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5G: Need for the Hour

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2.1 Introduction

Current legacy mobile networks in lace, offer plethora of services. Mobile technology is the most ubiquitous technology and has influenced the society more than any other technology. The society has witnessed technological advancements in past years which have 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 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 2030s and beyond.

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.

5G will not only enhance the speed but upgrade the technology expansively [1]. Automation services, service-aware networks, context awareness, real-time monitoring services, critical services and many more application

areas will dominate the society. 5G networks will introduce new levels intelligence both at device and at network level followed by various emerging disruptive technologies. It will enable devices and network elements to automatically sense the requirements, situation, availability and so on, based on which it accordingly adjust connection speed, degree of latency, alert messages, device power configurations and so on.

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 provides 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. The application areas and potential 5G target includes zero-outage probability, connecting rural and remote areas, universal internet connectivity, virtual reality, real-time applications and so on.

5G will dominate other mobile networks if it's said standards and features are met. The initiatives and research on 5G is burgeoning at an alarming rate. The race is just not only between the telecom companies now, social media companies like Google and Facebook are also competing for 5G. The race is ramping up to reach gigabit speeds per second, increased capacity and mainly rural connectivity at an economic and affordable rate.

The figures are shocking but there is still a huge percentage of population that is deprived of even basic connectivity. The technologies have grown and developed better in urban scenarios but the rural population is left uncovered from the radar of connectivity. Thus, 5G aims to reduce this gap and the rural and sparsely populated regions to provide basic connectivity along with seamless internet connectivity.

2.2 Mobile Communication Aeon

The wireless mobile communication technologies have gradually evolved to serve the society and meet its basic needs. The technology was analogue when it first came into picture, then came the era of digitization which left its remarkable impact on communication systems and today we have advanced digitized technologies with additional features. There always have been a driving force for the development and deployment of any technology, whether it is analog or the recent evolving "Long Term Evolution (LTE)" and "LTE-Advanced (LTE-A)".

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)" characterised "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. 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 [3].

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).

2.3 WISDOM and Its Task Groups Abstract

"Wireless Innovative System for Dynamically Operating Mega Communications (WISDOM)" is the standard for the 5G mobile communication to be developed in India by 2020. It is a novel technology based on the Cognitive Radio which employs the feature of the opportunistic sensing of the spectrum holes or white spaces. The state of Art technology generations which have already been implemented or are being implemented are 1G, 2G, 3G and 4G. The 4G technology being the latest in the mobile communications serves to provide 100 Mbps of data services. But still the demand for services has not seen saturation. Therefore there is a need to forge a new generation of Mobile Communication which can take care of arising services like wearable or flexible mobile devices, UHD video streaming, navigation and cloud services and many more. WISDOM is proposed to be providing 1Tbits/s of speed at Mm-wave frequencies at short range communication and 300 Mbps of data rate for individual mobile subscribers.

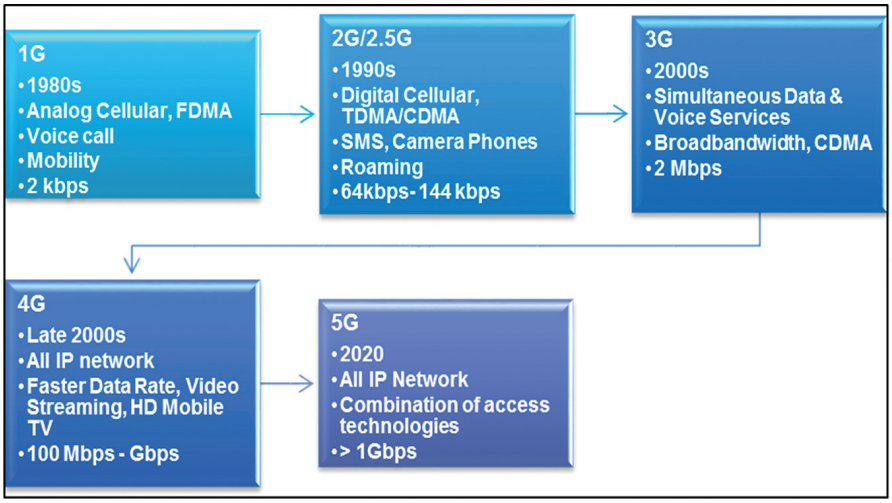

Figure 2.1 Mobile wireless technology.

"Global ICT Standardization Forum for India (GISFI)" is an organization is involved with the standardization of the 5G standard [4]. For the standardization it has five existing task groups namely Security and Privacy, Future Radio Networks and 5G, Internet of Things, Cloud and Service Oriented Network and Green ICT. Recently two new task groups are added namely Spectrum Group and Special Interest Group. Each of the above groups has their own tasks and WISDOM presents challenges in each of the task groups. The challenges are to be sequentially met with one task group completing the challenge the other task group takes the next challenge. The Figure 2.2 suggests the pathway to 5G technology. The concept of Collaborative Communication, Navigation, Sensing and Services (CONASENSE) and Human Bond Communication (HBC) elaborates the idea for 5G together with WISDOM. CONASENSE suggests that all the operations will be carried out collectively and the information will be shared between the elements as they will inter relate among themselves to give high end services to the users [5] while HBC emphasises that with the increase in bandwidth in the successive generations there exists a window where we can look after the other three senses which are touch, smell and taste [6]. Thus, there are challenges needs to be taken care in the 5G.

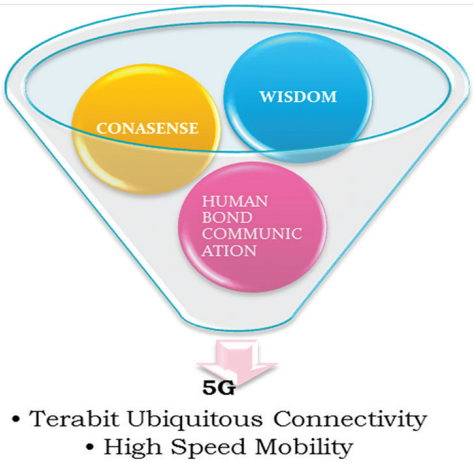

Figure 2.2 Collective CONASENSE, WISDOM & HBC for 5G.

2.4 Towards 5G System

This Section discusses about need for 5G technology as well as different applications such as use cases, self-driven cars and so on.

2.4.1 Requirements and Drivers

One side where the technology is flourishing at the same time we have sectional population who are still deprived of basic connectivity. With 5G networks 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 probability so that basic connectivity is assured [7].

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 fulfill 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 ($<$1 ms)
- Energy Efficient Network
- Scalable frequencies to accommodate both low and high data-rate requirements.

2.4.2 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 [7, 8].

2.4.2.1 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.

2.4.2.2 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.

2.4.2.3 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.

2.4.2.4 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.

2.5 How 5G will Change the Society

5G will bring 100 times faster ultra-high speed mobile internet offering speeds more than 10 gigabits per second. This will enables users to download complete movies in 5–6 seconds as per Global Tech and telecom companies report. Apart from speed, 5G will connect billions of new heterogeneous wireless devices ranging from smart gadgets to wearable to embedded industrial products apart from phones, tablets, laptops and many more. The digital offset/Response time popularly known as latency is also guaranteed to be minimised up to 1 millisecond, which is roughly 50–80 milliseconds in current networks. Reduced latency can enable many critical and sensitive applications. Extremely fast response times will make 5G networks to play vital role in traffic automation and control.

Some of the most transformative changes that will be eminent in 5G scenario are namely Rural Connectivity, Universal Internet Access, Unified Air Interfaces and Affordable Broadband.

2.5.1 Rural Connectivity

With the deployment of 5G networks, the world will witness complete transformations. Development will be inevitable as cities will grow into smarter mega cities and so do the villages. Thus having a well-connected communication system will serve as the backbone of the network. Rural connectivity is essentially important.

With the current networks data depicts only 70% of the world's population is under the radar of connected society concept. Rest of the population is still deprived of the basic connectivity. Suggested by a survey report, it is said that by 2020, 85 percent of world's population will be under 3G coverage while 60 percent will be under 4G coverage. 5G networks assure to provide low-cost solutions to provide seamless coverage in rural ends. 5G systems play significant role in making ONE connected world [9, 10].

Rural Connectivity can be achieved via Network slicing efficiently. The network slices can be exploited to provide optimized connectivity depending upon use-cases, applications and users. This technology can efficiently be used for resource management. Another efficient technology to achieve Rural Connectivity will be SDN, NFVs and different virtualization technologies. These technologies provide abstracted services and make network flexible and scalable. Virtualized functions gelled with network slicing is used for network orchestration and enhance network coverage. Carrier aggregation can also be used to provide access to user devices.

The prime hindrance in the path of rural connectivity is the lack of potential economic support per square unit. In rural areas another important hindrance is the uneven population distribution. New hardware will be required to provide rural access.

2.5.1.1 Challenges faced by LTE and other technologies

The indispensable challenge to provide rural connectivity via the LTE services was cost. In absence of required economic standard from the smaller and rural carriers, the larger carriers were dominant in the market. Innovative and combination of access technologies are used to provide broadband and voice services. 4G subsystems incorporated smaller cell concept to meet growing demand for data. This serves as a base layer for developments and deployments of 5G rural concepts.

2.5.1.2 Carrier aggregation for rural connectivity

Carrier aggregation is the technology used to achieve high data rates that increases the transmission bandwidths over single carrier or channel. It is

also known as Channel aggregation. It is used in LTE-Advanced networks where it enhanced the transmission bandwidths and bitrates using more than one carrier. LTE-A offers considerably higher data rates than LTE systems. Both Frequency Division Duplexing and Time Division Duplexing support Carrier aggregation for high data throughput. It aggregates, two or more Component Carriers resulting into wider bandwidths. The user end device receives/transmits one or multiple component carriers which may be contiguous and non-contiguous in nature [10].

The access to the user devices can be provided through carrier aggregation of narrow bands. In rural connectivity, mm-waves cannot be used as eNodeB has to provide large coverage thus narrow bands are preferred. Figure 2.3 depicts the rural connectivity using carrier aggregation technique.

In remote areas with least population, the carrier aggregation can be done by a single eNodeB but in areas where more than one eNodeB have coverage the carrier aggregation can be provided by using spatial diversity and combining carriers of all the eNodeB. This approach restricts multiple deployments thus significantly reduces infrastructure costs and maintenance.

In Urban areas, particularly in the indoor environments, user maintained access points provide access in Plug and Play manner. Carrier Aggregation is used to provide sound backhaul to such access points resulting into an energy-efficient network.

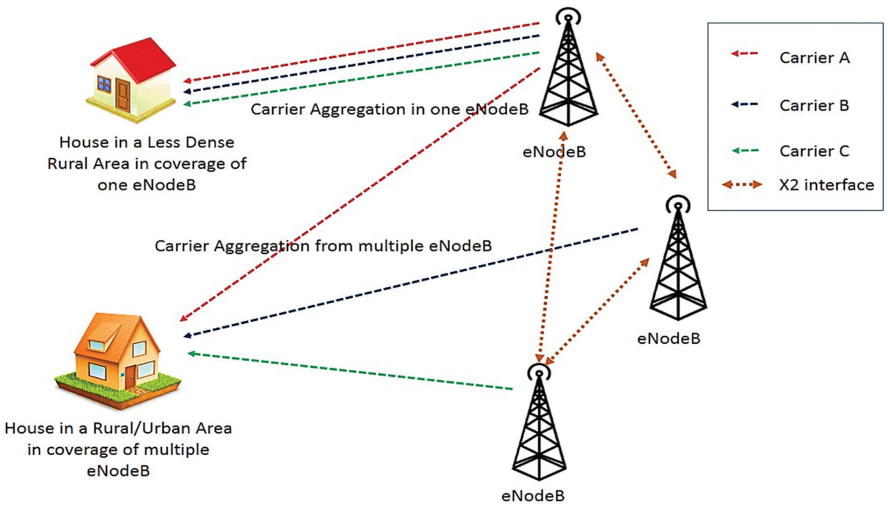

Figure 2.3 5G Rural Areas.

2.5.2 Universal Internet Connectivity and Affordable Broadband

Internet has always been there as an active participant in any technical or non-technical, economic, social etc. growth and development. With the technological uplift of mobile communication serving nearly 70–80 percent of humanity, Internet can be used as "An Enabler to Zero Outage Probability". Universal Internet access can solve coverage problems to nearly 95 percent.

The global standard for 5G networks needs to be formulated at the earliest. The standards include services, co-existing capabilities and most importantly an affordable broadband connectivity of rural communities. The broadband internet connectivity will improve and enhance society both in economic as well as uplift the social and technical standards. Another breakthrough approach to have last-mile connectivity is the Spectrum Sharing, which utilizes white spaces available. The network technologies need to be affordable both in economic as well as availability sense. The spectrum sharing enabled broadband localization and made it available at low costs to support many services like VoIP (voice over IP), video streaming, fast internet access and many more [9, 10].

These emerging technologies are accepted if co-exist with the existing one as an enhancements. The new technologies need to satisfy the mobile ecosystem along with local service providers, existing infrastructures and policies.

2.6 Emerging Technologies in 5G

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 [3, 7, 8]. The brief description of emerging technologies to achieve the defined requirements are:

2.6.1 Massive MIMO

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 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 [11].

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.

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 suffer from pilot contamination from other cells. Effective Channel Estimation/Feedback required incorporated with fast processing algorithms.

2.6.2 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, 12].

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.

2.6.3 Software Defined Network

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].

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 [8].

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.

2.6.4 Millimeter-wave

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

The mm-wave 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 [5, 13].

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

2.6.5 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 for self-organizing networks by increasing frequency reuse, spectral efficiency and energy efficiency. The basic challenges associated with the CR are [11, 14]:

- 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.
- 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.

- 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.
- Routing: the routing mechanism still have rooms for development to ensure security.

2.6.6 Heterogeneous Networks

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 [3, 4].

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

2.6.7 Internet of Things

The Internet of 'everything' (IoT), demand faster connectivity and huge capacity so that it can connect the world with entities. It has changed the concept of connectivity and access. IoT connects people, appliances, vehicles, service based applications and many more with the digital world. IoT forms a major and very important part in the 5G networks as it will seamlessly connects web of users, devices and services [3, 4, 11].

The existing technologies would not be efficient enough to deploy IoT communication and connectivity which dictates higher reliability, vast capacity, faster broadband, connectivity and many more. The applications namely under IoT are Videos services, Rural and urban applications, diverse device connectivity, control and monitoring applications, active response systems and many more.

2.7 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.

5G has to face many challenges before it can be adopted into society. Giants of telecom industries are contending to get 5G standards at the earliest. Existing mobile-broadband technologies will provide sound backbone to overall access technologies. Provisioning Rural Connectivity and Universal Internet Access with affordable broadband will be major challenge before 5G becomes mainstream.

Acknowledgement

Authors would like to thank former researchers from Vishwaniketan namely, Sounak Moulik, Nitish Mital and Sandeep Mukherjee for their contributions that are valuable in preparing this chapter.

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