Key Enabling Technologies of 5G Wireless Mobile Communication

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Sudhir Sharma[1], M Deivakani[2], K Srinivasa Reddy[3], A K Gnanasekar[4] and G Aparna[5]
[1]Assistant Professor, Birla Institute of Applied Sciences, Bhimtal, Uttarakhand India. e-mail:sudhir.sharma3304@gmail.com
[2]Associate Professor, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India. e-mail:mdeivakani82@gmail.com
[3]Ph.D. Research Scholar, Vels Institute of Science, Technology and Advanced Studies, Chennai, Tamil Nadu, India. e-mail:ksrmlgnlgap@yahoo.co.in
[4]Professor, Rajalakshmi Institute of Technology, Chennai, Tamil Nadu, India. e-mail:gnanasekar.ak@ritchennai.edu.in
[5]Research Scholar, University College of Engineering, Osmania University, Hyderabad, Telangana, India. e-mail:aparnaece27@gmail.com
Corresponding author e-mail: ksrmlgnlgap@yahoo.co.in

Abstract. 5G (fifth generation) is more reliable at a very low cost and provides 10 times more capacity than other generations. Some of the countries namely India, South Korea, San Marino, China have conducted experiments for the implantation of 5G. 5G Wireless Technology used for mobile communication will be expected to be launched in India by 2020. Companies such as Nokia, Ericsson, Intel, AT&T, BT, Qualcomm, Verizon, and Samsung are developing the new wireless mobiles for 5G. High speed, low latency, and high capacity are the main characteristics of 5G for supporting different real-time multimedia. So, there is necessary to develop the 5G enabling technologies. The key enabling technologies used in 5G networks include Device-to-device (D2D) communication, Machine-to-machine (M2M) communication, Millimetre Wave, Quality of Service (QoS), Network Function Virtualization (NFV), Vehicle-to-everything (V2X), Full-Duplex and Green Communication. 5G allows transmitting data at 10-20 Gbps which is 100 times greater than 4G technology which creates new IoT robotic surgery applications. This paper explains about evolution and overview of 5G wireless technology with its features, applications, equipment providers, technological challenges, impact on society, etc. and also describes the architecture of 5G along with its key enabling technologies.
Keywords: 5G, Millimetre Wave, NFV, QoS, WWWW

1. Introduction

During the last decade, mobile communication and wireless networks have advanced more rapidly to develop future generation networks known as 5G which is also used as a worldwide wireless web (WWWW) with lower cost, high capacity, low latency, higher connectivity, and higher data rate. Many organizations, standardization forums, and many projects have been initiated research on 5G to overcome the drawbacks of present technology. Companies such as Nokia, Ericsson, Intel, AT&T, BT, Qualcomm, Verizon and Samsung are developing new wireless mobiles for 5G. 5G wireless networks are used for ultra-high-speed with the enhancement of cellular networks which provide remarkable services. The characteristics of 5G technology include ultra-fast data rate, connectivity, ultra-low latency, densification, ultra-reliability, and responsiveness. The main requirement in 5G is without any limitation of density zone, coverage edge, access policy for supporting high-resolution multimedia (HD) broadcasting service. 5G is integral to several techniques and is faster than 4G networks which provide high-speed broadband services.

5G networks provide facilities such as mp3 recording, camera, audio player, large phone memory and video player, etc. 5G technology deals with wireless multimedia mobile internet networks which makes the complete real wireless world without any limitation and used as WWWW which is supported by IPv6. 5G can be used as a Ubiquitous Computing Paradigm to interconnect anytime, anywhere with anyone across the entire world by reforming the user handsets operates at very higher bandwidths for supporting broadband always. Increased scalability, low latency, high reliability, high spectrum efficiency, throughput, connection density, and energy-efficient mobile communication technology are the most important elements in the evolution of 5G technology. 5G mainly focuses on transmission access, new architecture, spectrum, and Multiple Input and Multiple Output (MIMO) diversity. In 5G, mm-wave bands are used to increase the throughput requirements, and MIMO is used to increase network capacity. In 5G, mm-wave bands use 24-100 GHZ range frequency bands which are capable of supporting a large number of devices and show the performance of outlining requirements of 5G services. In 5G, MIMO uses multiple antennas at both transmitter and receiver stages for transmitting a single channel which increases spectral efficiency and data rate. The methods employed in MIMO increases the network capacity linearly with the number of antennas used. 5G can be formed by interconnecting different technologies, networks, and applications simultaneously for providing services such as voice, data, video, internet, multimedia, and other broadband services.

The earliest paper in 5G Wireless Technology is reported in [1]. In their work, the authors described the growth of 1G-5G along with 5G network architecture with its services. Arun Agarwal et al., [2] had concluded the role of 5G and its functional concept. Rupendra Nath Mitra et al., [3] indicated the research direction and the development of 5G technologies along with the salient features. Guangyi Liu et al., [4] focused on the application of mobile communication and also a demonstration of the efficiency requirements and the capabilities of 5G. Rakesh Kumar Singh et al., [5] explained all generations of mobile technologies along with basic concepts and architecture including its features and offered services to them. David Soldani [6] has defined usage and the technological requirements of 5G and its enabling technologies. Siddhika Arunachalam et al., [7] explained the introduction, evolution, requirements of hardware, and software along with specifications with the architecture of 5G. Uvika Kujur et al., [8 presented a detailed description of the different mobile generation technologies of 5G including its enabling technologies. Swati Yadav et al., [9] described the differences between 1G to 5G with its advantages and disadvantages of each and also explained as 5G as Intelligent Technology. Udit Narayana Kar et al., [10] had given the introduction of 5G and explore about 5G technology.

Kelechi G. Eze et al., [11] explained the features of 5G and also presented a brief introduction to 5G technology. Opeoluwa Tosin Eluwole et al., [12] explained about 1G to 5G technologies with its characteristics of each and also enabling technologies of 5G with current technological trends. Ahmed Elmokashfi et al.,[13] have discussed the overall architecture of 5G NFV, IoT applications, and key enabling technologies. Damanpal Singh et al., [14] defines the communication technology with present and future impact, usage of technologies, and the introduction to 5G along with technical details. Naveen Chhaganlal Rajput [15] explained the requirements of 5G and services provided by 5G. K.L. Bhawan [16] presented an overview of 5G- Key capabilities and applications in detail and also explained as identification of 5G which are providing disruptive capabilities. Mohsen Attaran [17] has focused and discussed 5G as a transformative, disruptive technology. Amit Kr. Jain et al., [18] presented the Overview of 5G, radio spectrum, the architecture of Cognitive Radio (CR), UDRAN, Software-defined networking (SDN), SD, mixed infrastructure, and also impact of 5G network on the Society. Tian Qin et al., [19] enable the history of 5G, working, enhanced capabilities, 5G impact, equipment providers in 5G technology, and its health effects. Pekka Pirinen [20] explained the basic building blocks of the 5G core system and its main challenges and tackling methods along with its capacity boosting technologies.

In this paper, Section 2 deals with an overview of 5G wireless technology with its features, equipment providers, applications, technological challenges, and impact on society, etc. Section 3 deals with architectural details and functionalities. Section 4 deals with the key enabling technologies of 5G. Finally, the last section presents conclusions about 5G wireless communication technology.

2. An Overview on 5G Wireless Technology

2.1. 5G (Fifth Generation)

5G network supports software as well as consultancy and because of switching, router technology is used to provide high connectivity. 5G is more reliable at a very low cost and provides 10 times more capacity than other generations. Instead of service-centric and operator oriented, 5G is consumer-oriented technology as compared to other technologies in which consumers are given priority. Considering some user-oriented features namely storage, security, high speed, low cost, artificial intelligence, etc. led to the development of 5G technology. 5G supports the 4th generation + wireless world wide web (4G + WWWW). WWWW is used to interconnect the entire world and also capable of supporting services and applications. 5G operates using IPv6 protocol which utilizes Code Division Multiple Access, Beam Division Multiple Access, and millimeter wireless which provides larger than 100 Mbps, 1 Gbps at full speed, low speed respectively. 5G works with Orthogonal Frequency Division Multiplexing (OFDM) encoding wireless communication technique and aims to access high-speed unlimited information anytime and anywhere from any location to the entire world. 5G supports a maximum speed of 10-20 Gbps and is used to provide services such as download and upload Ultra HD and 3D Video, allowing remote control of vehicles such as cars and drones which enables the connectivity of IoT devices and creates new applications like robotics surgery. All mobiles in 5G will have an IP address to support advanced billing interfaces and virtual private networks. 5G provides the users with zero latency and is used for interconnecting 100 billion devices meeting consistent performance across different features such as ultra-high connection density, mobility, and traffic volume density. 5G services are characterized by high mobility or connection density or traffic volume at stadiums, subways, office towers, low-density residential areas, wide-area coverage, high-speed railways, fast ways, and open-air gathering are challenging for 5G. 5G performance is derived for all services such as cloud storage, smart home, Internet of vehicles, virtual reality, augmented reality, OTT, and ultra-high-definition video services. High speed, low latency, and high capacity are the main characteristics of 5G for supporting different real-time multimedia.

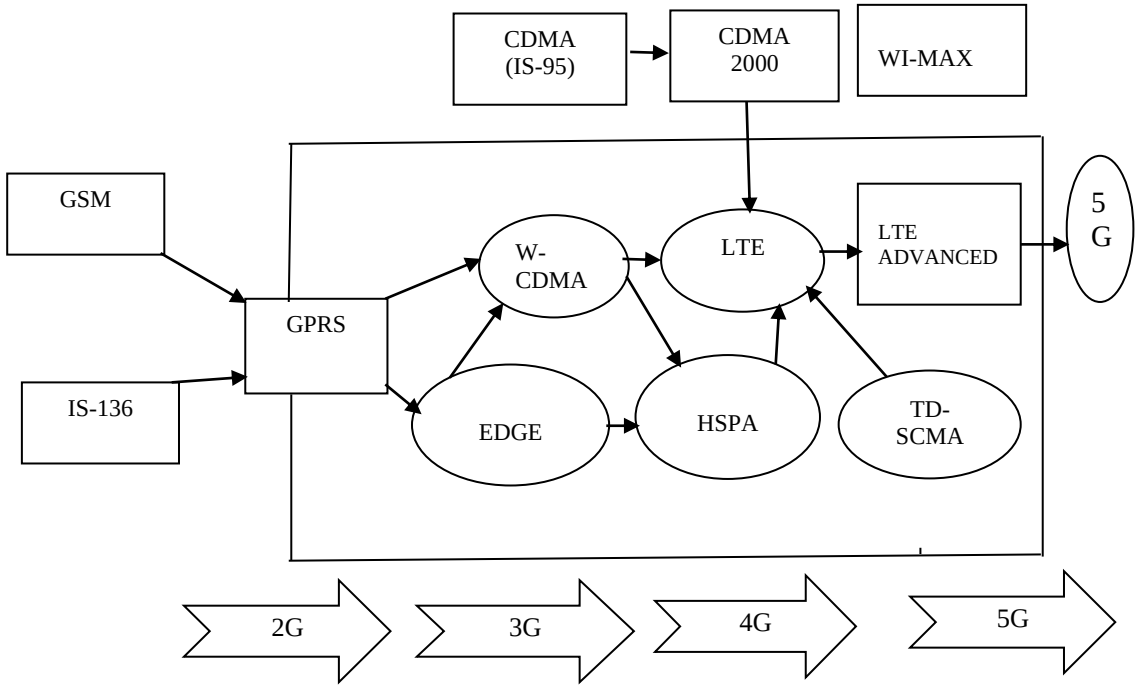

Figure 1. Technological representation of 5G wireless communication

2.2. Features of 5G Mobile Technology

5G wireless technology provides some important features such as

- Higher Resolution and highest bandwidth to provide quality services
- The unified global standard facilitates like service portability and global mobility
- Better and larger network area coverage
- Tools of subscriber supervision for fast action
- Security, Multi-Mode User Terminal, remote diagnostics
- Lower power consumption, enough capacity for unlimited data transfer, ultra-low latency
- Supporting a large number of devices and virtual private networks.
- Architecture as device-centric, distributed, programmable, and cloud-based
- Better connectivity, irrespective of location, lower cost of infrastructure development
- greater speed, possess greater capacity, Reduced Latency
- Energy efficiency and spectral efficiency, multiple data transfer paths, etc.

2.3. Equipment Providers in 5G Technology

Device manufacturers, equipment manufacturers, and operators are all investing in 5G technology as shown in given table 1.

Table 1: Equipment Providers of 5G

Device Manufacturers	MOTOROLA, ONE PLUS (1+), OPPO, ZTE, MI, HONOR, LENOVO
Equipment manufacturers	HUAWEI, ERICSSON, INTEL, QUALCOMM
Operators	VERIZON, SPRINT, T, DOCOMO, BCE, TELUS, ROGERS, SHAW, VIDEOTRAN

2.4. Companies Investing in 5G Technology

- Nokia, Ericsson, and Huawei have invested 21.2%, 17%, 15% of the total revenue towards research and development respectively in 5G technology.
- Nokia and Vitell broadcasted the first end-to-end 5G network in Vietnam and confirmed 42 commercial deals in 5G across the world. Nokia also received $40 million from the Federal Government to research in Canada on 5G wireless technology.

2.5. First Research Done by the Countries on 5G:

2.5.1. India. In India, the first trial was conducted by Huawei and telecom giant Airtel at a network center in Manesar, Gurgaon, and achieved user throughput as more than 3 Gbps using the general set up which consists of 5G core, 50 GE Networking Slicing Router, and 5G Radio Access Network (RAN). This is the highest throughput measured in the 3.5GHz band with 100MHz bandwidth for a mobile network and approximately 1ms end-to-end latency. India will be expected to launch 5G by 2020.

2.5.2. South Korea. The first country which was used 4G in South Korea, therefore developing 5G has become a priority for the government of South Korea and can be seen as the most advanced in 5G deployments. There are two service providers namely SK Telecom uses spectrum in 3.5 and 28GHz and Korea Telecom in 2017 announced that is ready for trial on 5G network ahead of 2018 inter Olympics in Seoul, South Korea and expected to cover events in Gangneung, Bokwang, Seoul, Pyeongchang, and Jeongseon.

2.5.3. San Marino. In Europe, San Marino is the first country that uses 5G networks. Italian Telecom had also tested 5G in Tulin and Milan, but it is found better to test 5G in San Marino than in Italy because of less restriction to use airwaves. By estimating the factors such as utilities, cars, transport, and healthcare, the European Commission issued a 5G plan which results in economic benefits using this technology. Italian Telecom Companies namely Ducati and Maserati have started working on better usage of 5G wireless technology.

2.5.4. China. China has started research and development, testing phase includes novel multiple access, new waveforms, advanced coding, and high-frequency communications, etc. 5G trial phase includes edge computing also network slicing. China Mobile operator is planned to develop 10,000 base stations of 5G. Promotion Groups such as China Telecom, China Unicon, and China Mobiles are operators participating in the IMT-2020 and NTT Docomo is the Japanese Operator.

2.6. Applications of 5G

Using 5G, One can able to

- Vote from his/her mobile.
- Sense tsunami/earthquake before it occurs.
- Expand our coverage by using our mobile phone.

In addition to the above applications, 5G mobile

- Will ring according to our mood
- Can perform radio resource management
- Can share our workload
- Can give our live shares etc.

5G wireless technologies include some of the significant potential applications such as virtual reality/augmented reality/tactile Internet.

2.7. Technological Challenges of 5G

Several transformational challenges occur during the transition from 4G to 5G and these must be tackled for the realization of 5G effectively. 5G faces some challenges with the new technologies enabling 5G. 5G networks, with the highest cost and incompatible with 2G, 3G, and 4G/LTE phone, a requirement for a new phone which is more expensive. To overcome these challenges, need to have a different cellular architecture design and also requires a very long battery life, network scalability, stringent latency, femtocells, and green communications.

To minimize the cost and satisfying all these requirements simultaneously is a challenging task.

- Inter-cell interference is caused by variations in the size of concurrent small and macrocells.
- In efficient Medium Access Control.
- In traffic management.

2.8. Impact of 5G on Society

Fifth-generation networks are used to avoid cell phone broadband connections in rustic regions because installing a huge number of base stations becomes more costly and the average revenue per user will be very less. By using TV White Space and offloading considerations, the installation of 5G networks will be feasible in rustic regions at low cost utilizing a smaller number of base stations operating at high frequency or ultrahigh frequency.

In robotics surgery, a doctor can use VR goggles to perform surgery remotely by haptic feedback instantly. Mobile operators are involved with smart city projects ranging from street lighting, public transit, and water management and also projects related to smart buildings and smart homes which increases the demand for 5G technology. Using 5G, the automobile industry will be completely revolutionized and high revenue for the industry will be generated. Using a high speed of transmission, IoT will be implemented. 5G networks use higher frequency fields that penetrate human tissue causes heat stroke and burns depending on exposure duration, frequency, and temperature increases. But, there is no evidence for these adverse health effects due to exposure to high frequency for the long term than the below thermal threshold.

2.9. Future Span of 5G

- Nano-core combines with artificial intelligence (AI) will be incredible and is the future enhancement.
- Using a mobile phone, one can control robots.
- What our brain thinks, our mobile can automatically type the message.

3. The architecture of 5G Technology

3.1. ISO-OSI Model Layer Protocol Architecture of 5G Mobile Technology

5G technology uses the network layers as shown in figure 2 and is discussed as given below:

5G model/5G Layers	ISO-OSI model Layers
Application Services	Application
	Presentation
Open Transport Protocol (OTA)	Session
	Transport
Upper Network Layer	Network
Lower Network Layer	
Open wireless Architecture (OWA)	Datalink
	Physical

Figure 2. ISO-OSI Layer Model with 5G network

3.1.1. Physical and Datalink Layer. These layers depend upon Open Wireless Architecture in 5G technology.

3.1.2. Network Layer. Internet Protocol (IP) is used in Network Layer. Internet Protocol version 4 (IPv4) has limited address space, which is improved in Internet Protocol version 6 (IPv6) using a larger packet header and still, mobility remains a problem. To overcome this problem, 5G technology uses mobile IP, so that mobile is connected to many wireless networks at the same time. To use 5G for virtual multi wireless networks, the Network layer is divided into two sub-layers.

3.1.3. OTA Layer. For wireless mobile networks, Transmit Control Protocol (TCP) modifications are proposed to retransmit damaged or lost TCP segment through wireless links as it encounters with high speed and higher download. So, 5G plays an important role for mobiles to download updated version reasonably.

3.1.4 Application Layer. In this layer, intelligent algorithms are used to overcome loss values in parameters such as delay, reliability, losses, bandwidth, and jitter in the 5G handset and to provide Quality of Service (QoS). 5G provides an intelligent behavior facility using a large number of algorithms for selecting the best wireless connection among different networks. In this layer, terminals have information storage and access to quality testing.

3.2. Network Architecture of 5G Mobile Technology

For mobile, wireless communication 5G is IP based and to make fast also secure, 5G contains different components in its architecture as shown in figure 3 and is as described below:

3.2.1. General Packet Radio System (GPRS). It is developed during the third generation for internet access towards the end to end wireless communication which provides a data rate from 56 kbps-114 kbps and also provides internet connections to mobile and computer users continuously. During internet access, it consumes very little battery.

3.2.2. Enhanced Data GSM Environment (EDGE). This provides an evolutionary path and is developed to increase the bandwidth of GPRS.

3.2.3. 3G. It is used to access wireless mobile communication with low cost, greater security features, high-quality video calls, and conferences.
3.2.4. WLAN. Wireless Local Area Network (WLAN) provides communication among devices and also with the facility of wireless communication. WLAN provides a high-speed wireless connection that increases productivity, scalability, and mobility.
3.2.5. LTE. Long Term Evaluation (LTE) uses all IP networks and supports voice communication and data. For achieving up to 100Mbps data rate, LTE supports MIMO and becomes a standard for high-speed data transmission for mobile networks. The handoff feature from region to region is smooth which can be supported by LTE with its modified architecture.

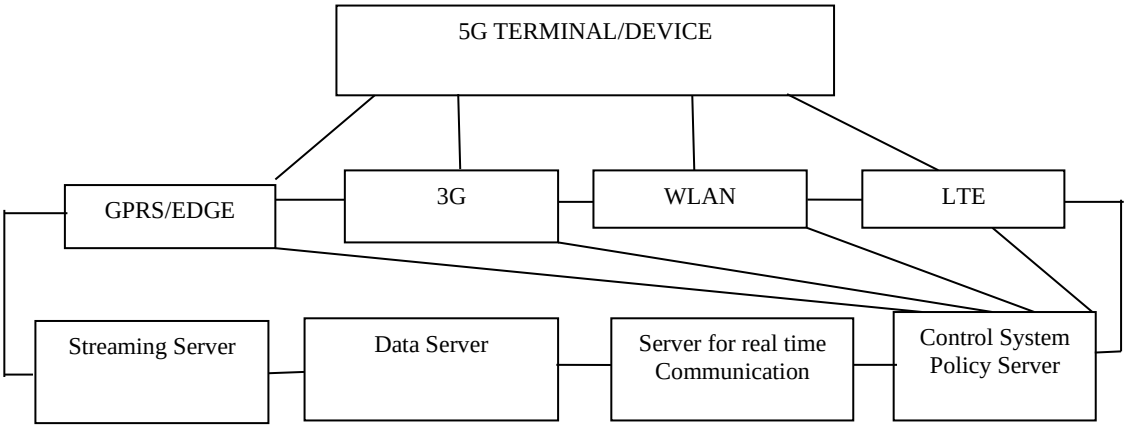

Figure 3. General Architecture diagram of 5G wireless communication

4. Key Enabling Technologies of 5G

4.1. Device-to-Device(D2D) Communication
D2D is considered a key technology used to establish direct connectivity between user equipment (UE). For providing a higher data rate, offering peer-to-peer service, and improving coverage, D2D technology is used and it will be implemented by a 5G cellular network. D2D communication provides several advantages such as coverage expansion, power management, spectrum efficiency, improving capacity with reuse of radio resources which allows network functions to devices that also provide services namely safety, traffic offloading, and location-based proximity services. D2D communication is divided into different types based on intervention with network control from infrastructure such as autonomous, network controlled, and network-assisted D2D.

- In autonomous D2D, devices in the network establish links and communicate with each other in a fully distributed manner similar to ad hoc, each device head handles all functions of the network similar to self-organizing networks.
- In network-controlled D2D, all devices are allowed for data communication only, when the network is fully centralized,
- In network-assisted D2D, infrastructure supports network functions such as security, synchronization, and link management are supported by infrastructure.

D2D communication can be categorized based on spectrum resources as In-band and Out-band D2D. Reuse of radio resources, dedicated resources allow sharing the same spectrum for Cellular and D2D devices in In-band communication. Various spectrums for scientific, industrial, and medical ISM bands are used for cellular networks in Out-band D2D communication without interference between D2D and cellular communications which allows communicating cellular networks and D2D simultaneously.

Communication between two devices without using a base Station in a point to point radio technology is known as D2Dcommunication in cellular networks which generally operate on both in-band or out-band spectrum. D2D communication reduces all of their associated overhead with it by reducing base stations, communications between devices, and datacentre. D2D communication allows Peer to Peer or direct device to device communication which eliminates or base station or IP-based oriented connectivity. D2D communication can use an unlicensed ISM band or licensed cellular band (as in LTE Direct) which can provide security services and resource management from the cellular network.

4.2. Machine-to-Machine(M2M) Communication

For transmitting a small size of sensed data with time constraints, M2M communication is used. According to spectrum resources, two types of Random Access Technologies (RAT) namely Lower Powered Wide Area Networks (LPWAN) and Cellular IoT are used. To handle a large number of simultaneous connections in a large coverage area, the network capacity must be adequate. To enhance energy efficiency and communication, data aggregation and data offloading are used in M2M communication. M2M Communication provides Intelligent machines that automatically done all data generation, processing, and data transfer operations. Deployment with using actuators sensors, machines, and objects that works independently with small or without human assistance is known as M2M communication. For example, sensors are used to record the occupancy of car parking spaces in real-time. In M2M communication over 5G, researchers provided various mechanisms for supporting small data bursts for reducing consumption of power and to avoid network congestion.

4.3. Millimetre Wave (mm-Wave)

Mm Wave in 5G is emerging as a key technology for next-generation in the mobile industry which significantly increasing network capacity, and user experiences. Mm Wave bands have been utilized for large bandwidth 30–300 GHz (1–10 mm wavelength) which supports Gigabit wireless services such as ultra-high-definition TV also very high-speed internet access. The mm-Wave suffers from more path loss compared to microwaves i.e., due to an increase in frequency, the received power is reduced to low. Secondly, because of the rain and atmosphere, the mm-Wave signal suffers from high absorption losses. These are suited for line-of-sight communication and if there are large obstacles in their path, mm waves are highly vulnerable to blockages. To handle narrow beams effectively, mm-Wave systems contain high directional antennas in a large number of arrays which also appropriate for short-range communication. 5G systems use both mm-Wave spectrum and microwave due to limited spatial coverage of mm-Wave. Therefore, to handle mm-Wave and microwave base stations and user equipment uses separate signal processing components. Mm Wave signals are used in cellular access if the base stations are densely installed which enables the highest data rates. The need for a high cost of transmitter and receivers and very high path loss is practically limited. In 5G, many small cells are overlaid on macrocells, and each cell contains its base station interconnecting each with fiber cable becomes much expensive. Hence, the network can be organized with mm-Wave which will be cost-effective, mm-Wave is used for high-speed WLAN, WPAN indoor services in macrocells.

4.4. Quality of Service (QoS)

The control activity for providing good QoS is the measurement of traffic. QoS is used measure the network's ability to obtain the highest bandwidth dealing with performance factors like uptime, latency, and error rate and managing, controlling network resource data types as files, video, audio by setting priorities which can exclusively be used for streaming media, IPTV, online gaming, video conferencing, VOIP and video on demand. To provide priority to networks including controlled jitter, dedicated bandwidth, low latency are the main goals of QoS.

For QoS implementation, fundamental components are used such as:

- To Coordinate QoS, between network elements from end to end, marking and identification techniques are used.
- Single network element with QoS.
- QoS policy, accounting, and management functions are used for controlling and administration end-to-end traffic across a network.

4.5. Network Function Virtualization (NFV). NFV is the observation using SDN. Both NFV and Software-Defined Networking (SDN) are not fully dependent on each other, but they are mutually beneficial. Without using SDN and vice versa, network functions can be virtualized and employed. NFV decouples network functions effectively which implements in software because it is complementary to SDN. The overall network architecture of NFV is more flexible for speed and adaptive reconfiguration which can decouple network functions from hardware devices such as switches and routers centralizing at remote network servers. The important advantages of NFV such as centralized network, hardware savings, an extension of capabilities, reduced power consumption through equipment consolidation, cost minimization, physical versus virtual network management, cloud abstraction, and guaranteed network delivery, and so on. The combined functions of NFV and SDN make more advantages than hardware networks.

4.6. V2X Communication. With the advantage of higher traffic information systems, autonomous cars, and more reliable safety services used for the development of technology for vehicles with low latency, higher data rate, and reliability is known as vehicle-to-everything(V2X) communication which includes vehicle-to-pedestrian (V2P), vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication. For enabling V2X communication, D2D communication for cellular networks is more suitable because D2D provides a long transmission range and short end-to-end latency. With high mobility, it can support road safety services and all nodes move at the highest speeds in vehicular networks. The characteristics of V2X communication are as follows.

- E2E delay: 10-100 ms
- Reliability: 10^{-5}
- Positioning accuracy: 30 cm
- Data rate: 10-40 Mbps

4.7. Full-Duplex and Green Communication

To double the data rate, Full-duplex communication uses the same frequency band and allows both uplink and downlink communication at the same time, whereas the traditional transceivers use half-duplex. To achieve acceptable reception quality, various algorithms are used to suppress self-interference due to outgoing signals from a local antenna.

Green communication is used for reducing energy consumption in which base stations consume a large amount of energy. If a large number of base stations are used, then there is a serious issue for the environment. Energy efficiency can be improved by reducing radiofrequency transmit power. Transmitting reference signals between a base station and user equipment only is necessary rather than in every subframe reduces energy expenditure. Introducing a duty cycle mechanism by shutting down some base stations when traffic is low is also another solution to reduce energy consumption. Green energy sources such as solar or wind energy can also be used by the service providers. Base stations can also be used to provide coordination by transferring the excess of stored energy from one base station to the other base station which has lower energy.

5. Conclusion

This paper presents a brief description of the evolution of 5G mobile communication technology, a discussion about an Overview of 5G wireless technology in detail along with the architecture. Comparison of 5G models along with the ISO-OSI Model, explained in detail about key enabling technologies of 5G is also discussed in this paper, and concluded that 5G works with many devices with higher data rates which is used as WWWW.

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