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4. Recent Advancement and Future Perspective of 6G Communication

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Abstract:

A number of intelligent applications are being integrated with the advent of 5G wireless communications technology. However, the 5G specs strongly fall short of the demands of new, developing technologies. Data rate, capacity, latency, resource sharing, and energy per bit are a few of these. Research is concentrating on 6G wireless communications, which is allowing many technologies and creating new applications, to satisfy these demanding requirements. The integration of terrestrial, aerial, and marine communications into the sixth- generation (6G) wireless communication network is anticipated to result in a strong network that is more dependable, quick, and capable of supporting a sizable number of devices with ultra-low latency needs. Researchers from all across the world are putting forth cutting-edge technologies including blockchain, terahertz and millimetre wave communication, tactile internet, non-orthogonal multiple access (NOMA), tiny cell communication, fog/edge computing, and artificial intelligence/machine learning. As the foundational technology for the development of communications beyond 5G and 6G. We give a thorough analysis of the 6G network dimensions with air interface and related prospective technologies in this post. More precisely, we emphasize the various characteristics and use cases of the planned 6G networks. We also go through the B5G/6G network's key performance indicators (KPI), difficulties, and potential future research areas.

Keywords:

6G, Machine learning, Artificial intelligence, Quantum communication, Blockchain, IoT, Cloud.

4.1 Introduction:

A new communication system has been launched almost every 10 years, enhancing QoS and adding new features and technology. Although 5G has not yet been formally released, 6G communication system is the focus of current research. The rationale is that 5G offers a high- standard infrastructure that makes a range of technologies possible, including self-driving cars, artificial intelligence, mobile broadband communication, the Internet of Things, and smart cities. The use of smart gadgets, however, is expanding year over year and will continue to dramatically rise as time goes on, placing limitations on the 5G communication network.

The focus of research on 6G mobile cellular systems has started now that the launch of 5G systems is well underway. It is anticipated that a 6G system will be standardized, with deployments beginning around 2030, continuing the history of a new generation of cellular system every ten years or so. It is time to start looking into novel technology components for 6G as it frequently takes more than 10 years for a unique technology to become commercially viable.

The goal of this work is to develop a vision of future communications that will serve as guide for future research. We make an effort to present a comprehensive picture of communication requirements and technology in the 6G era. Some of these needs could already be able to be satisfied by integrating new technologies into the 5G framework. In general, we anticipate that any changes that can be made to the 5G framework in a backward-compatible manner and at a fair cost to satisfy new performance needs will be implemented as part of the 5G evolution.

On the other hand, the next generation will include changes that represent a fundamental shift and are incompatible with the current 5G architecture or can only be implemented at a significant cost to the network or devices. In addition to providing customers with improved mobile broadband, it is anticipated that 5G would allow Industry 4.0 by digitalizing and connecting all objects, large and small the fundamental framework of the future digital world will be made up of digital twins of diverse items that were formed in edge clouds. Future digital services will be built on an essential foundation that will include digital twin worlds of both biological and physical things.

It will take a tremendous amount of capacity with low latency to realize a full digital world that is an accurate and complete depiction of the physical world at every spatial and temporal instant. The emergence of new virtual worlds with digital representations of made-up items that may be integrated in various ways with the digital twin world to create a mixed-reality, super-physical world will also be made possible by the advent of digitalization. With the development of wearable devices like smart watches and heart rate monitors as well as ingestible, implantable, body arm or skeleton, and brain activity detectors, human biology will be precisely mapped every moment and integrated into the digital and virtual worlds, opening the door to new superhuman abilities. User interfaces for augmented reality will make it possible for humans to effectively and intuitively govern all of these worlds, whether they be physical, virtual, or biological. Along with the new communication requirements, the following key new themes emerge when considering such a future: (i) end devices evolving from single entities to a collection of numerous local entities working together to create the new man-machine interface; (ii) ubiquitous universal computing distributed among numerous local devices and the cloud; (iii) knowledge systems that store, process, and transform data into actionable knowledge; and (iv) precision sensing. Several publications have recently expressed their opinions on 6G. We use a special and broader viewpoint, concentrating not only on the technological developments but also the expected human transformation in the 6G era, which aids in giving an understanding of the performance specifications and design concepts for 6G. Our perspective on the changes in technology begins with the current state of 5G networks, moves to how they are changing, and then considers what may drastically change after that. We also discuss potential changes to the type of standards required in an era of open platforms.

4.2 Related Work:

Deep learning for network anomaly, fault diagnosis, intrusion detection and prevention, network configuration, and optimization has been investigated, Muhammad Waseem Akhtar et al. [1].

6G has the option to send data with the highest level of security. The aforementioned security issues will be made worse by the addition of the Internet of Everything to 6G and the provision of additional management, including smart homes, emergency clinics, transportation, smart grids, etc, SamarElmeadawy et al. [2]. We can easily make our drones smarter by utilizing artificial intelligence and 6G connection. Smart robots will be able to share their knowledge and provide faster online data transfer since they will be equipped with drone-to-drone and drone-to-infrastructures for communication, SamarElmeadawy et al. [3].

Following the 6G vision and service specifications, some use case concepts for the 6G, including autonomous vehicles, smart cities, flying networks, holographic, telemedicine, and tactile internet, are described, Ashish Kr. Gupta et al. [4]. The possibility for autonomous 6G wireless systems is offered by AI technology. Intelligent agents are capable of actively and automatically identifying and fixing network problems. AI-based network management helps maintain network health by monitoring network status in real-time. Additionally, AI approaches can give edge devices and edge computers intelligence, enabling them to have the ability to understand how to resolve security issues on their own. Also anticipated with 6G are autonomous applications like autonomous robots and autonomous aerial vehicles, Zhengquan Zhang et al. [5]. Some technologies, such as index modulation, artificial intelligence, intelligent surfaces, simultaneous wireless information, power transmission, etc., are highlighted in existing studies as potentially crucial for 6G. Our paper discusses the benefits and drawbacks of these technologies and provides recommendations for further research on 6G applications, Amin Shahrak et al. [6].

Few recent research on 6G offer an overview; instead, they concentrate more on speculating on potential future technologies. Our study examines virtually every 6G vision currently in existence and offers a comprehensive overview, covering both physical and network layer technologies. Furthermore, we give a complete understanding of the current technologies that might be used in 6G based on how well they satisfy the requirements of a potential 6G network, giving a thorough awareness of each technology's specific advantages. Additionally, 6G wireless communications connect the communication systems from the sky to the deep sea using the space-air-ground-sea integrated network (SAGSIN) in order to achieve the goal of global coverage, Ashish Kr. Gupta et al. [7].

Additionally, because blockchains are immutable, unaltered decentralized databases, they are utilized to manage and share the spectrum resources, which may do away with the need for a central authority, Guangbin Xu (CIC Senior Member) et al. [8]. Various candidate technologies have been proposed to overcome the bottleneck of existing wireless communication systems to meet 6G’s requirements. For example, artificial intelligence (AI) is expected to enable a significant paradigm shift in 6G wireless networks, including machine learning, deep learning, etc, Hutesh Baviskar et al. [9].

4.3 Application:

Every communication system opens the door to new features and applications. 5G was the first generation to introduce AI, automation and smart cities. However, these technologies were partially integrated. 6G is introducing more technologies and applications providing higher data rates, high reliability, low latency and secure efficient transmission. Figure 4.1 shows the main applications, trends and technologies introduced in 6G. In this section, some of these technologies and applications 6G are discussed.

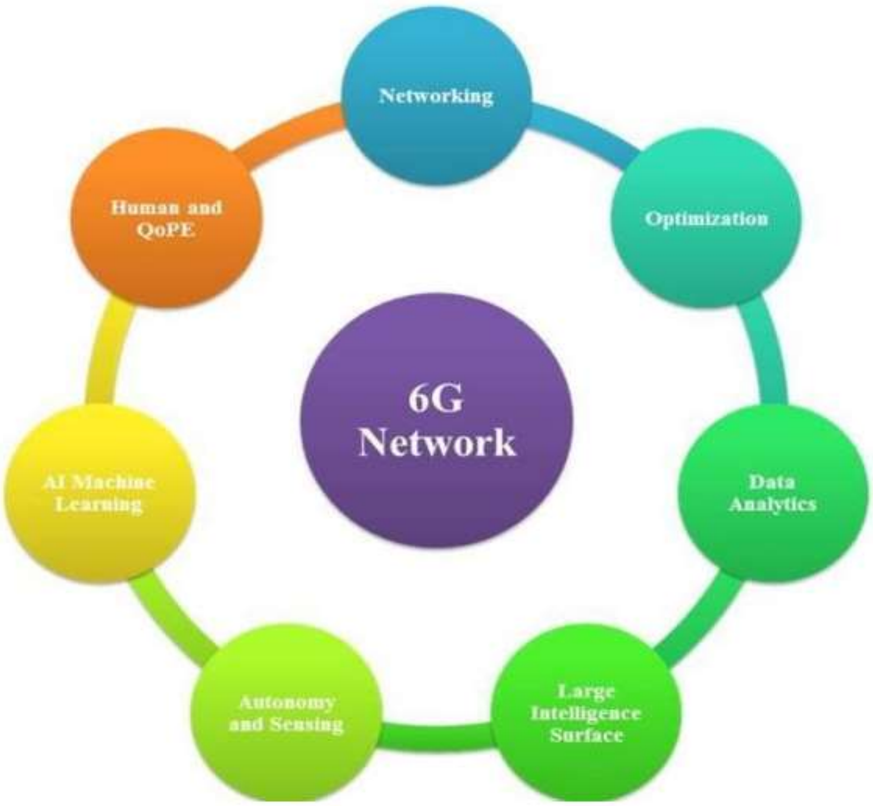

Figure 4.1: The main applications, trends and technologies introduced in 6G

4.3.1 Tera Hertz Communication:

The RF band is almost full and it is not able to support the increasingly growing demand in wireless communications technology. The THz band, ranging from 0.1 THz to 10 THz, will play a crucial role in 6G supplying more bandwidth, more capacity, ultra-high data rates and secure transmission. The THz band will support the development of minuscule cells in nanometre to micrometre dimensions supplying very high-speed communications within a coverage area of up to 10 m and supporting the Internet of Nano-things. Technologies using frequency bands below 0.1 THz cannot support Tbps links, therefore, 6G will be the first wireless communication system supporting Tbps for highspeed communication [4].

4.3.2 Cell-Free Communication:

Unmanned Aerial Vehicles (UAV) were proposed to be used in other generations in places where there is no infrastructure. However, this technology will be fully used in 6G allowing cell-free communication. When the user equipment (UE) moves from one cell coverage to another, the user ‘s call should be transferred to the other cell.

This handover might be unsuccessful and, in some occurrences, the user ‘s call is terminated and the QoS will be reduced in the system. 6G will end the problem of cell coverage as the UE will be connected to the whole network, not a specific cell. Using UAV will allow integrating different technologies allowing the UE to utilize the technology having the best coverage without any manual configurations on the device [6].

4.3.3 Artificial Intelligence:

Artificial Intelligence (AI) was not involved in 4G or any previous generations. It is partially supported by 5G making difference in the telecommunications world opening the doors for emerging remarkable applications such as. However, AI will be fully supported in 6G for automation. It will be involved in the handover, network selection and resources allocation improving the performance, especially in delay-sensitive applications. AI and machine learning are the most important technologies in 6G [2].

4.3.4 Holographic Beamforming (HBF):

Beamforming is using a directed narrow beam with a high gain for transmitting and receiving using antenna arrays by focusing the power in a minimized angular range. It offers better coverage and throughput, higher (SINR) and it could be used to track users. Holographic beamforming is an advanced beamforming approach utilizing (SDA). Holographic refers to using a hologram to achieve beam steering by the antenna, where the antenna is like a holographic plate in an optical hologram. SDAs are cheaper, smaller in size, lighter and require less power compared to the traditional phased arrays or MIMO systems. As C-Swap are considered as the main challenges in any communication system designs, using SDAs in HBF will allow flexible and efficient transmitting and receiving in 6G [8].

4.3.5 Extended Reality:

Extended reality (XR) is a new umbrella term including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). VR is a computer-simulated reality experience using a headset that generates sounds and images creating an imaginary world. AR uses the real world and adds to it using a specific device such as the mobile phone.

Audios, videos, Global Positioning System (GPS) could be used to create an interactive environment. Pokémon is a well-known example ´ of AR. MR merges between the real and the virtual worlds creating a complex environment. XR is all the real and virtual environment combined. 6G will be very useful for this feature due to the strong connectivity, high data rate, high resolution and low latency [4].

4.3.6 Blockchain Technology:

The data in the blockchain technology are represented as distributed blocks connected to each other and cryptographically secured. Blockchain will be used in managing and organizing big data and in managing huge connectivity in 6G.

It will be used also in spectrum sharing allowing the users to share the same spectrum solving the problem of huge spectrum requirements in 6G and guaranteeing secure, low cost, smart and efficient spectrum utilization. Integrating the blockchain with AI and using Deep reinforcement learning will improve the QoS allowing smart-resources sharing, implementing an advanced caching scheme and making the network more flexible [1].

4.3.7 Automation:

Currently, researchers focus on automation, robotics and autonomous systems. 6G will support these technologies providing direct communication between them and the server and direct communication between them, i.e.: robot to robot communication and robot to the server communication. Full automation will be provided by 6G including automatic control processes, automatic systems and automatic devices. 6G will support the existence of Unmanned Aerial Vehicles (UAV) which will be used in wireless communications providing high data rates instead of the traditional base stations (BS) [2].

4.3.8 Wireless Power Transfer:

Wireless energy transfer will be involved in 6G, providing suitable power to the batteries in devices such as; smartphones and sensors. The base stations in 6G will be used for transferring power as Wireless Information and Energy Transfer (WIET) uses the same fields and waves used in communication systems. WIET is an innovative technology that will allow the development of battery fewer smart devices, charging wireless networks and saving the battery life-time of other devices [2].

4.3.9 Wireless Brain-Computer Interface:

Recently wearable devices are increasingly used, some of them are brain-computer interface (BCI) applications. BCI applications involve smart wearable headsets, smart embedded devices and smart body implants.

Using BCI technologies, the brain will easily communicate with external discrete devices which will be responsible for analysing brain signals and translating them. BCI also will involve affective computing technologies, in which devices will function differently depending on the user's mood.

BCI applications were limited because they require more spectrum resources, high bit rate, very low latency and high reliability. However, 6G will support more applications such as the five-sense information transfer, in which 6G will transfer the data generated by the five senses of the human allowing the interaction with the environment [5].

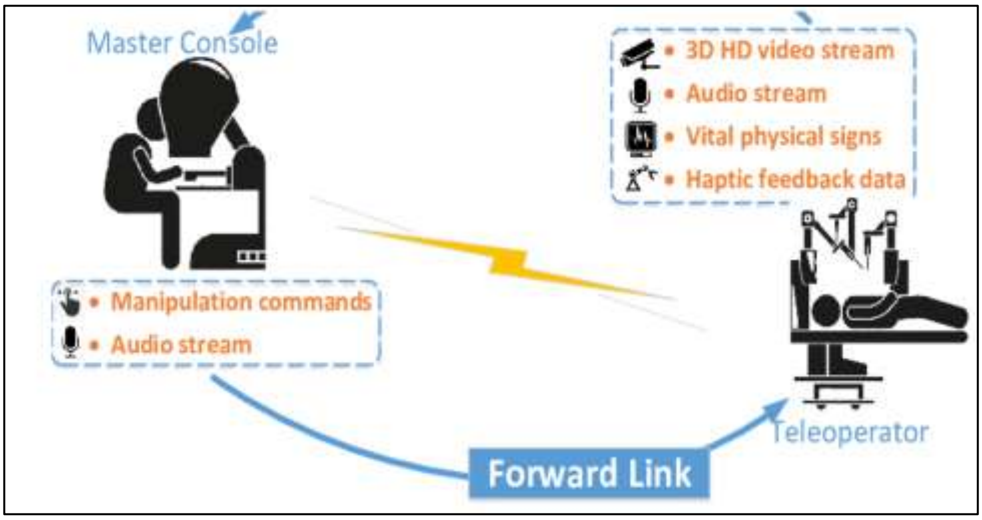

Figure 4.2: A loop explaining the communication between the master console and tele-operator

4.3.10 Healthcare:

The lack of electronic healthcare in other wireless communication technology was because of low data rate and time delay. 6G will provide secure communication, high performance, ultra- low latency, high data rate and high reliability enabling the full existence of remote surgeries as in Figure 4.2 through XR, robotics, automation and AI. Also, the small wavelength due to the THz band supports the communication and the development of nano sensors allowing developing new nanosized devices to operate inside the human body [4].

4.4 Requirements:

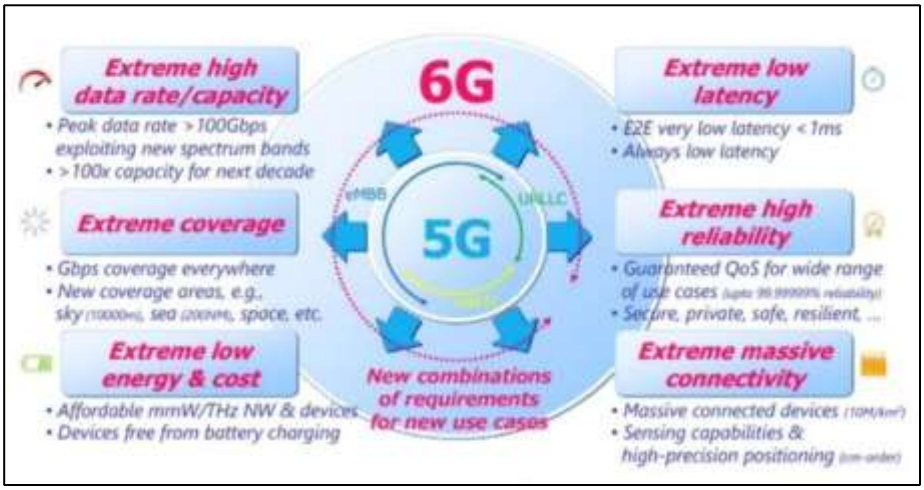

Figure 4.3: The primary requirements of 6G networks

6G System Architecture:

6G mobile networks target ubiquitous intelligence, computing power, and high-speed wireless connectivity throughout air, space, and sea. The vision to achieve this objective is integrating underwater communications and satellite communication networks to provide network coverage throughout the globe [5,13].

There is a need for a super speedy service in 6G mobile networks with data speed close to about 1000 Mbps [11,14]. Some of the requirements of 6G can be listed as – holographic communication, ultra-high broadband, multi-sense transmission, ultra-high throughput, reliability, low latency, etc. [5,15]. Figure 4.3 shows the primary requirements of 6G networks [16].

Probable solutions can be using smaller cell sizes and higher frequency bands. However, smaller sizes of cells will lead to more power consumption and high operational costs, and high frequency bands can suffer path loss. Therefore, we have to put a limit to decrease the size of cells and increase the frequency bands. Fully-decoupled radio access network (FD-RAN) architecture has been proposed, where the network functionalities are fully decoupled and will be deployed by every independent network entity. Implementation of multi-point coordination and centralized resource management can obtain an elastic resource cooperation in a fully decoupled RAN. The control base station of FD-RAN co-ordinates with decoupled uplink and decoupled downlink in a centralized way, which has a similar architecture as cloud-RAN [14].

6G will use a very wide variety of computing, networking, communications, and many sensing technologies to offer smart applications. The key enablers are AI, edge-intelligence, blockchain, homomorphic encryption, network slicing, and integrated network for space, sea, and ground. Fig3: shows the requirement of 6G wireless connection.

4.5 Technologies & Recent Advancement:

4.5.1 Evolution of Earlier Mobile Networks:

A. Evolution from 1G to 4G:

In the 1980s, the 1G network was initially intended simply to provide voice communications. It does not adhere to a specified wireless standard and instead transports data using analog modulation methods. There are a number of problems facing this generation, including handover, security, and transmission. Digital modulation techniques, such as TDMA, are utilized in the second generation of mobile phones to supply voice and text messaging services. The GSM mobile communication method is widely used in our day and age. 2G authentication employs the challenge and answer method. Since its introduction in 2000, the 3G network has offered users download and upload speeds of up to 2Mbps. Today's technology makes it possible to access services like TV streaming, internet browsing, and video streaming at a speed never before possible in mobile communication.

B. Evolution of 5G:

Data speeds may improve as the 5G network approaches commercialization due to complicated systems and high-security architecture. The ability of 5G to connect a growing number of devices while yet providing higher-quality services to all network users makes it unique.

C. 5G Timeline:

A initiative to construct Internal Mobile Telecommunications (IMT) networks for 2020 and beyond was launched by the ITU-R in 2012. In 2013, the European Commission provided funding for 5G networks as a part of its Horizon 2020 program. Verizon's own 5G radio technology was tested in 2016, while the ITU-R published their vision for IMT-2020 in 2015. In 2016, the US FCC allowed high-band spectrum for 5G wireless services, and the first 5G release was approved by the 3GPP in 2017[7]. Leading Chinese carriers tested 5G in urban areas, and 5G applications were on display at the Pyeongchang Winter Olympics. In 2018, the UK spent £1.4 billion on 2.3 GHz and 3.44 GHz spectrum, and AT&T launched a new mobile 5G service in significant urban areas. 2020 saw the completion of the 5G standard, Release 16 (NR Phase 2), with China having more than 100 million subscribers. The COVID-19 epidemic prevented the 3GPP Release 17 standards from being finished in 2020. In Japan, 5G technology will be used for smart city applications during the 2021 Summer Olympics in Tokyo. In 2022, Release 17 is anticipated to be finished. Three billion 5G mobile users, or 28% of all mobile subscribers, are expected by 2025. In April 2021, the 3rd Generation Partnership Project (3GPP) announced 5G Advanced, an update to the existing standard that would add capabilities and improve efficiency. 5G Advanced, according to Nokia's Bell Labs, delivers high capabilities, extreme connectivity, and high security. enhanced significantly MIMO 5G Advanced enhances Massive Multiple-Input, Multiple-Output (MIMO) performance in a 5G network. When several antennas are utilized at the transmitter and receiver, data transmission speeds may be enhanced. Massive MIMO is the practice of expanding a system's transmitters and receivers to accommodate a large number of users [11]. Bell Labs predicts that base stations that can manage 64 to 512 transceivers will be necessary for 5G Advanced and subsequent standards. As a consequence, commercial networks using 5G Advanced technologies will be better equipped to support networks with lots of high-throughput data users. Below, we go through the advanced 5G's plans and features that have been realized. decreasing capacity Release 17's standard will include RedCap (Reduced Capacity). RedCap, a 3GPP modification to Release 17's specification, outlines how 5G-capable devices would consume less bandwidth under the new standard. RedCap allows wearable and IoT devices to operate on a 20 MHz channel as opposed to the 100 MHz channel that 5G NR typically uses. While the bandwidth requirements for RedCap devices are decreased in Release 18, reliability with current 5G NR and RedCap devices will be preserved. By supplying time references directly from the network, 5G Advanced seeks to increase accuracy in milliseconds. The upgrade freeze for 3GPP Release 17 will affect enterprise customers and is anticipated to persist until the second quarter of 2022. By enhancing cellular positioning accuracy to under 10 cm, 5G Advanced will also improve. 5G Advanced will facilitate communication in extended reality (XR) and increased energy efficiency.

Release 18, which is scheduled for implementation in 18 to 24 months, will include system updates from AT&T Labs, including vertical services. It is anticipated that the current 5G phase would significantly enhance data speed, location, time, and coverage, laying the groundwork for the development of 6G [3]. Future lifestyles, industries, and civilizations will depend on next-generation wireless networks since future 6G applications will have higher requirements and a larger network capacity than existing 5G networks. Wireless communication will significantly advance by the year 2030, with 6G serving as a crucial communication and informational backbone. For demanding applications like virtual, augmented, and mixed reality, the next generation of wireless networks should enable high data speeds, reduced end-to-end latency, higher dependability, large cell capacity, and wider coverage area. A very low latency communication, a peak data rate of at least 1 Tb/s, high mobility, huge capacity owing to IoE, reduced energy consumption, a data rate nearing 10 Gb/s, spectrum efficiency, and strong 3D coverage extension are among the requirements that the future generation should meet. Future 6G scenarios include intelligent society, intelligent life, and intelligent production. Three categories—smart production, smart life, and smart society— are used to group these scenarios. After 2030, the digital economy could outgrow itself, and 6G will enable intelligent production through automation, virtual reality, and information technology. Through twin body area networks and intelligent interaction, smart life will alter our daily lives, and smart society will greatly expand public service coverage, bridging the digital barrier across locations. Numerous research has been conducted on 6G networks, with current articles concentrating on 6G's fundamental technologies, long-term goals, use cases, and needs. From the standpoint of the client, some authors have forecast a quick and large cost reduction, while others have talked about probable long-term issues with the rollout of the 6G network. In conclusion, it is anticipated that 6G networks would improve social governance and provide the groundwork for a better society. Figure 4.4: shows the evolution of 6G Technology [2]. The advancement of wireless communication of new technologies and applications, as well as the ongoing research and development in the field.

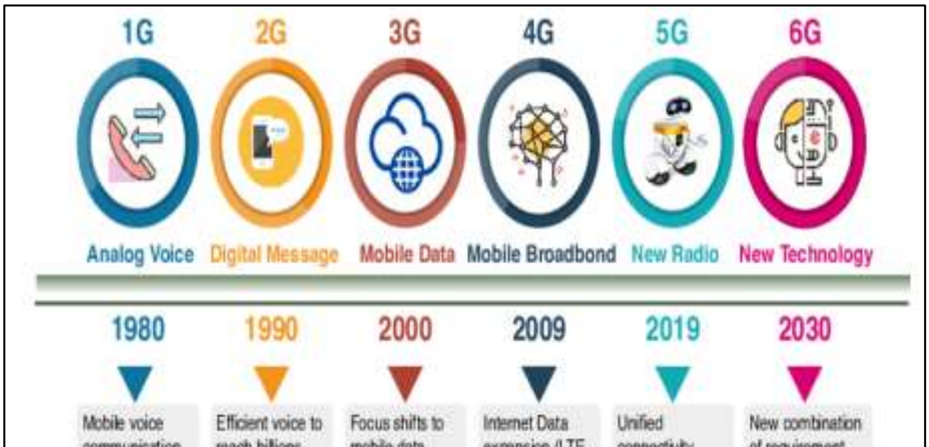

Figure 4.4: The evolution of 6G Technology

4.6 Future Perspective:

Machines, gadgets, robots, and even humans will be connected in factories with the arrival of IoE and B5G/6G. Additionally, in certain industries, specific scenarios won't involve any human engagement. The majority of factories nowadays need to be quick, clever, automated, and secure. These facilities help improve the manufacturing process. They are capable of intelligently balancing the market's supply and demand [1]. They can foresee when 'machines' will require repair. Through global control canters, large multinational corporations may remotely supervise their plants. Based on previously gathered data, the businesses may also intelligently forecast the success and failure of a product line flow.

The COVID-19 epidemic prompts a hasty creation of the concept for the factory of the future in an effort to limit the number of employees within factories. Future wireless communication is expected to provide several difficult applications, with the factory of the future being one of them. To remotely manage industries, sophisticated XR tools and human senses identification procedures are needed. For the provision of equipment, gadgets, robotics, and networks, digital twins will be deployed. Huge amounts of data will be sent between devices and gathered by operators in control canters. Accurate localization is required for many vehicles, including freight trucks, robots, and drones [12]. Self-healing factories are a necessity. Due of these difficulties, specialized wireless networks with high data throughput, dependability, and low latency are required. However, this calls for brand-new solutions, which 6G can handle at the level of the communication system. D2D will be made available in 6G to address latency and capacity problems. According to Xiao and Zeng, digital twins will use big data-based, real-time analytical applications methodologies. Furthermore, sophisticated artificial intelligence techniques like explainable AI, distributed AI, layered AI, etc. would be necessary to manage this dynamic and extremely complicated system. Advanced localization and method backed by the 6G network will be necessary for high-accuracy positing (1 cm).

4.7 Conclusion:

Technology has a great impact on the lifestyle of human beings. Wireless technologies have revolutionized businesses, living standards, infrastructure, and many other aspects of human life. Mankind is in a constant struggle to find elegant solutions to various problems and is in search of new avenues to progress. Tis desire of mankind has evolved wireless communication from 1G to 5G. However, this development has not stopped here. The researchers around the world are working hard for the development of 6G communication network, which is expected to be rolled out by 2030. In this paper, we covered various aspects of 6G wireless networks with different perspectives. We provided a vision for B5G/6G communications, 6G network architecture, KPI requirements, key enabling technologies, their use-cases, and network dimensions that will landmark the next generation communication systems. Furthermore, a way out is discussed how these potential technologies will meet the KPI requirements for these systems. Finally, the opportunities and research challenges such as hardware complexity, variable radio resource allocation, pre-emptive scheduling, power efficiency, the coexistence of multiple RATs, and security, privacy and trust issues for these technologies on the way to the commercialization of next-generation communication networks are presented.

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