 January 2014.
[6]. Roadmap and work plan on future technologies (2020) from 3GPP, ITU, WRC, APT, CJK, China IMT2020, etc.
[7]. ITU recommendations ITUR M2083 (09/15).
[8]. ITU recommendations IMT 2020 and beyond.

Manjit Singh was President of Himachal Futuristic Communications Ltd. (HFCL), heading HFCL's technical operations and business development. He directed the successful implementation of CDMA, GSM and WLL equipment including PDSN, billing, customer care and SMS/VMS systems.
Prior to joining HFCL, he worked for Compton Greaves Limited as Vice President Telecom Services.

He served Government of India for over 27 years. During this period, he served in several key positions of national policy, Director responsible for maintenance and switching in the Ministry of Telecommunications, New Delhi, and, General Manager in charge of two large telecom circles in North India. He was responsible for the planning, installation, commissioning, and monitoring of several large telecom networks in this period.

Mr. Singh served on the technical groups of two world telecom forums: the ITU (International Telecommunications Union) and the APT (Asia Pacific Telecom). As Chair of the India DECT Forum from 1997-1998, he played a pivotal role in promoting Wireless Local Loop technology in India and abroad. Mr. Singh is a Fellow of the IETE and holds a B.Sc. (gold medallist) degree in Electrical Engineering from the University of Punjab.