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SOLUTION TO NEXT GENERATION DEMANDS UPCOMING COMMUNICATION TECHNOLOGIES

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ABSTRACT

Today, almost every telecom company is pulling their socks up to bring 5G standards. 5G networks are considered to be the next generation's "Smart" networks. It will incorporate intelligence with speed which will help management of billions of connected devices and numerous emerging technologies. 5G networks will emerge as an enabler for connected world. 5G technology aims to enhance the connectivity and mobile broadband. The swift from 3G to 4G has witnessed vast developments. The driving force behind 4G was Speed and it introduced fast video streaming with fast mobile broad bandwidth. The appetite for broadband has clearly fuelled the development of mobile cellular networks.

The eminent 5G features are broadly higher bandwidths, lower latencies, several times faster data rates, highest degree of scalability, high throughputs, enhanced capacity and so on. It provide opportunities to different technologies which can be exploited to achieve desired level of configurations to meet 5G standards. 5G will be used to meet the requirements which were untethered with the communication generations familiar to us. This work highlights the overall requirements, use-cases and potential candidates for 5G. Paper also proposes novel architecture for 5G network while explaining the components and working.

Keywords: 5G, Mobile Technologies, 5G-architecture, Technologies.

INTRODUCTION

The legacy networks in the lace provide us with plethora of services but facing shortcomings to meet advancing need, speed and desire for more. Revolution in the field of mobile communication has influenced the society more than any other technology. The society has witnessed technological advancements in past years which has dramatically changed the way mobile and wireless communication systems are being used. The appetite for broadband has clearly fuelled the development of mobile cellular networks.

The 5G propose to set new standards to define Connectivity and Communication. It aims to enable a human-centric mega communication society [1]. 5G will mark its immense potential both at customer-end as well as in Industrial applications. 5G will be capable of providing higher speed with latency reduced up to 1millisecond. It will enhance the capacity and coverage with very high bandwidth and data-rates in ultra-dense environment. Research and developments are initiated to set standards that will define and implement 5G best.

5G society as a flexible, dynamic and connected society needs to support integration of heterogeneous access technologies, billions of devices, evolved business models and use cases, new threat models and so on. The revolution in mobile communication had always surprised mankind. Within the time span of almost a decade, mobile and wireless communication technology has something big to give. Each succeeding generation has successfully fixed the loopholes of its predecessor and had rooms for the next generation. The 5G is the future of the communication after the success of 1G, 2G, 3G and the recent 4G. 5G is still under developed and fighting for standards which will exist in 2020s and beyond.

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The paper is organized as follows. Section II provide an introduction and summarizes the characteristic features of different mobile and wireless communication technologies. Section III discusses factors which led towards growth of upcoming 5G technologies. Section IV deals with different use-cases of 5G. In Section V, we will summarize different evolving technologies that can be used in implementing 5G. In Section VI we will propose a novel 5G architecture. Section VII discusses different research programs going in the field of 5G and finally Section VIII will conclude the paper.

MOBILE AND WIRELESS COMMUNICATION TECHNOLOGY

Since the wireless communication is developed, each passing decade witnessed growth and development. The basic analog telephone systems enabled with mobility features marked the revolutionary the mobile communication era. The development and deployment of each generation

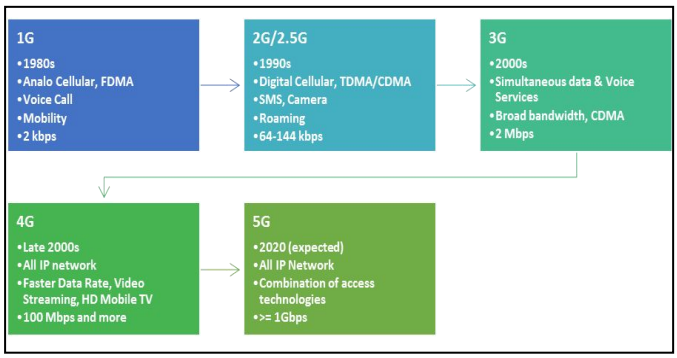

Figure 1 Generation of Mobile Communication

of mobile communication always had a strong driving force. The advancements in human need triggered the infinite race. The race had participants from all-analogue era to recent evolving all-IP based "Long Term Evolution (LTE)" and "LTE-Advanced (LTE-A)" technologies.

The need for untethered telephony with wireless real-time voice communication has dominated the success of cordless phones, followed by the "First Generation of Mobile Communication (1G)". The transition from 1G to "Second Generation of Mobile Communication (2G)" characterized "Short Message Service (SMS)" text messaging as its killer application. Gradually with the widespread usage of computers, Internet ruled the technological advancements and filed its candidature as the killer application for the next successor which was "Third Generation of Mobile Communication (3G)" [2]. The emergence of smartphones that integrated the features of computers with the cellular technology to provide services at fingertips and eventually gave birth to the "Fourth Generation of Mobile Communication (4G)", famously known as LTE. The access to faster data speeds and video streaming were the killer applications in 4G [3]. The 4G evolved with all IP services as its key differentiator but raised the unanswered question for power efficiency and low frequency networks in densely deployed environment.

With "Fifth Generation of Mobile Communication (5G)", mobile operators would create a society offering massive connectivity which will act as an enabler for Machine-to-Machine (M2M) services and the Internet of Things (IoT).

5G: DRIVERS AND REQUIREMENTS

One side where the technology is flourishing on its heights we have sectional population in the society who are still deprived of basic connectivity. The connectivity is challenged in terms of network coverage, unavailability, varying economic levels and so on. With 5G expectations are high not only to provide efficient low power network devices, faster data rates, seamless connectivity and integration of existing technologies through 2G, 3G, 4G, and Wi-Fi but also to provide rural connectivity with zero outage so that basic connectivity is assured [4].

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The fundamental drivers for 5G networks are:

- Real-time interactions.
- Ultra-high definition videos.
- Critical applications that include medical assistances, traffic management and so on.
- High quality of service, reliability and security.
- Billions of heterogeneous devices.
- Seamless connectivity
- Diverse services and new evolved use-cases.
- Efficient interoperability between available spectrums.
- Redesigned Air-interface and RAN systems.
- Enormous network deployments with demanding features like Device-to-Device (D2D), dynamic spectrum sharing, self-backhauling and so on.

To fulfil the targets for the 5G wireless networks, the formulated requirements and key components are:

- High Data Transfer Rate both in the Uplink and the downlink
- Improved Spectral Efficiency
- Power Management
- Communication Reliability
- Network Coverage
- Network Deployment
- Network Security
- Tactile internet
- Support for high mobility
- Low Latency (<1ms)
- Energy Efficient Network
- Scalable frequencies to accommodate both low and high data-rate requirements.

5G USE-CASES

With the transition of LTE and LTE-A systems into the future communication system offering plethora of services has defined several new use-cases. These new use-cases being unique in nature will prove to be the corner stones in the 5G networks as they will decide the success and faster adoption of the emerging 5G and how these potential markets can be exploited to have monetary value. Some of the eminent use-cases are defined as [4, 5]:

Augmented Reality

In augmented reality the digital information is blended with user environment in real-time. It exploits wide variety of user experiences and instances. High bandwidth and low latency will be prime necessity for augmented reality.

Self-Driven Cars

As a step toward automated traffic control measures, the vehicles will be enabled with communication capabilities and can sense roads and other co-vehicles to resist accidents. Coordinated vehicles with the traffic control system will enhance the speeds and reduce the risks. High bandwidth, fast data handling and responses in fractions of nanoseconds will be its prime requirement.

Video-Conferencing and Real-time Video Applications

Real-time video application will emerge as a crucial component in emergency services. It can be used in monitoring applications, security issues, remote medications, identity recognitions and so on. Although 4G systems offer these applications like video conferencing and video monitoring to some extent, 5G networks adds up even more reduced latency and enhanced cloud services.

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Machine Type Communication

5G scenario will witness billions of connected devices by the time it is deployed so it becomes critical to have the devices connected and coordinated so as to have seamless services. Evolving 4G offers connected machine type communication subject to enhancements in 5G for more accessibility, simplified usage, flexibility, faster speeds. D2D communication will become eminent specifically in home application systems which include connected devices like smart meters, automated home appliances, smoke detectors and so on.

EMERGING TECHNOLOGIES IN 5G NETWORK

The 5G networks will form a service defined platform that regulate its availability, connectivity, system robustness, speed and latency. Major requirements for 5G networks are high bandwidth, improved spectral efficiency, minimal latency and seamless integration of existing technologies. 5G amalgamates the evolving technologies independently with the recent technologies being deployed in LTE and LTE-A systems. The brief description of emerging technologies to achieve the defined requirements are [3-5]:

A. Network Function Virtualization

"Network Function Virtualization (NFV)" is an emerging technology that will set standards for technological revolution in 5G networks. It separates service logic from the hardware platform. The network-based services are enabled by software which formerly requires a specialized hardware [3, 6].

It has brought beneficial transformation both in terms of performance as well as in terms of cost. Its functions are irrespective of location and thus results into a flexible and scalable network with enhanced capacity. It is capable of placing the functions either centralized or near the nodes depending upon the use-cases. It incorporates virtualized services which drastically reduces the investments for the devices. However designing network to efficiently enable services and manage orchestration through software is still a challenge.

B. Software Defined Networks

"Software Defined Radio (SDN)" is a continuation to the NFV services. It basically separates the DATA and the CONTROL planes. It abstracts functions into virtual services. It configures load and demand through software to maintain the quality of services (QoS) and consumption time [3, 5].

It offers an alternative to the physical infrastructure to manage network in a simple cost-effective approach. It allows different service deployments using the same physical and logical network infrastructure. It facilitates an Open Standard Network where the direct programmability feature separates the data and control planes controlled by SDN controllers. It also let the operators to configure, manage and optimize network resources and regulate traffic load dynamically.

However, IT revolution from existing physical structures to software functions has brought various complexities to manage operator side services. With SDNs, its standardization, unified interface and security are major issues. NFV and SDN are already being developed in LTE networks as the fundamental component.

C. Millimetre Wave Technology

"Millimeter wave (mmWave)" contest as one of the promising solutions to 5G networks. It exploits high frequency band ranging from 20-80 GHz [7, 8]. This technology offers more bandwidths to be allocated to render faster deliveries, high-quality video and to increase the communication capacity.

The mmWave differs from other technologies in terms of high propagation loss, directivity, and sensitivity to blockage. It eliminates the severe path loss by exploiting the high beamforming gain from large number of antenna elements.

The challenges associated with the mmWave technology are mainly interference management, IC and system design, spatial reuse and so on. Despite of challenges it have its remarkable applications in deploying small cells and femto cells and in forming wireless backhaul [8]. It offers both co-located and distributed architectures.

D. Cognitive Radio

The Cognitive Radio (CR) is a salvation for the scarce spectrum bands. In CR a transceiver intelligently sense the used/unused channels and selects vacant channel on sharing basis for transmission. It acts as the key enabler

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for self-organizing networks by increasing frequency reuse, spectral efficiency and energy efficiency [8, 9]. The basic challenges associated with the CR are:

1) Choice of sensing algorithm: There are a number of sensing algorithms. The Energy detection algorithm, the Matched filter algorithm and so on have their own merits and demerits.
2) Concern about Latency: 5G aims to provide latency less than 1milliseconds but in CR sensing time and the time to set-up connection is challenging.
3) Handover: The number of handovers in case of CR are predicted to be higher than the licensed spectrum handover and that will increase turnaround time of the network.
4) Routing: the routing mechanism still have rooms for development to ensure security.

E. Massive MIMO

"Multiple Input- Multiple Output (MIMO)" systems are used to enhance the data transfer rates both at device and network levels. It incorporate multiple antennas at both the transmitter and receiver ends to accommodate more data [8] and ultimately leads to improved performance in terms of reliability, spectral efficiency, and improved radiated energy efficiency. The use of large number of antenna results into high throughput, increased spectral efficiency per unit area, enhanced diversity and compensation for the path loss. Massive MIMO allow high resolution beamforming which are useful at higher frequencies. The antenna elements are designed in a manner to use extremely low power.

It also mitigates the intracellular interference using linear precoding and detection methods along with diminishing the effects of noise and fading. Massive MIMO systems can be exploited for MAC layer designing without complicated scheduling algorithms [8].

The major challenge with Massive MIMO system is the amount of Baseband Processing required for the huge amount of antenna usage and the huge number of antennas demand phase synchronization among them. The Massive MIMO systems suffers from pilot contamination from other cells. Effective Channel Estimation/Feedback required incorporated with fast processing algorithms.

F. Heterogeneous Networks

The Heterogeneous Networks (HetNet)" offers macro, pico or femto cell deployments in an ultra-dense manner to provide maximum network coverage and has its applicability at network level. This reduction in the cell size resulted into increased spectral efficiency and reduced transmission power apart from increased network coverage. The femtocells can be deployed as low power cells in residential and enterprise scenarios whereas the picocells considered as high power cells can be used to provide outdoor coverage and in macrocells to fill coverage gaps. It also facilitate integration of various access technologies from legacy systems such 2G, 3G, 4G, Wi-Fi and so on based on coverage area and proposed topology.

Small cells are the corner stones in the HetNet deployment resulting into a flexible and scalable network. The major challenges with the HetNets are Intercellular Interference, Distributed Interference coordination due to uncoordinated access points, efficient MAC measures, device discovery and most importantly, connection-establishment and power- management. It can be a potential candidate for 5G networks to ensure zero outage probability in terms of network coverage

G. Multicarrier Techniques for 5G

Despite of the success of OFDM, new waveforms for 5G are being considered to bring additional enhancements to the spectral efficiency both at the network level and at device level. Various multicarrier techniques taken up as the candidate for 5G are namely Orthogonal Frequency Division Multiplexing (OFDM), Filter Bank Multicarrier Technique (FBMC), Generalized Frequency Division Multiplexing (GFDM), Universal Filter Multicarrier Technique (UFMC) and Carrier Aggregation [10].

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The waveforms for 5G should be capable to support high speed video downloads, real-time gaming applications, vehicular communications, automated self-driving cars, IoT/M2M communications, high data rate transfer with least latency, fast switching between uplink and downlink and so on while maintain the QoS level.

1) *OFDM*

OFDM proved its effectiveness with 4G in context to the enhanced spectral efficiency while operating well in the presence of selective fading, high data rates and wide bandwidths [11]. Since past decades OFDM have been used with broadband wired and wireless communications for its advantages [12].

Figure 2 Ofdm Working Principle

Figure 3 Fbmc Working Principle

OFDM systems can be used with MIMO communications in 5G context offering full flexibility. Similarly with Multiple access communication it offers low complexity and either synchronization or interference cancellation in downlink and uplink respectively. But this multiplexing technique cannot be used in case of CR communications and in dispersive channels.

However, in OFDM we have to use large number of orthogonal frequencies which makes frequency planning difficult in terms adjacent cell interference and frequency reuse. To mitigate interference, complex frequency scheduling is required which makes system difficult and the use of Cyclic Prefix (CP), eats up data stream space are prominent demerits in case of OFDM.

2) FBMC

FBMC uses Orthogonal Frequency Interference Mitigation to mitigate the adjacent channel and the interference caused. Sub-carriers are individually filtered unlike OFDM and provide high spectral efficiency in absence of cyclic prefix [10-12].

Unlike OFDM, FBMC offers higher bandwidth efficiency and needs no interference cancellation or synchronization when used with multiple access communications downlink and uplink respectively. FBMC systems are highly suitable to be used in CR communications and can be optimized to meet doubly dispersive channels.

The demerit of FBMC is that it introduces overhead in the overlapping symbols in the filter bank. And also in a wider bandwidth system it is very difficult to obtain RF performance. This technique can only be used under certain conditions with MIMO systems.

3) UFMC

UFMC is designed to overcome the disadvantages of CP-OFDM and FBMC and generalize their advantages. It performs filtering on a per sub-band basis as it split the signal [10, 11]. ISI protection is used instead of cyclic prefix.it is seen as an enhanced CP-OFDM to improve signal quality.

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4) GFDM

GFDM is a multi-carrier system and it digitally implements classical filter band approach. It allows CP insertion for low complex equalization at receiver side. It is similar to OFDM but its cyclic prefix is shortened to enhance spectral efficiency. QAM is used to modulate the subcarriers individually.

GFDM carriers are non-orthogonal but exhibit mutual interference adjusted by individual transmitter filters and signal bandwidths. GFDM reduces PAPR and control out-of-band emissions where the OFDM fails.

Thus, the performance of GFDM is worse than OFDM because of non-orthogonal carriers but its filter design is dominating.

5) Filtered OFDM

This is an enhancement to OFDM using filters. It splits the available bandwidth for transmission splits up into sub-bands accommodating various services with most suitable waveform and numerology [11]. The spectral efficiency is enhanced allowing multiple services carried in the spectrum.

The above comparison showed that, a single waveform cannot be sufficient to meet the 5G requirements. Thus, multiple access and advanced waveform technologies needs advancements and integrated with essential modulation and coding algorithms to meet up 5G needs and result into a scalable network that will effectively accommodate massive connected devices with reduced latencies.

5G ARCHITECTURE

5G architecture should accommodate all the upgraded technologies both from legacy systems and the recently emerging ones to provide seamless services. Since LTE has already evolved as all IP network and all IP-based network will be continued in 5G architecture. Unlike previous generations 5G will utilize the maximum spectrum with best optimized access technology to form a sound delivery sub-system [13].

Adaptive new air-interfaces and radio access network demands a complete renovation to accommodate existing platforms, dense environment, new technological advancements, massive devices, high-speed networks and so on to have a network of massive capacity. The backhaul, self-organizing networks, HetNets, D2D communication, CR technologies will be the players. Following figure 4 gives a rough idea about 5G architecture and components.

The architecture above has been explained in terms of NFV. In the proposed architecture the UEs communicate with each other via D2D communication and also the eNodeB communicates to the cell edge device through D2D relaying. The devices in the lower side communicate through the EPC and one of the three devices in the coverage of two eNodeBs, so both the APs communicate with the devices based on the load on the eNodeBs. The above explained feature has been adopted from the "Coordinated Multipoint (CoMP)" used in LTE systems. This feature can be enhanced using Massive MIMO where the degree of freedom to provide service to UE will increase substantially. Many APs will provide Massive MIMO access and if the devices are provided with a permanent IPv6 address then the data can be routed through different APs to a unique IP but this will create a number of link layer addresses and multiple routing table in the network. These multiple networks will route the packets and at the UE different packets have to be ordered and then processed [14].

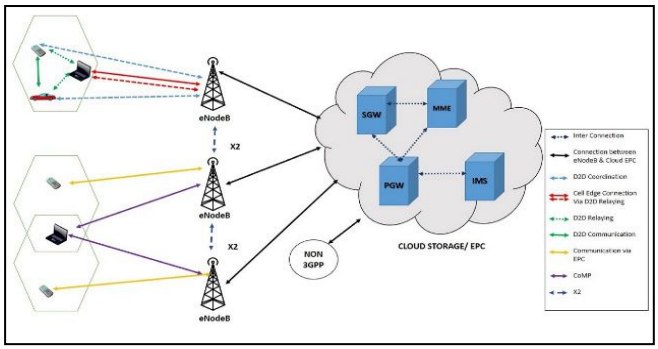

Figure 4 5g Network Architecture

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All the eNodeB will be connected to the cloud. It is called a cloud because here at the interface between the eNodeB and the core, a hypervisor program will be there. The functionalities of the SGW, PGW, MME and IMS will be carried out at the cloud and the hypervisor will decide where the data is to be directed. Both wire-line and wireless accesses will be covered by the 5G core which is transformed as server that will run software. The Virtualization function will separate control and data planes. The operator will work independently over network topology and connections. The network architecture defines a fully distributed network with single level of hierarchy.

Architectural Benefits

The benefits proposed architecture over legacy systems are:

- Direct D2D Communication between the devices unlike the legacy networks were D2D is used only to improve the cell edge performance.
- D2D relaying also to be introduced in 5G which will let the devices and machines communicate among themselves either directly or through relaying by other devices in the ad-hoc mesh network without the use of EPC.
- The User access points in the femto cells will be user maintained points and will work on Plug and Play basis. The user access points will provide the user devices access through mm-wave but providing access to the user access points to the backhaul through the mm-wave is a matter of research with feasibility testing in terms of absorption losses.
- The cloud and NFV will make the implementation of network functions through soft wares running on general purpose processors and not ASICs. This will save costly hardware changes which are proprietary in nature.

Security Considerations for 5G

For the 5G systems, security will be the major and most critical challenge as the connected entities will demand enhanced security at each level and in each area. A secured, trusted and protected architecture system will led the foundations of the 5G aeon. 5G will not be only concerned with individual accesses and their need instead it will handle sensitive areas that need high level of privacy and trust. The security considerations for the 5G society need to provide new levels of performance to meet the desired throughput, latency, speed and service to billions of connected devices and so on.

The security mechanisms should provide secure data and voice transmissions, secure storage of data at clouds, secure identity management to devices, security to users' privacy and above all the mechanism should safeguard the network.

The challenging security issues having potential to become major threat to the society. Billions of connected devices, increased data transfer rate, new disruptive technologies and so on for 5G will impose high level of threat and security issues. The security infrastructure should have varying degrees at should be present at various levels.

Security Drivers

The security drivers for the network in legacy systems were mainly to render connectivity and fair usage charging and to keep users' privacy maintained. But 5G security drivers demand much more than these basic requirements. The new security measures will be formulated based on following constraints:

- New Trust Models are needed to connect billions of devices which are heterogeneous in nature dynamically, safeguarding their data and privacy.
- New model to access Software Driven Applications required as new technologies like cloud computing, NFV, SONs, CR and so on will dominate the network.
- Robustness of the network need to be enhanced as networks integration will expose it more to cyber vulnerabilities.

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- Safeguarding the Privacy and Security Assurance against the network clouds, malicious attacks, cyber threats etc.
- Identity Management will be one the prime requirements as devices will be participating in the network randomly.
- Efficient Handover Management system.
- The security mechanisms need to be built at the core level instead of add-on features.

RESEARCH AND DEVELOPMENTS IN 5G

5G being in its infant stage, R&D initiatives are taken across the globe to come up with the best solution to mobile communication world. R&D activities involve a huge contribution from the academicians, Research institutes and from telecommunication industries. 5G has been in real discussion since early 2008. Many projects and research groups have been established to work hand-in-hand towards 5G.

The European countries are working on Horizon 2020, EU FP7 program which includes METIS 2020, 5GNOW, MAMMOET and so on. The Surrey University took up the activities under 5G Innovation Centre (5GIC). Asian countries are engaged in projects initiated by Korean 5G Forum Initiative, IMT 2020 5G promotion group, China and ARIB 2020 & beyond Ad Hoc group by Japan. The leading universities from America namely NYU, MIT, Berkeley, Stanford and so on are involved in 5G research and development. Various NSF projects- FIA Program, Xdensification and so on are being carried out along with Qualcomm Institute's initiatives under Intel Strategic Research Alliance. Many Internationally renowned organizations including ITU, IEEE, 3GPP, NGMN and so on are involved in activities for developing 5G standards.

"Wireless Innovative System for Dynamically Operating Mega Communication (WISDOM)", is an ambitious project based on 5G innovations. It targets to set standards to best suit the Indian scenario and prospective to define 5G [1]. The project was initiated in 2008 to develop 5G mobile communication in India by 2020. The initiatives taken under WISDOM are followed by research programs at "Centre for TeleInfrastructure (CTIF)", Aalborg University, Denmark.

CONCLUSIONS

5G will the revolutionarily transform the way we are communicating today. It will take things a step ahead of our imaginations. Massive connected devices, high bandwidth, energy efficiency, cost effectiveness and so on will be its characteristic feature. 5G systems will play vital role in forming human centric society where everything and anything will be connected to provide service.

To meet up the various new use cases, evolved requirements and service oriented delivery in 5G things need to be transitioned. The transition from legacy systems including the evolving LTE and LTE-A will co-exist in the new scenario to set an interoperable society.

There are many potential candidates to be exploited to fulfil 5G as a scalable, manageable, and flexible network. The key technologies including multicarrier techniques, modulation, coding techniques and so on have to be blended to give desired outcome. The virtualization will play main role in providing seamless access to billions and trillions of connected devices forming a flexible network.

5G claims to be faster than 4G with greater bandwidths, faster downloads, critical applications and so on. Its implementation has to overcome barriers like deployment cost, crowed frequency range, integrated devices and so on. The integrated devices at user ends will be one of the major pull back as it involves evolving existing billions 2G, 3G, 4G handsets to 5G compatible devices. An optimized and adaptive network framework accommodating everything from past to future technologies together with trending needs will mark 5G's success.

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The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

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