Challenges, Issues and Role of the 5G Network to the new developments

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Abstract - Due to revolutionary developments in electronic and communication, mobile and handheld devices have become a part of our daily life. As a result, the volume of data traffic on the Internet is increasing day by day. To provide unlimited, uninterrupted and content-rich services to these devices, the 5th Generation (5G) of network technology emerged. A 5G network can provide better Quality of Service (QoS) along with higher data rates than 4G network and have less latency. The paper appraises various generations of wireless networks. Furthermore, it explores various challenges in implementation of the 5G network and application areas of the 5G network.

Keywords: **Internet of Things, Device-to-device communication, Smart Health, Smart farming.**

1. INTRODUCTION

To provide ubiquitous services to mobile devices the cellular system came into existence. Now a-days, Industry and academia both are trying to develop better alternatives to provide high-speed bandwidth and real-time services to mobile devices. 5G enables next generation wireless networks to provide better End-to-End (E2E) connectivity in on-demand fashion. Analysis by Computer Information System Company (CISCO) state that mobile data traffic may increase up-to 4.8 Zettabyte (ZB) [1] per year by 2022, or 396 Exabyte's (EB)/ month, while it was only 1.5 ZB/year or 122 EB/month in 2017. In another analysis by CISCO, it is projected that in 2020, approximately 50 billion smart devices will be linked to the Internet. Figure 1 shows growth of Internet of Things (IoT) enabled devices on the Internet. In the last decade, IoT has reformed the pervasive computing due to numerous application areas such as smart city, smart agricultural, smart health etc. The IoT paradigm encompasses a group of smart devices and sensor nodes. Sensor nodes monitor the predefined parameters and shares via the Internet. In an analysis, it is found that there will be billions of devices with on average six to seven devices per person by the year 2020 [2]. In 2022, more than one trillion sensor nodes will be attached to the Internet. It is also expected that in the next twenty years approximately forty-five trillion devices will be attached to the Internet. To provide uninterrupted services to these mobile devices is compelling to search for an alternative to 4G. It is an assumption that a new generation of cellular is proposed approximately every Ten years. The last generation of cellular network, i.e. 4G network was introduced in 2011 and it is expected that 5G [3] network may be standardised and deployed in 2020.

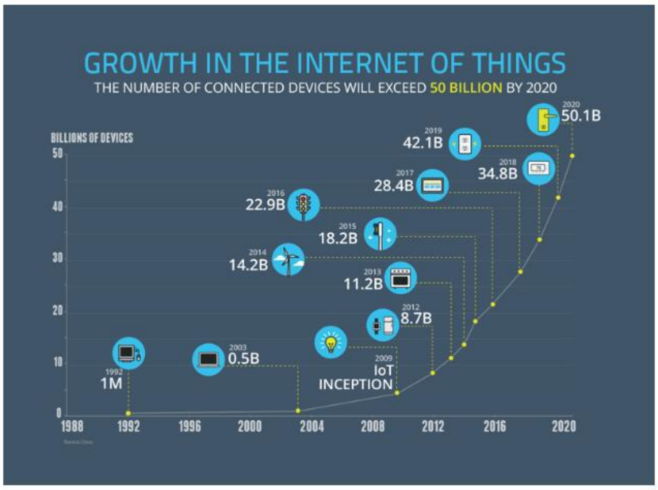

Fig.1. Growth of IoT enabled devices on Internet

The scope of the 5G is not limited to the radio technology; it can also provide services to fixed host communication, cloud infrastructure, etc. The extension services of the 5G mobile network improve the ecosystem of the telecommunication network and provide services to the healthcare industry, agriculture industry, and smart city projects in an energy efficient manner. 5G builds the foundation of digitalization from personal communication to the interconnection of society. Digitalization builds incredible prospects for mobile communication but suffers from severe challenges towards mobile communication technologies.

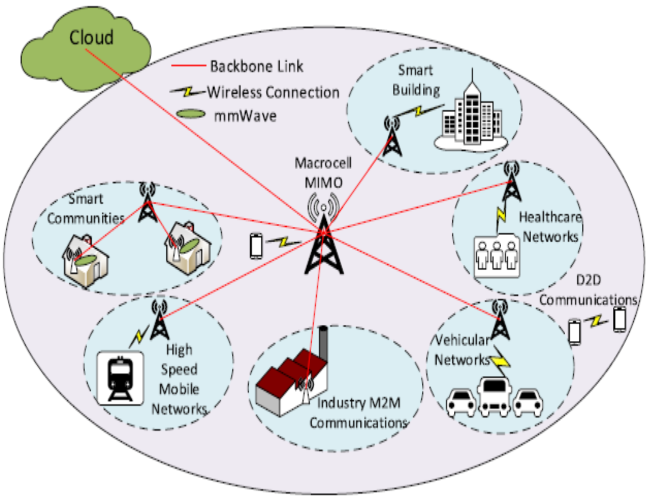

Fig. 2. Application area and technologies of 5G

1.2 First Generation Networks (1G)

The First Generation (1G) wireless networks were standardized in early 1981 for voice communication. It was able to handle data transfer speeds of up-to 2.4kbps. The most popular 1G-access technologies were Advanced Mobile Phone System (AMPS), Nordic Mobile Phone System (NMTS), Total Access Communication System (TACS) etc. Analog signals were responsible for carrying out voice in 1G. It suffers from various issues such as low graded signal quality, low capacity, less secure and unreliable handoff.

1.3 Second Generation Networks (2G)

The Second Generation (2G) of wireless networks was standardized in 1990. It was primarily used for voice communication and was able to handle data transfer speeds up-to 64kbps. It was also able to data communication with limited speed. The most popular 2G-access technologies were Global Systems for Mobile communications (GSM), Code Division Multiple Access (CDMA) and IS-95. 2G technology was also able to send text messages, picture messages, and MMS Multimedia Messaging Services (MMS). It is also able to provide secure point-to-point communication i.e. only the intended receiver can receive and read the message. 2G was suffering from some of the critical issues such as low data rate, limited capacity of cells, higher handover latency, limited mobility etc. Also the 2G enabled phones have limited facilities.

1.4 Extension to Second Generation Networks (2.5G)

It was an extension of second-generation wireless systems. It introduces a packet-based switching technique known as General Packet Radio Services (GPRS). Furthermore, it is able to provide better communication by use of packet switching and circuit switching techniques along with services provided by 2G. It is able to handle data transfer speed up to 144kbps. The most popular 2.5G-access technologies were GPRS, Code Division Multiple Access-2000 (CDMA2000) and Enhanced Data Rate for GSM Evolution (EDGE).

1.5 Third Generation Networks (3G)

F.Third Generation (3G) wireless networks were standardized in 2000. The basic objective to design 2G was voice communication and high-speed data transfer up to 2Mbps. The most popular 3G-access technologies were Wideband Code Division Multiple Access (WCDMA), CDMA2000 and Universal Mobile Telecommunications Systems (UMTS) technologies. To utilize the benefits of 3G

1.6 Extension to Third Generation Networks (3.5G)

It was an extension of 3G wireless networks and standardized in 2008. It was primarily designed to improve the data rate of present 3G networks and was able to handle data transfer speeds of up to 3.6Mbps. The most popular 3G-access technologies were HSDPA (High Speed Downlink Packet Access) and HSUPA (High Speed Uplink Packet Access). The 3.75G system was proposed as an improved version of the 3G network. The technology used in it was High Speed Packet Access Plus (HSPA+). The technology used in it was known as Long-Term Evolution technology (LTE) and Fixed Worldwide Interoperability for Microwave Access (WIMAX). These technologies are able to provide high-speed services such as on demand videos, composite web services, social media services etc. to multiple users simultaneously. Although 3G technology brings a radical change in the field of communication it suffers from expensive implementation, compatibility issues with 2G systems, heavy radiation of magnetic waves affects our brains etc.

1.7 Fourth Generation Networks (4G)

Fourth Generation (4G) wireless networks were standardised in 2010. 4G is designed to handle data transfer speed up to 300Mbps along with Quality of Service (QoS). In 4G, the user can watch online High Definition (HD) video and can play online games. The most popular 4G-access technologies are Voice over LTE network VoLTE (use IP packets for voice). 3G Partnership Project A. (3GPP) is presently standardising Long Term Evolution (LTE). It reduces latency for critical applications and provides secure mobility. It also supports IoT enabled devices to interact in an efficient manner. Like 3G, 4G is also costlier in terms of hardware and implementation. For communication, it requires high-end multifunctional devices, which should be compatible with 4G technology.

B. 3G and 4G systems mainly focus on delivery of contents to mobile devices rather than efficient delivery. the 5G wireless network is able to provide services to billions of devices with latency close to zero. It is expected that 5G will be standardised in 2020. 5G can handle data transfer speed up to 10Gbps along with QoS. Higher speed allows watching online Ultra High Definition (UHD) video and playing online games

C. Smartphone-based specific applications were developed to handle video calling, online games, email service, social media services such as Face book and Orkut etc.

2. ISSUES AND CHALLENGES IN DEVELOPMENT OF 5G NETWORK

Challenges are an inherent part of the new development. The primary objective of 5G is to provide high-speed mobile broadband and better throughput along with ultra-low latency, high reliability and security in comparison to 3G or 4G networks

2.1 High Data Rates and Increased Network Capacity along with Energy Optimization

5G has a complex infrastructure. Within a smaller geographical region, it requires a large number of Base Stations (BS) to install. It will increase high data transfer rate and reduce the energy consumption, although it will increase the cost of the network. To achieve high-speed, Cognitive Radio Networks (CRN) and Massive Multiple Input and Multiple Output (m MIMO) [11] architecture will be deployed. To increase the efficiency m MIMO uses a large number of antennas in comparison to communicating devices. The m MIMO uses frequency range 30-300 GHz and wavelength 1-10 mm.

2.2 High Data Rates, Network Capacity expansion with Energy Optimization Full Duplex Communication Channel

4G network uses half-duplex [6] communication i.e. there are two separate channels one for uploading and another for downloading. On the other hand, 5G is designed for full duplex communication i.e. it will access the same channel for access and backhaul. Although it will increase link capacity, save the frequency spectrum and be economically better, practical implementation is very difficult due to interference. Therefore, it also requires a mechanism to cancel the impact of interference.

2.3 Environmentally Friendly

4G Radio Network (RN) consumes approximately 70-80% of total power. This leads to emission of CO_2 in a large amount and creates a negative impact on the environment. Various solutions are proposed in 5G for the same. It includes Cloud-Radio Network (CRN), Visual Light Communication (VLC), millimeter wave (mm Wave) communication, D2D communication, Massive Multiple Input and Multiple Output (m MIMO) architectures to make 5G environmental friendly

2.4 Low Latency and High Reliability

The roundtrip latency of the 4G network is around 15 milliseconds (ms). It is assumed that the 5G network will have extremely low latency and result in lower packet loss and improve the reliability of the network. To achieve this, efficient caching [12], mm Wave, m MIMO architecture can be incorporated in 5G network

2.5 Network Performance Optimization

The 5G network will have extremely low latency. It will directly affect the quality of service, end-to-end delivery, ease of connectivity, reliability etc., To improve QoS [5], delay bound QoS, intelligent equipment and load balancing schemes are incorporated.

2.6 High Mobility and Handover

5G network will be based on small cell network architecture rather than Base Station (BS) centric architecture or more precisely device centre architecture. The cell may be a microcell or picocell. These cells are connected through ideal or non-ideal backhaul architecture [13]. Due to smaller cells, there will be high mobility and handover [14-17].

2.7 Security and Privacy for Network and Mobile Hosts

The traditional mobile communication networks focus on communication services to individual customers whereas 5Gfocus on individual as well as industry-oriented services. The mobile IoT devices need less security whereas high-speed mobile services require high security. The major security challenges in 5G networks are Denial of Service (DoS) attack, hijacking attacks, signalling storms, Resource (slice) theft, security keys exposure, IMSI catching attacks, IP spoofing, scanning attacks, TCP level attacks, Man-in-the-middle attack, configuration attacks, penetration attacks, user-identity theft attack etc.

2.8 Data Volumes

The exponential growth in mobile users and IoT devices increases the volume of data on the Internet. 4G networks may not be able handle such a huge volume of data. The 5G network is capable of handling large amounts of data between end devices with the help of optimized architecture.

2.9 Device-to-device (D2D) Communication

D2D [18] communications are mostly outside the territory of present cellular networks. These direct links directly communicate without involving the base station in communication. The walkie-talkie is an example of this but for communication a narrow spectrum is available and hence a bandwidth is available to communicate. The 5G system enables multi-RAT (Radio Access Technologies) systems for seamless communication. The D2D communication may be single-hop or multi-hop. 5G allows D2D communication using LTE-Advanced, LTE Advanced Pro. Figure 3 shows a high-speed D2D communication model in 5G.

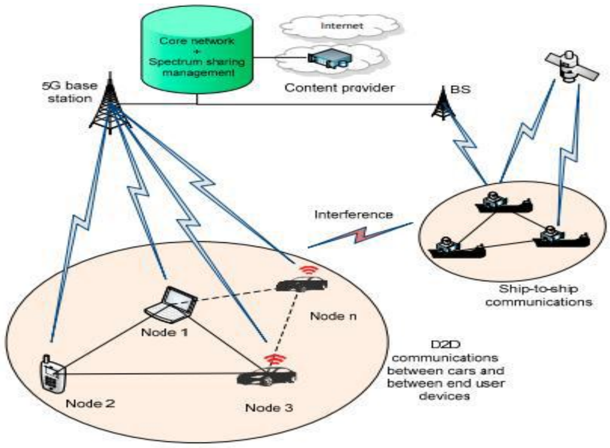

Fig. 3 D2D communication model in 5G

3. APPLICATION AREA OF 5G NETWORKS

It is presumed that 5G will be up to 100 times faster than the present cellular system with lowest latency and quality of services. The future application area may include:

3.1 Immersive Entertainment

As the number of users on the Internet is increasing exponentially, it is difficult to provide live high definition videos to end users due to limited bandwidth capacity of 4G network and it is near to impossible to deliver ultra-high definition videos. The 5G network will be able to support the immersive entertainment [19] anywhere at any time due to low latency and big bandwidth offered by it. 5G is able to project live virtual reality streams of sports, adventures, and real world images on a Smartphone or head mounted display (augmented reality). Figure 4, shows a head mounted Immersive Entertainment device.

Fig.4. Head mounted Immersive Entertainment device

3.2 Environmental Monitoring

Monitoring the changes in the environment is one of the most critical challenges to the world. Living beings suffer from sudden change in the climate due to unknown natural and environmental disasters, e.g., storm, flooding, drought, tsunami etc. Sensor nodes [20] are fixed at remote locations to monitor the environment [21] and the 5G network transmits the information immediately. By doing this, we can save the lives of living beings. Recently, we have seen people lost due to the tsunami in Jakarta, Indonesia. Figure 5 shows measuring of environmental data with the help of sensor nodes.

Fig.5. Measuring of Environmental Data

3.3 Smart Agriculture

The Indian agricultural system is based on traditional technique. Smart Agricultural [22] is a modern technique to monitor and automate the agricultural system to increase the quantity and quality of agricultural products. Smart agricultural systems gather real-time information about crops with the help of sensor nodes installed in the field. 5G is capable of sharing up-to-date information measured by sensor nodes. The information may be analyzed using Fog or Cloud computing and sent to the specific user to whom it is valuable. Smart farming has a number of application areas such as water management, injection of fertilizers, soil amendment, livestock safety and maturity monitoring, crop status, drilling, seeding and spraying, temperature, humidity, etc. In association with the Department of Telecommunications (DoT), Samsung had announced its plan of commencing the First large-scale 5G trials in India Figure 6, shows smart agriculture system using 5G network

Fig.6. Smart Agriculture System with 5G network

3.4 Smart Metering

In existing metering systems, analog or digital electricity meters are mounted at the consumer place. It measures the consumption of electricity based on power used by electric equipment. These meters can be tampered very easily even without a trace. It indirectly affects the economy of the country. Smart meter [23] is an advanced technique to measure the consumption of energy. It records the frequency and voltage in real time fashion and communicates the recorded information to the central system using wireless media. The information consists of timestamp, Unique ID (UID) of meter, current reading of meter, maximum power supplied by meter etc. Smart meters allow controlling and balancing of the load remotely i.e. increase or decrease the load on demand. 5G is capable enough to provide services like a smart metering system in real time fashion.

Fig.7. Smart Metering System with 5G network

A study in 2016, for the European Commission estimated that in Europe, smart meters with 5G data capabilities could provide annual benefits of €6.47bn in 2025, rising to €7.37bn in 2030 [24]. Figure 7 shows a smart metering system using a 5G network.

3.5 Smart Health

The recent developments and advancement in the field of medical technology significantly improves the living standard of people and makes them healthier. Still healthcare services [25] rural areas are worst due to unavailability of doctors, medical information, and medical services. As a result, healthcare is a critical issue in both urban and remote areas. 5G, robotics and artificial intelligence are able to provide healthcare services to patients from anywhere. The patient health can monitored with the help of virtual visits i.e. tiny sensor nodes may implanted or attached to wearable cloths and these nodes are able to monitor vital parameters such as blood pressure, sugar level, heartbeat, anxiety etc. on real time basis and sends the information to the hospitals and relatives on real time basis. These records will be available to physicians and medical professionals anytime and anywhere for investigation. 5G will not only be cost efficient but also provide convenience and better and timelier medical outcomes. 5G can transmit large imaging files efficiently. According to research, it is estimated that the telemedicine market may increase at a compound annual growth-rate of 16.5% from 2017 to 2023 [26]. Telemedicine requires a high-speed data transmission network that may send real-time high-quality video wirelessly. 5G enables high-speed connectivity among a series of connected sensor nodes, cloud-based storage and services. 5G will allow cloud-based storage of electronic medical records of individual patients. The 5G system will allow continuous monitoring, predictive analytics, remote diagnosis and imaging, efficient management of these records, which may have medical images and video. Figure 8, shows a smart health system using a 5G network.

Fig.8. Smart Health System with 5G network

3.6 Remote Object Manipulation

Remote object manipulation science [27] is in its childhood. It allows performing some actions / operations by an object at a remote location. A non-living object such as a robot performs the operation. This may include surgery, diffusion of bomb/mines, etc. According to the report, approximately 48% of patients are ready to accept remote robotic surgery, whereas 61% people believe that robotic surgery is very risky as it depends on Internet services. The 5G network is capable of providing ubiquitous networks for remote services. Healthcare industry, IoT industry and M

3.8 Internet of Vehicles (IoV)

Vehicular Ad-hoc Network (VANET) is a subclass of Mobile Ad-hoc Network (MANET) [28] and Internet of Vehicles [29]. In VANET, the vehicles communicate with another vehicles, acknowledged as Vehicle-to-Vehicle (V2V) communication or fixed infrastructure Road Side Units (RSUs), acknowledged as Vehicle-to-Infrastructure (V2I) communication, continually to gather information about road conditions, traffic, congestions etc. A large number of vehicles are moving on the road and to exchange up-to-date information the communication delay must be least. 5G is capable of exchanging real-time information among vehicles connected through the Internet. 5G is capable enough to provide services to the Intelligent Transportation System (ITS) . Figure 9, shows ITS enabled vehicles connected through the Internet via the 5G network.

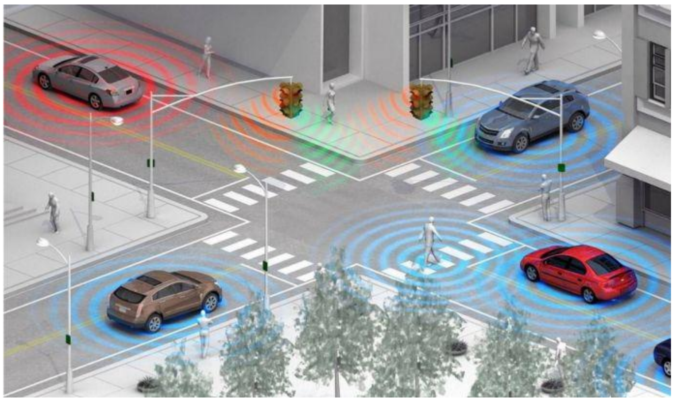

Fig.9. Vehicles connected through Internet via 5G network

3.9 Smart Wearable's

5G makes life easier for these gadgets, doing away with any requirement of top-end, overtly costly processors. 5G will lend them the required computing power and therein, the superfast speed and reliable connectivity that they need to do justice to the user. The combination of 5G and wearable's [30] are expected to be so powerful that it will make the Smartphone revolution seems like a miniscule advancement. In a technical report, it is found that wearable and artificial intelligence devices improve the performance of the healthcare sector by monitoring various vital parameters related to human health. Figure 10, shows a smart wearable wristwatch with 5G network.

Fig.10. Smart Wearable wristwatch through 5G network

3.10 Mobile Video Surveillance

Security is one of the critical issues of smart cities. The security can be managed by mobile video surveillance [31]. It may be part of trains, metros, buses, taxis, transport vehicles, police cars, drones etc. 5G is able to provide real time updates for each movement of the above.

3.11 Smart Transportation

Traffic congestion is one of the major challenges to society nowadays. It indirectly affects the productivity of industries, creates environmental pollution and degrades the quality of life in society. 5G technologies are able to collect huge amounts of data real-time information from vehicles, drivers, road sensors and cameras installed at the side. It will help to manage traffic flow [32]. For example, it can manage the traffic signals according to density of traffic and road usage and limit traffic entering a congestion zone. Figure 11, shows an example of a public transportation system connected through 5G network

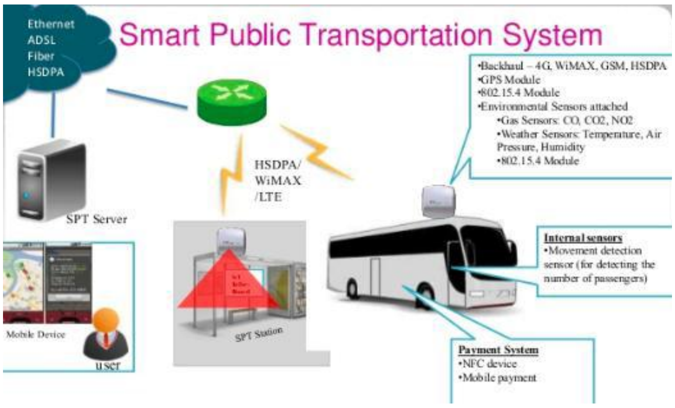

Fig.11. Smart Transportation system connected through 5G

3.12 Smart Home

A smart home is a house in which most of the home appliances such as light, refrigerator, televisions, air conditioners, security system etc. are monitored and controlled through the Internet. A node in general is a Smartphone connected to the Internet. These appliances are equipped with IoT sensor nodes [33-34] and controlled using Low-Power Wireless Personal Area Networks (Lo WPAN) mobile communication protocol. Figure 12, shows an example of a smart home connected through a 5G network.

Fig.12. Smart Homes connected through 5G network

4. CONCLUSIONS

Rapid development in IT and electronic industries focuses on development of hand-held and tiny sensor devices. These sensor nodes, especially IoT enabled devices, form a network. A high-speed data network is required for communication among these devices. 4G is unable to meet the demand of bandwidth and latency. As a result, industries and researchers presented 5G as an alternative to 4G. 5G networks are capable of meeting industry requirements. Initially the paper briefly introduced various wireless generations. Furthermore, the paper discusses various issues and challenges in implementation of 5G networks and its solutions. IoT devices have numerous application areas. Hence, later on, the paper explores the various application areas of the 5G network.

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