Chapter 10
Different Aspects of 5G Wireless Network: An Overview

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10.1 Introduction

The remarkable development of cell phones in the recent years has encouraged the researchers to move towards developing 5G technology which is aimed to overcome drawbacks of 4G [1]. There is a dire requirement for wireless technology for wide variety of applications such as IoT (Internet of Things), infotainment systems, and security in vehicles, to name a few [2]. 1G was first afloated in 1979 by Nippon Telegraph and Telephone (NTT) and employed the use of analog signals for data transmission which led to many problems such as data encryption and security [3]. 1G technology provided seamless mobile connectivity introducing voice services. To overcome the challenges of 1G, 2G network Concept was launched in 1991 by Radiolinja in Finland. It had a Data bandwidth of 64 kbps and used TDMA (Time Division Multiple Access) multiplexing. It worked on Circuit switching and PSTN (Public Switched Telephone Network) core network. There was a remarkable improvement in the quality of phone calls and increased the voice capacity [4]. Due to low bandwidth of 2G, the constraint in communication led to concept of packet switching which was used in 3G. Thus 3G was launched as a pre-commercial network in 1998 by NTT Docomo in Japan. It has Data bandwidth of 2 Mbps and uses CDMA (Code Division Multiple Access) multiplexing in the core network. But the spectrum and latency being on the lower side, 4G concept was launched in 2015. It uses Data bandwidth of 1 Gbps and has CDMA multiplexing done in this standard. It works on Packet switching giving mobile ultra-broadband access. Under this

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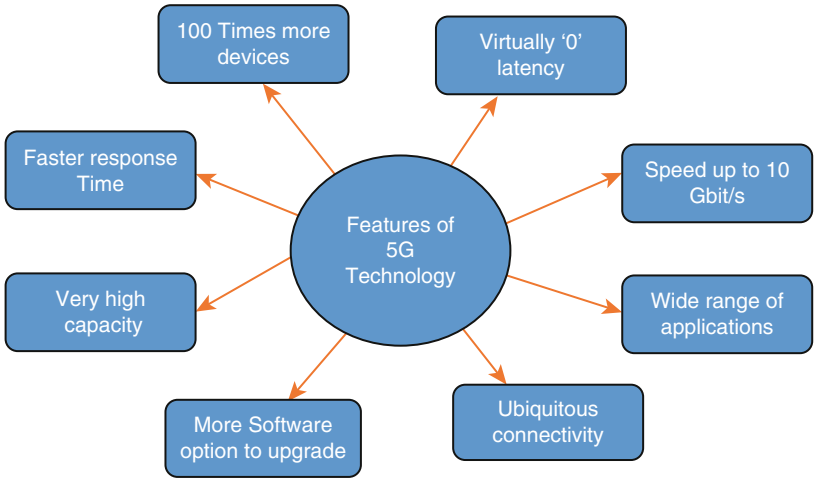

Fig. 10.1 Features of 5G

standard Traditional voice calls were replaced by IP telephony. To increase the data speed and bandwidth usage, 5G was introduced in 2012 at Mobile World Congress. It will have a Data bandwidth of more than 1 Gbps where CDMA multiplexing is done. It works on the concept of packet switching. The 5G mobile network uses OFDM technique and comprises wireless systems which are packet switched and has area coverage which is vast. 5G ranges in frequency from 30 to 300 GHz with high throughput in millimeter, which enables a data speed of 20 Mbps up to 2 km [5]. Wireless World Wide Web (WWWW) applications can be provided by these specifications of 5G [6].

We would like to give different aspects of 5G network in this chapter and discuss on it. This chapter is structured in the following manner. Section 10.2 deals with the related work. Section 10.3 gives an overview of 5G. Section 10.4 deals with the performance parameters of 5G and its evaluation. Section 10.5 deals with implementation of 5G. Section 10.6 presents the challenges in deploying 5G. The chapter is concluded in Sect. 10.7 (Fig. 10.1).

10.2 Related Work

In April 2008, NASA started to develop 5G technology under the supervision of G. Brown and was implemented by Machine-to-Machine Intelligence (M2Mi) Corp [7]. European Union (EU) began exploring the possibilities and options related to 5G technology by launching eight such projects. 5G presented an overview of wireless future communication and €50m was granted for research in this field by EU for 5G deployment by 2020 [8]. The 5G project ought to be a smart and

economical wireless infrastructure which shall use small and light antennas which makes use of directional beam forming that can bounce back signals off buildings using the high-frequency spectrum [9]. EU started another group known as METIS which started on 1 November 2012, in regard of 5G. METIS has proposed these 5G schemes that put forth the challenges in future and shall act as a reference guiding future work. An augmented number of connected devices are handled proficiently along with competent user experience, extended life of battery, less latency and authenticity.

Thus, METIS had a crucial role before global standardization, of awakening consensus for major external stakeholders [10]. The iJOIN EU project was launched in November 2012 which mainly focused on "small cell" technology, which makes use of radio wave spectrum and related limited and planned resources [11]. In the year 2013, Samsung Electronics announced their plan of bringing in a 5G wireless technology. But during testing, the transfer speed was 1.056 Gbit/s for the sent data of 5G network [12]. NTT DoCoMo merged with the following companies and the institutes to come up with the following results in the field of 5G technology.

10.2.1 Ericsson

The area of technology which the trails were related on was architecture of "small cell" which comprised of network which was variegated, 15 GHz frequency bands which included high-speed and high-capacity transmission for the broadband communication. 5G system would be an amalgamation of associated Radio Access technologies which includes some LTE versions [13, 14].

10.2.2 Nokia

NTT Docomo and Nokia consented to cooperate on 5G technologies research and work together on a Concept system of 5G Proof. These two companies continued to work together on the future of radio access systems and to research on potentials of the technology of wave in millimeters at very-high-frequency spectrum band [5].

10.2.3 NEC

Its main agenda was to testify large number of antennas for "small cells" with amplified time-domain beam-forming technologies. Thus, this technology was expected to enhance MIMO technology. MIMO is expected to support mobile data coverage for many users at once and mitigating interference while enabling 5G features such as high speed, better communication, and capacity [5].

10.2.4 Tokyo Institute of Technology

NTT Docomo and TIT worked on a joint experiment and invariably achieved a packet transmission uplink rate of 10 Gbps which is almost 1000 times the rate of LTE prevalent today. A spectrum of 11 GHz and bandwidth of 400 MHz was relayed by a mobile station. Multiplexing various streams of data using 8 transmitting and 16 receiving antennas of similar frequency used MIMO technology [15].

10.2.5 Alcatel-Lucent

Under their perspective, 5G telecom networks shall cater to as per user requirements to build the network the user desires. An advanced, flexible network infrastructure uses interface as air which benefits from both virtual network and networking outlined by software [5].

10.2.6 Fujitsu and DOCOMO

Both built a collaboration for the 5G realization. With the help of experimental practices with DOCOMO, they aspire to testify 5G and thus further endow to society by bringing in further enhancements of IoT and Big Data [16].

10.2.7 Samsung

It designed the world's very first technology using flexible transceiver arrays which operates in Ka bands in the millimeter-wave, it has 28 GHz frequency, ranging till 1.056 Gbps of speed and extending up to 2 km. The technology using flexible transceiver arrays uses around 64 antenna elements, which is used to centralize radio energy in close to surmount the weaker propagated characteristics of millimeter bands, directional bands are used [16].

10.2.8 The Federal Communications Commission

On 14 July 2016, FCC initiated to start using advanced bandwidth in the high-band spectrum which is underutilized and can be used for 5G wireless communications. The Snapdragon X50, the first 5G modem by Qualcomm, was announced on 17 October 2016 as the first commercial 5G mobile chipset. The first ever 5G

deployment was done on 9 February 2018 at Winter Olympics in South Korea. European Union law makers on 2 March 2018 proposed onto a deal of bringing in the 3.6 and 26 GHz bandwidths by 2020 to make adjustments for 5G. Other countries where 5G deployment happened are Australia (by Telstra), Bangladesh (by Huawei), Finland and Estonia (by Elisa), Indonesia (XL Axiata with Nokia), Norway (by Telenor), Philippines (by Global Telecom), and Qatar (by Ooredoo) [17].

10.3 What is 5G?

With the idea of upgrading the present telecommunication standards, 5G concept was proposed to provide large broadcasting of data along with significant improvements in performance parameters. It ought to be a packet switched wireless system to support Virtual Private Network (VPN). It uses CDMA as well as BDMA (Beam Division Multiple Access). The data speed and capacity is expected to be higher than 4G. It aims at providing ubiquitous connectivity, more software options to upgrade, and wide range of applications. Appropriate QoS (Quality of Service) is provided to the people according to their requirements. The main goal of QoS is to give priority to networks with less latency, a checked jitter, and dedicated bandwidth. There is presently no standard for 5G deployment; however international agencies like IEEE, IET, ITU, and FCC are working on the standardization of 5G. The International Telecommunications Union (ITU) has lately started researches which outline stipulations for International Mobile Telecommunications (IMT) 2020.

10.4 Performance Parameters and its Evaluation

Several parameters are considered for inspecting and monitoring quality and performance of the networks.

10.4.1 Network Performance Parameters

Network performance refers to analysis and review of certain attributes in a collective network which help in advancing the service quality. The performance level of a given network can be measured using it as a qualitative and quantitative process. We experienced a varied change in parameters from 4G to 5G which can be stated as under (Table 10.1).

Table 10.1 Changes in network parameters from 4G to 5G

Parameters	4G LTE	5G
Data rates	500 Mbps in 4G	1–10 Gbps in 5G
Capacity	100 s GB/user	36 TB/user
Latency	About 10 ms	About 1 ms
Frequency bands	700–2100 MHz	28–40 GHz
Spectral efficiency (DL)	15 bps/Hz	30 bps/Hz

10.4.2 QoS (Quality of Service) Parameters

QoS Parameters are used to obtain the overall performance of a network a user primarily observes. The parameters being Bit rate, IP packet loss, transmission delay, throughput, and availability.

IP Packet loss: ITU-T recommends that the main stiff QoS packet-loss purpose should be less than 1×10^{-5} for a large end-to-end QoE [18].

Network Availability: Network Availability can determine the total free time of a network which includes the network peripherals such as routers, multiplexers, and switches.

Contention Expected ratio: Around 50:1.

10.4.3 Evaluation of Performance Parameters

Evaluation of any technology plays a crucial role before implementing and maintaining the standard. Henceforth the performance parameters of 5G can be analyzed using the following simulation tools:

WiSE (Wireless Simulator Evolution): It is a dynamic system-level simulator used in evaluation of 4G/LTE with beam-formed channel state information-reference signal (CSI-RS) transmission, Class A precoder for 32 antenna ports and advanced CSI feedback. It has been validated with the Third Generation Partnership Project (3GPP) calibration campaigns [19].

NS3 Network Simulator: It is an open-source network simulator written in C++ and python. The mmWave model is used for 5G network simulation using Evolved Packet Core (EPC). It is written in C++ and provides support for TDD and OFDM.

Opnet Simulator: This simulation tool analyzes the behavior and performance of any given network. It is an event-driven simulator which uses LTE-A model along with IEEE 802.15c standard.

10.5 Implementation of 5G

With an aim to surpass the challenges and successfully deploy the 5G wireless system, certain design notions need to be followed by the 5G architecture. They can be stated as under.

10.5.1 Massive MIMO

It is a sub-six GHz physical layer technology designed for wireless access in future. It uses a large array of antenna elements at base station to serve numerous sovereign terminals at the same time. The benefits of massive MIMO can be stated as excellent spectral efficiency and superior energy efficiency. The main characteristics are [20]:

1. Absolute digital processing with antennas having their own RF.
2. Computationally inexpensive decoding algorithms.
3. Array gain which results in closed loop link budget enhancement.

10.5.2 Ultradense Networks (UDN)

UDN has high density of radio resources when compared to current networks. In this network the base station density possibly reaches the user density and the inter site distance is only a few meters. It ought to increment the capacity, competence of radio links energy and obtain an enhanced victimization of spectrum. UDNs can use the prevalent benefits given out by direct transmissions, and density of large nodes brings out novel challenges. Here interference in an UDN which becomes more severe as volatility increases. There may be a large number of strong interferers. Hence the future of 5G wireless network is invariably an ultradense cellular network [20].

10.5.3 Moving Networks (MN)

By moving network, we mean a moving entity, possibly with high or average speed and carrying a few or hundreds of passengers. Thus, it will be required in 5G that moving network users under high mobility can communicate subject to specific Quality of Experience (QoE) constraints, i.e., the communication experience should be similar to non-moving cases. Consequently, more innovative services for moving network users can be realized [21].

10.5.4 D-2-D Communications

Packets of data are exchanged locally in between the devices which makes use of proximity based services. The potential gains involved in D2D cellular communication are:

1. Capacity gain: Practical sharing of spectrum resources between cellular and D2D users leads to this capacity gain.
2. Latency gain: Direct communication between devices without the presence of intermediate infrastructure decreases the inherent latency.
3. User data rate gain: With increase in proximity and convenient propagation conditions with high peak rates, user data rate gain increases [22] (Fig. 10.2).

10.5.5 URC (Ultrareliable Communication)

URC is a communication service which has certain level of enabling a tremendous degree of availability and reliability. Some of the applications of URC are industrial automation connectivity, reliable connectivity in the cloud, and reliable vehicle coordination through wireless communication [23].

10.5.6 Massive Machine Communications (MMC)

It aims at providing measurable connectivity solutions intended for a vast number of network-enabled devices. MMC communication will be connecting more than billions of IP-based devices via 5G wireless network. The concept of MMC comprises a group of radio ICT and approaches which includes access technologies

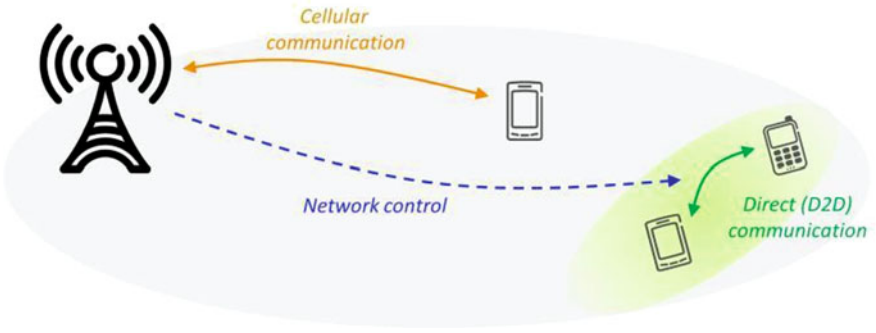

Fig. 10.2 Working of device to device (D2D) communication

such as direct access through a junction, access through an aggregated point, and fiber-optic communication between devices [24–26].

10.6 Challenges in Lieu of 5G Deployment

Though the 5G technology standard seems to be a massive leap in the field of telecom industry, there are certain challenges related to the deployment of this standard. A faction known as RAN (Radio Access Network) Research furnished a report in the year 2015 that coherently predicted 5G implementation to be slow. They stated that until the year 2030, 4G will dominate the wireless technology market. RAN Research even quoted few reasons for the same:

1. Till date 4G hasn't been developed entirely and the 3GPP which is a union of standards and implementation proposes to continue developing 4G till 2020.
2. In the USA, the deployed 4G still doesn't entirely meet the standards of 4G. The wireless companies should continue to make sound advancements to upgrade the existent 4G and thus improve the cellular telecom technology according to RAN Research [27].

10.6.1 Radiation Hazards

As cited in the Los Angeles Times, there is a potential increase in the radiation due to the up shoot of the number of transmitters and receivers and an array of new Internet-enabled devices is deployed to bring in new evolving telecom standards. The harmful effects of radio frequency radiation have left a grim persistence in mobile technology [27, 28].

Studies show that the biological effects which are caused due to the exposure to the radiations of RF are disturbance in cell metabolism, decrease in melatonin, and breakage of DNA strands.

10.6.2 Bandwidth Utilization

5G shall use both low (lower than 1 GHz) and high frequency (between 1 and 6 GHz) and frequencies greater than 6 GHz, referred to as "millimeter wave" frequencies. The 5G spectrum guarantees extended coverage due to the presence of low frequencies, very less power consumption, and high speed owing to the large channels in VHF bands. Thus, the diversity in the bands will be useful in meeting up every aspect of 5G and provide a harmonized global framework [19].

10.6.3 Efficient Medium Access Control

In a network, which consists of a large amount of access nodes and terminals of user, the user throughput will inherently be low, there will be an increased latency, and the number of hotspots in cellular technology won't be enough to cater high throughput. So there is a need for extensive research to optimize this efficient medium access control technology [29].

10.6.4 Traffic Management

Due to the presence of a large amount of Machine to Machine (M2M) devices a cell contains, there will be a serious system challenge which will give rise to overload and congestion, when compared to inherent human to human traffic in a wireless telecom network [29].

10.6.5 Communication, Navigation, and Sensing

5G technology in spite of having a strong computational power in order to employ the tremendous volume of data coming from various sources requires large infrastructure support [29].

10.6.6 Security and Privacy

Encryption and protection of personal data is by default the most important challenge 5G shall face. Ambiguity related to privacy, cyber security, and security threats has to be clearly defined by the 5G standards [29].

10.6.7 Legislation of Cyber Law

With the increase in data speed in 5G technology, it may lead to an increase in Cybercrime and other online fraud. Hence a proper cyber law should be drafted which would legislate such online crimes and reduce the effect of cybercrimes in critical agencies like government and political, which is a national and international issue [29].

10.7 Conclusion

In this chapter, we have brought into picture the aspects of various universities and industrial organizations to establish the standardizations of 5G. A number of conglomerates have executed considerable work in order to hasten the process of launching this standard. With the ever advancing and unpredictable future, we should anticipate an augmented pace in change of technology in spite of the presence of numerous hindrances and scope in development of 5G, with a great reliance on the consequences. But this 5G theory makes room for the challenges on which there is scope for further development.

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