K. Thakur et al., *Emerging ICT Technologies and Cybersecurity*
https://doi.org/10.1007/978-3-031-27765-8_5

5. 5th Generation Wireless Technology

Kutub Thakur[1] ✉, Al-Sakib Khan Pathan[2] ✉ and Sadia Ismat[3] ✉
(1) Department of Professional Security Studies, New Jersey City University, Jersey City, NJ, USA
(2) Department of Computer Science and Engineering, United International University, Dhaka, Bangladesh
(3) Department of Professional Security Studies, New Jersey City University, Jersey City, NJ, USA

✉ **Kutub Thakur (Corresponding author)**
Email: kthakur@njcu.edu

✉ **Al-Sakib Khan Pathan**
Email: sakib.pathan@gmail.com

✉ **Sadia Ismat**
Email: sismat@njcu.edu

An Introduction to 5G Technology

The fifth-generation technology, precisely referred to as 5G technology, is a wireless technology based on the cellular cells like the existing 4G LTE (Long-Term Evolution) technology network. This technology has

been designed for higher speed, performance, and efficiency in communication network. This is the advanced generation of wireless communication that offers seamless mobility with greater throughput and better utilization of the available wireless and other technological resources used in the materialization of this prospective technology.

There are numerous features, capabilities, and characteristics that make this technology as one of the most futuristic technologies for many years to come. A few very prominent features and characteristics of the 5G technology are summarized below [163–165]:

- It is the latest generation of wireless-based cellular technology developed under the auspice of 3rd Generation Partnership Project (3GPP), which consists of a huge group of numerous technological companies and related organizations that develop advanced wireless communication standards for the advancement of wireless technology.
- 5G technology offers the capabilities to connect every device, people, objects, and machines seamlessly with full mobility and greater data speed to bring forth the fourth industrial revolutions in the world.
- It offers higher peak data speed in multi-Gbps, highly reduced network latency, gigantic capacity of network, greater reliability and availability, huge coverage area, larger number of users, and highly enhanced user experience to the end users.
- 5G technology is also known as heterogeneous network that works on the existing 4G LTE networks by expanding the effectiveness of resource usage with the help of the latest air interface and service layer protocols.
- It uses Orthogonal Frequency Division Multiplexing (OFDM) for signal modulation or encoding across the wide range of channels for reducing the interference between the signals.
- The other technology that improves the speed, performance, and latency of the network is 5G NR air interface, which is also known as "5G New Radio" interface.
- 5G technology is capable of using the combination of multiple spectrums of frequencies, commonly low-band, mid-band, and high-band frequencies simultaneously to increase the capacity of the network and data transmission.

- It operates in 6 GHz bands as well as in 24 GHz bands simultaneously by binding multiple channels of 20 MHz each to form bigger airwave for the transmission of bigger data rates and for the substantial decrease in network latency.
- 5G technology uses massive MIMO (Multiple Input, Multiple Output) antenna technology
- In other words, the 5G technology is capable enough to support multi-bands such as low, mid, and high as well as all types of spectrums such as shared spectrums, licensed and unlicensed spectrums of frequencies simultaneously.
- The designed capacity of 5G network is 100 times the increase in capacity of the network as well as network efficiency.
- It can provide about 20Gbps peak data speed and more than 100 Mbps average data transmission rate.
- The basic working principle and structure of base-transceiver station (BTS) is almost the same. The area around the base station is divided into sectors which are targeted to provide better airwave for greater data transmission.
- 5G wireless technology supports 3 channels of 100 MHz to combine in low and mid bands and up to 8 channels of 100 MHz to form 800 MHz combined band for data usage to increase the speed multiple times as compared to the LTE 4G technology. In fact, the latter combines 7 channels of 20 MHz capacity to form 140 MHz spectrum for data transmission.
- For combining, splitting, and sharing of the frequency channels, both 4G and 5G use Dynamic Spectrum Sharing (DSS) protocol.

Importance of 5G Technology

5G wireless technology is the next-generation technology, which is going to impact all spheres of life, business, society, governments, industries, procedures, and a range of related technologies simultaneously one way or the other. This huge impact on numerous domains is due to the power of 5G technology characterized by high-speed, adoptability, low-latency, enormous capacity, improved performance, greater efficiency, reduced carbon footprints, super-smooth mobility, and many others. All those features, characteristics,

and capabilities of this next-generation wireless cellular technology make it highly important for all above-mentioned domains. Let us explore the importance of 5G with respect to a few major domains [166, 167].

- **Automation**—5G technology accelerates the process of automation in a range of fields such as home automation, industrial automation, office automation, business process automation, cybersecurity management, and many others by leveraging the high-speed, huge capacity, and reduced latency in the network response.
- **Governments**—The importance of 5G for the governments is very huge in different departments and sectors such as land-records, smart cities, utility management, virtual monitoring, defense and security, voting systems, and so on. Thus, 5G can help governments exploit the available potential in all government sectors substantially —via wireless connectivity.
- **Social life**—In the social life, 5G enhances the standards of life by creating a great level of user experience in communication, web surfing, service utilization, software-driven services, telemedicine, well-being, infrastructure improvement and many others.
- **Modern technologies**—The most futuristic technologies such as IoT, cloud computing, software defined networks (SDN), network function virtualization (NFV), and many other emerging technologies can only get materialized if the communication bandwidth is faster, with greater capacity, low-latency, and better efficiency. All those features are provided by the 5G technology to realize those modern technologies.
- **Cybersecurity**—Though 5G technology can pose a few major challenges for the cybersecurity personnel to maintain the high-level security of an enormous network of billions of devices connected through a range of technologies and domains, it offers better opportunity for the security experts to leverage the power of 5G technology to develop faster and effective solutions that can monitor and avert the emerging cybersecurity threats in the real-time environment.
- **Industry 4.0**—The fourth industrial revolution, precisely referred to as 4IR or industry 4.0, is the fourth revolution in the world industry powered by the heavy automation, artificial intelligence, cloud

computing, cognitive computing, cyber-physical systems (CPS), industrial internet of things (IIoT) and many others. All those modern industrial concepts cannot produce the desired objectives until a power network with greater capacity, speed, performance, and latency is available to use. The 5th generation wireless network comes into play to fill that gap in both last mile as well as the core levels of communication networks.

- **Remote workplace**—With the advent of 5G technology, the domain of remote workplace will expand exponentially by using a range of heavy platforms to work in the real-time work environment powered video, audio, and other effective means of communication, collaboration, and coordination like a global office or workspace.
- **Healthcare**—5G can improve the performance or remote healthcare services and applications significantly. The remote medicine will get more benefits from the emergence of next-generation (5G) technology. E-Healthcare can be greatly benefited.

In a nutshell, the fifth-generation wireless technology will revolutionize all processes, applications, businesses, industries, governments, and social activities tremendously.

Evolution of Cellular Networks

Cellular networks have evolved through 4 decades out of numerous analog as well as digital technologies with task-specific applications and communication protocols. Roughly, the start of the cellular wireless technology dates back to 1980s when formal deployment of a cell-based communication system was done. The subsequent events, ages, and generations of cellar technologies are summarized in the following categories [168].

First Generation (1G)

The 1st generation cellular technologies can be tracked back in 1960s with very primitive research and development that pave for the starting mark of the first-generation technology of cellular communication. The main features of 1G technology include:

- The first-generation technologies started in 1979 when a commercial communication system based on cellular technology was launched in Tokyo, Japan.
- Later in 1980s, numerous countries launched the same in different names such as AMPS (USA), NMT (Nordic), and others.
- The 1st generation technologies used 800 MHz band for voice and signaling based on frequency division multiple access (FDMA) technology.
- This technology was analog wireless technology; so, highly prone to interference and numerous other disadvantages.
- The first-generation technology was limited to just voice calls with no support for text or any other software-based other applications.
- The initial paging networks are also considered as the part of first-generation wireless networks.

Second Generation (2G)

The second-generation cellular networks evolved to digital networks from the first generation (1G) analog networks. The frequency used by the second-generation networks was the same as used in the 1G networks. The main features and characteristics of the second-generation cellular wireless mobile technology are summarized as follow:

- Along with voice, the 2G technology supported text messaging, multimedia messages, and very low-speed Internet services simultaneously
- The operating frequencies of this technology were 1800 and 900 MHz bands
- It used the time division multiple access (TDMA) instead of frequency division multiple access (FDMA) modulation used in 1G analog technology
- For improving the Internet speed, additional technologies such as General Packet Radio Service (GPRS) and Enhanced Data Rate for GSM Evolution (EDGE) were introduced on the 2G networks powered by Global Systems for Mobile Communication, precisely known as GSM, which was launched in 1991 in Finland.

Third Generation (3G)

3G cellular technology is based on the core structure of wireless network governed by the Universal Mobile Telecommunication Systems (UMTS) standard for the core network to provide better Internet speed and performance. The other examples of 3G wireless technologies include IS95 (Interim Standard 95) used in the USA, CDMA-One, CDMA2000, and others. The most salient characteristics, capabilities, and features of 3G cellular technology include:

- The first role out of 3G technology-based networks was started in 1998.
- It offered better speeds up to 21.6 Mbps under HSPA + (Evolved High Speed Packet Access plus) technology stack enhancement. Initially, it was able to support up to 2 Mbps under different internet standards and technologies such as 1xRTT, 1XEv-DO, and others.
- At the core of the network, this technology started utilizing packet switching to improve the data throughput and performance of the data transmission as compared to the circuit switching used in the 2G and 1G networks at the core network.
- The operational frequency band of the 3G technology was 2100 MHz with channels bands of 15–20 MHz frequencies.

Fourth Generation (4G)

The fourth-generation cellular technology was developed under the consortium of 3rd Generation Partnership Project (3GPP) standard body. The most fundamental technology that refers to the evolution of the fourth-generation technology is known as Long Term Evolution (LTE). Meanwhile, the Wi-Max version is for fixed and mobile wireless communication. The other features and capabilities of 4G technology include:

- First launched in 2009 in Norway.
- It was released in two version referred to as R8 and R9.
- 4G uses Orthogonal Frequency Division Multiplexing (OFDM) as the core wireless modulation technology along with the support for multiple input and multiple output capabilities of wireless antenna for increased throughput.
- This technology mostly operates at 700 MHz band and supports high speed services based on video streaming, voice, and other

multimedia systems.
- The average peak speed supported by the 4G networks was up to 50 Mbps and average speed ranging in between 15 and 20 Mbps in real-world environments.

Fifth Generation (5G)

Fifth-generation of wireless technology is considered as the futuristic technology, which is capable of providing about 100 times faster speed as compared to the predecessor (4G) technology. It has reduced latency and improved performance by utilizing the modern supportive wireless and core technologies to build this state-of-the-art technology. This technology is designed to support up to 10 Gbps Internet speed with very negligible latency resulting in highly desirable user experience and a range of service portfolios. The other information on 5G is described in different categories in this chapter with enough details and related factual information.

Sixth Generation (6G)

The sixth-generation (6G) technology is under development and research phase. This technology has not materialized yet. It can be characterized as an upcoming futuristic technology. The available details of this technology will be discussed in Chap. 10 of this book when talking about the futuristic technologies of the world in telecommunication and information technology (which is also related to cyberspace and cybersecurity).

Key Features and Capabilities of 5G Technology

The fifth-generation technology is known for its greater features, higher capabilities, bigger capacity, faster speeds, and low latencies. The most salient features associated with these categories of characteristics can open up new era of technological revolution in all domains and industries of the modern world. This can enable the interconnectivity of massive networks of networks consisting of different things such as cars, home appliances, sensors, industrial machines, office equipment, traffic signaling systems, drones, mobiles, and many others. This massive connectivity would lead to unprecedented automation in all

businesses, processes, industries, and routine social and governmental activities. This technology can cater about 100 times more devices in a particular area of coverage as compared to the previous major wireless technology known as 4G technology. The speed of this technology can reach up to 100 times faster than 4G speed. The latency has reduced over 200 times as compared to the previous generation of technology. The most salient features, capabilities, and characteristics of 5G technology include [169, 170]:

- Basic characteristics include larger bandwidths, lower latency, and higher capacity.
- The 5G technology was launched in 2019 and will continue expanding for many years to come to reach at its full capacity and potential.
- The reduced latency can produce the response time to any visual event supported by the 5G technology is about 250 times faster than human response. Thus, a driver is about 250 times slower in response to any visual event during driving of a car.
- The speed of Internet supported by the 5G technology is about 10 times faster than the designated speed of 4G technology. 5G can produce as much as 10 Gbps. The bandwidth per unit area is about 1000 times in 5G as compared to the previous technology.
- This technology is specified under the specification of the next generation mobile network alliance (NGMN Alliance).
- The most salient capabilities can be defined as:
  - **eMBB**—Enhanced Mobile Broadband
  - **mMTC**—Massive Machine Type Communication
  - **URLLC**—Ultra-Reliable Low-Latency Communication.
- It uses millimeter waves, which are shorter than the microwave frequencies. Those frequencies increase the bandwidth and data speed significantly. The operating frequencies of 5G technology include 30 and 300 GHz bands.
- The use of high-frequency and millimeter wave-lengths result in higher bandwidth, speed, low latency, and greater capacity.
- It opens up the futuristic opportunities for numerous technologies such as Internet of Things (IoT), virtual reality and augmented reality (AR/VR), driverless vehicles, drones and robotics, and many others.

Architecture of 5G Network

The architecture of 5G wireless network technology is very modular and open powered by more software-defined infrastructure, and extensively open for custom development of interfaces, applications, and services. The architecture uses a few new components, application programming interfaces, cloud computing, edge computing, new radio interfaces, and many other incorporated into different domains of the network. The 3GPP specification describes the architecture of 5G technology into three major components as mentioned below:

- Core transport network
- Radio access network
- Service capabilities.

The complete architecture of 5G network consists of numerous parts of the existing 4G technology infrastructure along with the new additional advanced infrastructure that is fundamental part of the new technology. Thus, the entire architecture can be categorized in different factors as mentioned in below. The technical architecture of 5G networks is shown in Fig. 5.1 with a schematic diagram with different planes of services.

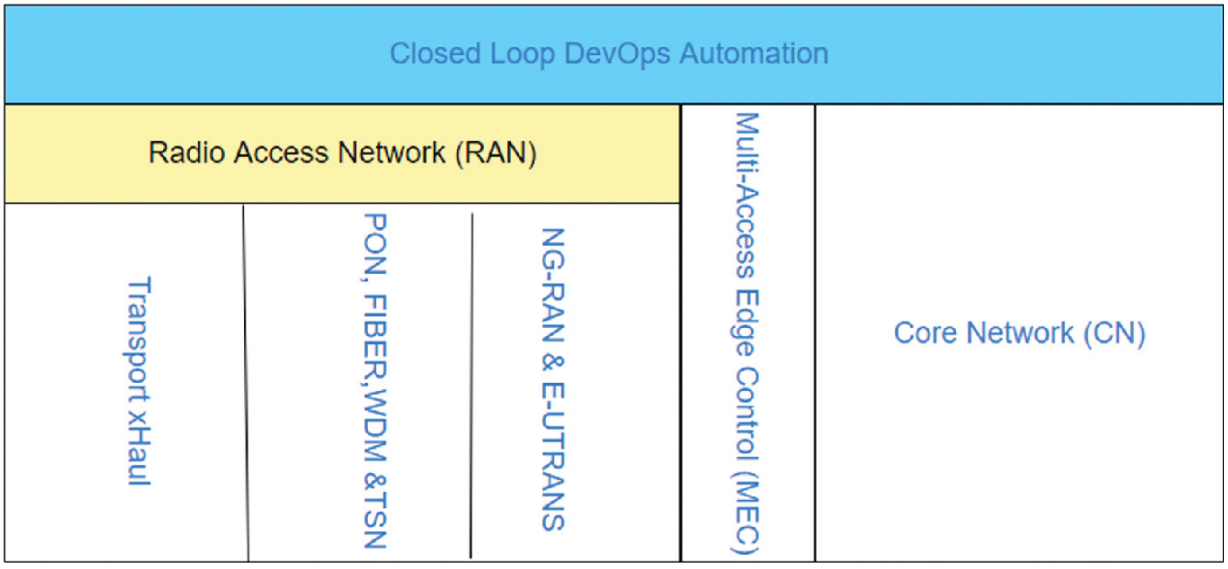

Fig. 5.1 Schematic diagram of different parts of 5G network

The core network consists of the servers, data storages, switches, and security systems sitting at the center of the service processing environment and backhaul transmission networks that interconnect with the core data network and radio access network through a range of specified connections and interfaces. The control layer, commonly referred to as Multi-Access Edge Control (MEC), shown in Fig. 5.1 is the control section of the services that interconnects the radio access network and core network functionalities through different control protocols and software defined services. Different control interconnection and interfaces are defined between the core and radio access network services for establishing different types of service controls among the services supported by the most advanced wireless technology in the world.

The radio access network is more advanced that supports numerous additional features and technologies such as eCPRI (enhanced/evolved Common Public Radio Interface), beamforming, MIMO, 5G NR, and many others. The service capability specifications are defined under a range of protocols and standards. Most of the services are developed through software applications running on the modern data networks reducing the dependency on the costly hardware as mostly used in the traditional telecommunication networks [171, 172].

The Closed-loop DevOps Automation is a development and operations management domain in which the repetitive tasks related to operations and maintenance, performance monitoring and correction, addition of new features and configurations to the services and continual monitoring of the 5G services are done in this domain of architecture. The automation of the operations and maintenance is one of the most powerful capabilities of 5G technology that make it one of the most automated communication systems powered by the DevOps methodology and protocols.

The 5G architecture is highly flexible and open for different level of service providers and users to use the architecture through customized service solutions, software infrastructure and applications. The process of using the same infrastructures for numerous virtual networks through virtualization is known as 5G network slicing. The slicing controller works like a control panel used in the cloud computing for

creating virtual networks based on the shared infrastructure. This is one of the most futuristic capabilities of 5G network that allows different types of business models used for selling and managing services on the shared as well as dedicated virtual networks. 3GPP has also specified 5G network architecture into multi-layers controlled through a management layer known as network slice controller or orchestrator as listed below:

- Infrastructure layer
- Network function layer
- Service layer
- Network slice controller (orchestrator).

The functional architecture of 5G technology is based on four major layers. Each layer consists of different components—both software and hardware that run on the 5G network architecture. Those four service layers are listed below [172]:

- Network layer
- Controller layer
- Management & Orchestration layer
- Service layer.

In the functional architecture of 5G network, the network layer is one of the fundamental layers in which a range of hardware applications used in the previous technologies such as firewalls, routers, load-balancers, and many others are implemented through Network Function Virtualization (NFV), which are designed to decouple the software from the hardware equipment previously used in older technologies in telecommunication. The most prominent examples of network layer include virtualization of appliances, network slicing technology, and others.

The control layer supports advanced software-defined control functionalities such as Intra-Slice Control (ISC) and Cross-Slice Control (XSC) functionalities that are used to establish the control systems between the network layer and Multi-access Edge Computing (MEC) control systems, which are defined to establish a relationship between the core network functionalities to bring them at the cloud computing edge, which is nearer to the end-users for providing seamless and

latency-free services in a shorter span of the distance from the service nodes and the end-users.

The management and orchestration layer of 5G network is highly futuristic layer, which can integrate numerous customized and standard operations and management protocols, tools, methodologies, and procedures. The most common examples of the management and orchestration functionalities supported in the 5th Generation technology include E2E (End-to-end) service management and orchestration, enterprise network management function, 3GPP network management, virtualization MANO (Management and Orchestration), transport network management, and many other customized automation and software defined management services.

The service layer of 5th Generation wireless operations is oriented towards the definition of different types of services defined through software applications in the cloud and connected to the 5G network for public offerings. The most common functions of service layer of the 5G technology include implementation of decision policies, definition of applications and services, and others.

Based on different concepts such as functional, business models, technical, operational, and infrastructure, the fifth-generation networks are classified to be flexible to meet the most complex technical, business and operational needs of the modern world in different scenarios and requirements.

Top Protocols Used in 5G Networks

The fifth-generation network (5G) is the most advanced communication network that uses a wide range of protocols and is capable of communicating with the existing communication protocols and networks along with a huge potential to establish interface with the customized communication protocols to integrate a range of services in the communication models supported by the fifth-generation communication network. A few very important models and protocols used in the 5G networks are described below.

3GPP

The Third-Generation Partnership Project, precisely referred to as 3GPP, is an organization with main focus on developing standards for the wireless telecommunication systems. Primarily, it was established in 1998 to specify the standards for the 3rd generation wireless network mainly focused on GSM core network, but the scope of the work of this standard body evolved and at present, it is the core standard development body behind the latest wireless technology known as 5th generation technology or 5G.

It consists of numerous organization partners that support the development of technology standards, specifications, and protocols for the advancement of the wireless technologies, network element compatibility, forward and backward compatibility, and other issues that can enhance the performance, quality, and value of the wireless communication services in the future. It has the major partners as listed below [173]:

- Association of Radio Industries and Business (ARIB)
- Alliance for Telecommunication Industry Solutions (ATIS)
- China Communication Standards Association (CCSA)
- European Telecommunication Standard Institute (ETSI)
- Telecommunication Standard Development Society India (TSDSI)
- Telecommunication Technology Association (TTA)
- Telecommunication Technology Committee (TTC).

There are three Technical Specification Groups (TSGs) that deal with different domains of wireless technologies for building specification and technical recommendations as listed below:

- Radio Access Network (RAN TSG)
- Service & System Aspect (SA TSG)
- Core Network & Terminals (CT TSG).

Those TSGs are supported by different working groups that meet on a regular basis for updating the standard work on the specified fields.

New Radio (NR)

New Radio is a 5G wireless technology standard developed by 3GPP in collaboration with its partners. This is a standard that defines a wireless interface, which is capable of performing the functionalities

defined under 5G network specifications. The 5G New Radio (NR) is specified under two different standards named as:

- **Non-Standalone NR**—This specification is designed for working compatibility with the existing 4G LTE wireless network to have control systems over the 5G data transfer. This standard was started in 1915 and the specifications were completed by the end of 1917. This specification is released under Release-15 of 3GPP.
- **Standalone NR**—This specification was started as the release 16, which was expected to be available in 2020 but due to COVID-19 pandemic, the release was delayed till 2022. Some works have already been done in this direction. This specification defines both control and data transfers under 5G specification without any control compatibility with the predecessor networks like LTE and others in the system. It will be a pure 5G wireless standard that will provide full power of 5G wireless network with high speed and low latency.

The most common features and specifications of 5G New Radio (NR) are mentioned in the following list [174, 175]:

- Uses two frequency band ranges as specified below:
  - Frequency range 1 (FR1)—410–7125 MHz
  - Frequency range 2 (FR2)—24,250–52,600 MHz.
- Dynamic sharing of frequency bands is possible in the non-standalone mode defined under the Release 15 of 5G NR in which the frequency bands can be shared with the existing 4G networks through 4G network controls and compatible with the 5G network capabilities.
- 5G NR supports 5 different sub-carrier spacing as listed below:
  - 15 kHz carrier spacing defined under FR1 with slot duration of 1 ms
  - 30 kHz carrier spacing defined under FR1 with slot duration of 0.5 ms
  - 60 kHz carrier spacing defined under both FR1 & FR2 with slot duration of 0.25 ms
  - 120 kHz carrier spacing defined under FR2 with slot duration of 0.125 ms

  - 240 kHz carrier spacing defined under FR2 with slot duration of 0.0625 ms.

- This standard was built from scratch to choose the best modulation, access technologies, and waveform to produce high speed wireless standard with very low latency and highly efficient usage of wireless resources.
- It is capable of using a range of frequency bands or spectrums such as 2.5–40 GHz including bands like 3.3–3.8 GHz and also using 4.4–5 GHz extensively.
- It supports optimized access technology such as Optimized Orthogonal Frequency Division Multiplexing (O-OFDM).
- 5G NR support beamforming technology for the user-specific signal transmission to provide the most efficient performance of the available wireless resources.
- Support of Multiple Input Multiple Output (MIMO) was also at the core of 4G technology but it will be more efficient and effective technology supported in the NR 5G radio standard such as Multi-user MIMO in combination with the next generation base station known as gNB in the 5th generation network (which takes the performance of the multiple channels to a new height).
- Supports small cell formation to provide higher data throughput near to the end users.

NextGen Core

NextGen Core is a very important part of 3GPP specification for 5G networks. The NextGen Core plays very crucial role in the core network of the 5G wireless technology to materialize high-speed Internet, virtualized services, and low-latency data transmission to meet the ever-growing demand for the Internet services in the world. The NextGen Core specification defines numerous innovative approaches to the core services based on different modern concepts of technologies such as cloud computing, virtualization, network slicing, and so on.

The most important specifications, features, aspects, and characteristics of NexGen Core protocol are listed below [176]:

- Supports numerous techniques, technologies, and schemes at the core-network service plane to produce high level of flexibility,

efficiency, and scalability.

- Defines software defined networking, precisely known as SDN, which replaces many hardware parts of the traditional mobile core network with software applications for faster access and operations of the services.
- NextGen Core support network functions virtualization, precisely referred to as NFV, which allows a large range of core network functions defined through software to virtualize and use in different schemes on the same hardware by configuring as per requirement of the services so that high performance core network of functions can be built.
- NextGen specifications define a very powerful functionality in which a particular hardware or core network element can be sliced or specified for numerous types of services as per requirements of the users. Each slice of the network can be used for providing unique and customized service as needed by the end-user. This functionality of NextGen Core makes it highly flexible and customized network that can be used independently for unique services for required level of performance on the same software and hardware resources.
- The performance of the NextGen Core network is defined by Next Generation Mobile Network Alliance, precisely known as NGMN Alliance.

LTE Advanced Pro

Long Term Evolution, precisely known as LTE is 4th generation wireless standard. A few more standards were defined for the enhancement of the LTE technologies and service capacity such as LTE Advanced and LTE Advanced Pro. LTE Advanced Pro, precisely known as LTE-A Pro, is a pre-5G wireless technology that can be easily integrated with the 5G non-standalone standard specified under Release 15 of wireless cellular technology. LTE-A Pro is defined under two releases of 3GPP known as Release 13 and Release 14.

The most important characteristics, features, specifications, and capabilities of LTE-A Pro standard are mentioned below [177, 178]:

- It is commonly referred to as pre-5G, 4.9G, 4.5G, and 4.5G Pro because it is predecessor of 5G technology and are compatible with the 5G technology release 15.

- Supports up to 3Gbps speed and 32 carrier aggregation.
- Supports sharing of licensed and unlicensed spectrum under the scheme of license assisted access spectrum sharing.
- It incorporates massive MIMO technologies in wireless transmission.
- LTE-A Pro deploys 256 QAM (Quadrature Amplitude Modulation) modulation scheme for signal coding.
- It is compatible with the first version of 5G and can be integrated with the existing 5G networks with separate control on the transmission systems.
- It is very useful for data-intensive and critical applications that require huge data rates and lower latency with faster speed.

EPC Evolution

Evolved Packet Core is an LTE standard that combines the voice and data through packet switching. This standard was defined by 3GPP project under Release 8. Earlier than this release, the voice calls would use the circuit switches and data calls would use the packet switches. This release paves the way for advanced core network based on the packet switching.

Impact of 5G Technology on Cybersecurity

The fifth-generation network is very different in many ways in comparison with the existing mobile cellular networks. The most important difference between traditional mobile cellular networks up to 4G and the 5G network is the replacement of numerous hardware devices with the software functions or applications such as firewall, routers, load-balancers, and many others. Thus, the traditional approach to the cybersecurity in the 5G environment will not work properly. It is required to change the way people should think about the cybersecurity in the new environment of 5G technologies.

The most important aspects of the 5G networks that pose serious challenges for the security personnel in the modern cybersecurity sphere include the following [179, 180]:

- Transformation of hardware-based switching networks to software-based routing network, which creates a large number of routing

points from where the hackers can intrude into the 5G systems.

- Moving away from the centralized switching systems to distributed systems of routing, which poses another risk for the security of the network.
- Virtualization of network functions poses a serious threat because in the traditional networks of cellular mobiles, the network functions were handled by specified hardware, which is being replaced by the software-defined functions and virtualization of those functions based on the custom-requirements of the users.
- Moving away from the traditional proprietary operating systems on the hardware equipment to the standard Internet protocols poses another very common risk of cybersecurity because every hacker knows about the standard protocols used in the 5G network.
- The network management platform is a software-based application powered by the standard Internet and IP protocols, which would pose a serious risk for the security personnel to cope with. This means, the entire 5G network is very open to attackers to intrude through different access points with its vulnerabilities.
- A huge number of access points and base-station units pose a serious threat at any locality where a hacker can have direct access to the base-station to intrude into the network.
- 5G supports high-speed and high-volume data transmission, which allows users to increase the number of connected devices in the field of the Internet of Things (IoT). Thus, without any proper protocol for the security of the IoT devices, it is a very critical issue to the security of the network of an extensively large network of connected devices.
- Dynamic Spectrum Sharing (DSS) through network slicing is a significant risk to the security of the 5G network because network slicing functionality of 5G network allows multiple streams of information or data to be transmitted through a shared spectrum. The security mechanism should also be dynamic as the spectrum sharing changes.
- There are millions of logged-in mobile users and billions of unregulated entry points to the 5G network which would expand the threat arena multiple times as compared to the traditional cybersecurity threat area.

- Unavailability of security protocols and standards for the Internet of Things (IoT) opens up an expanded risk domain in 5G environment in the form of man-in-the-middle (MITM) attacks through a huge number of connected IoT devices

Based-on the above-mentioned risk factors, it is very clear that the cybersecurity on the 5G should adopt a completely new approaches to cope with the emerging threat domain. The most important steps to properly handle the cybersecurity of the fifth-generation wireless network should include the following:

- A comprehensive cybersecurity plan and investment strategy to manage the security of the 5G networks effectively.
- Proper training of the operators, sub-contractors, and end-users to use the networks and devices more professionally.
- Using VPN (Virtual Private Network) services for connecting devices will be a very good option but may not be feasible for all users and operators.
- A comprehensive collaboration between the operators and governments for devising proper security mechanism and policies is very important.
- A comprehensive collaboration is required among the IoT device manufacturers to follow strict regulations regarding the security of the devices.
- Adaptation of artificial intelligence (AI), machine learning (ML), and other advanced automation technologies for the management of networks is highly desired to cope with the emerging risks of cybersecurity in 5G environment.

Sample Questions and Answers

Q1. **State the main features of 1G technology**.

A1. The main features of 1G technology include: