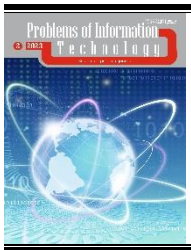

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6G Technology: perspectıves, problems and solutıons

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ABSTRACT

The standardization procedure of the fifth generation communication has already been completed and global spread has launched. To maintain the competitive advantage of wireless communication, researchers conceptualize next-generation (6th generation, 6G) wireless communication systems aimed at founding the stratification of communication needs of the 2030s. This article highlights the most promising research areas in the recent literature on the overall trends of the 6G project to support this view. It discusses the development and analysis of 6G wireless communication technology, which is projected to be implemented in the near future. Networks based on 6G wireless technology seem to be the most promising and developing field in the field of wireless technology. The article indicates the emergence and development of 6G to lead to a new wave of developments in the field of the Internet of Things (IoT). It touches upon the services applied during the implementation of the previous generation (5th generation, 5G) technologies and the emerging problems. It also reviews the benefits and challenges associated with the development of 6G wireless communication, which is designed to provide a better communication system in the future and to get many new perspectives.

1. Introduction

Communication is established between two or more objects located at a certain distance from each other without using wires through wireless communication technologies. Objects can be any electronic devices such as mobile phones, notebooks, desktop computers, etc. Various other network technologies are also used to connect these objects.

Communication system is formed almost every ten years to improve the quality of services (QoS), introducing new functions and applying new technologies. Although the 5G communication system is not yet widely implemented, researchers are already focusing on 6G technology. This is because 5G provides a high standard infrastructure enabling the use of various technologies such as artificial intelligence, mobile broadband communication, IoT, self-driving cars and smart cities. However, the proliferation of smart devices every year and the exponential rise in data traffic creates various challenges and limitations in the 5G communication network (Mehta, Patel, Joshi, & Modi, 2014; Prinima & Pruthi, 2016). These limitations lead to a new communication system that offers extremely low latency, high data transmission, more capacity, secure-error-free communication, and complete wireless coverage (Agiwal, Roy, & Saxena, 2016).

The main problem with 5G is data traffic overload due to massive network connections with a sharp increase in the number of users.

Thus, to achieve mass connections through 6G, it is necessary to provide it with more capabilities than those of the 5th generation technologies. This will not only lead to mass connectivity, but also increase speed, decrease latency, network resiliency and decrease energy consumption (Gupta, & Jha, 2015). Communication based on 6G wireless technology is a solution to the problems of enormous traffic volumes generated in the network and, accordingly, a significant increase in the demand for data transfer rates.

Networks built on the basis of 6G wireless communication technology are required to have the ability to process large volumes of data and transfer data to any device at a higher speed. These requirements can be achieved by adding various new technologies and services to the network. Some of the most vital trends underlying the growing relevance of 6G wireless communications are (Elmeadawy, & Shubair, 2019):

1) Green communication (environmentally safe);
2) Intelligent (smart) network;
3) Localization (adaptation to the geographical region);
4) Using a new range of radio frequency;
5) High reliability;
6) Low latency;
7) High speed data transfer capacity;
8) Network accessibility.

2. Development stages of wireless communication

Wireless communication reduces the communication vulnerability among users from all over the world. 6G is a wireless technology used in mobile communication (here G indicates generation). Wireless communication generations change every decade according to the general trends inherent in these technologies. Wireless communication technology is progressing and spreading from 0th generation (0G) to 6th generation (6G). Generations of wireless communication technologies are listed in table 1 (Mohammad, & Sumit, 2015).

Table 1. Wireless communication technology generations

Generation	Year	Features
0G	1970	Mobile wireless phone systems are used for communication.
1G	1980	Roaming is enabled, but the network function is not available for the usage between countries.
2G	1991	Phone calls, SMS, MMS.
3G	1998	Voice (audio) transmission, mobile Internet access, video calls, etc.
4G	2009	Along with all the features of 3G, it also provides additional features such as cloud computing, video conferencing, 3D TV, IP phone, gaming services.
5G	2019	Simultaneous connection of multiple users; reduced latency compared to previous generation mobile communications.
6G	2030	Application of terahertz frequencies and the concept of artificial intelligence making communication more efficient.

Each new generation of wireless communication technology comes with additional features. The key factor in 6G is combining all the functions available in the previous generation technologies - such as creating a denser-complex network, high throughput, high reliability, low energy consumption and a large number of connections. The most important requirement for 6G wireless networks is to process large amounts of data, provide very high data transfer rates for each device in the network, and ensure higher data transfer rates for the network as a whole. To improve communication technology, 6G will replace the gigahertz (Gbit/s) frequency of the previous generation with the terahertz (Tbit/s) frequency (Slastukhina, 2020).

Table 2 displays a comparative analysis of 5G and 6G wireless communication technologies (Abdel Hakeem, Hussein, & Kim, 2022; Oleinikova, Nurtai, & Shmanov, 2015).

The Long March 6 test satellite, the world's first 6G satellite, was launched into the orbit by the People's Republic of China, November 6, 2020. This satellite provides communication at terahertz frequency to increase network speed (https://www.bbc.com/news/av/world-asia-china-54852131, 2020). 6G can be applied in many fields such as wireless communication, virtual reality, wireless brain-computer interaction, robotics, haptic communication, industrial automation and IoT.

Table 2. Comparison of wireless communication technologies

Features	5G	6G
Frequency	3-300 GHs	Up to 1 THs
Data transfer speed (Uplink)	10 Gbps	1 Tbps
Data download speed (Downlink)	20 Gbps	1 Tbps
Maximum mobility	500 km/h	1000 km/h
User plane (U-plane) latency.	0.5 msec	0.1 msec
Control plane (C-plane) latency.	10 msec	1 msec
Process latency	100 nsec	10 nsec
Traffic bandwidth	10 Mbps/m2	1-10 Gbps/m2
Spectral effectiveness	10 bps/Hs/m2	1000 bps/Hs/m2

3. General architecture of wireless technology

Connection between objects (devices - transmitter and receiver) in the networks established through wireless technologies is not directly established. The transmitted data is first transmitted to the server, then certain data is transmitted from this particular network server to the receiver. In the data transmission process from the device to the server and vice versa, many intermediate technologies and concepts are used (Liu et al., 2022).

The architecture of wireless technology mainly consists of the following components (Abdel Hakeem, Hussein, & Kim, 2022):

1) EU, Equipment of user - is any type of device used by the user for direct communication. This can be a mobile phone, laptop or any other device equipped with a mobile broadband adapter. EUs connect to base stations (eNodeB, eNB). Equipment of user consists of three hardware components as follows (Ericson et al., 2021):

- Mobile terminal: to manage all communication functions.
- Terminal equipment: to complete (terminate) the flow of data by processing it.
- Universal microchip (integrated circuit card), or SIM-card: to run the application needed to store user data in messages.

2) ***Improved UMTS (Universal Mobile Technology System), i.e., EUTRAN (Evolved UMTS Terrestrial Radio Access Network)*** - terrestrial radio access network. It is a new radio access network consisting of base stations replacing UMTS systems of 3G mobile networks. Compared to previous technologies, it has advantages such as higher capacity traffic, reduced packet delay, and is optimized for data transmission rather than audio files. This is the main source of the high speed achieved in 4G networks. EUTRAN controls and manages all radio communication between the mobile unit and the packet core of the enhanced network. In addition, EUTRAN also acts as an intermediary between the EU and the EPC (Yang et al., 2019). The transmitted data is received by the EPC passing from one place to another at different base stations of EUTRAN (Figure 1).

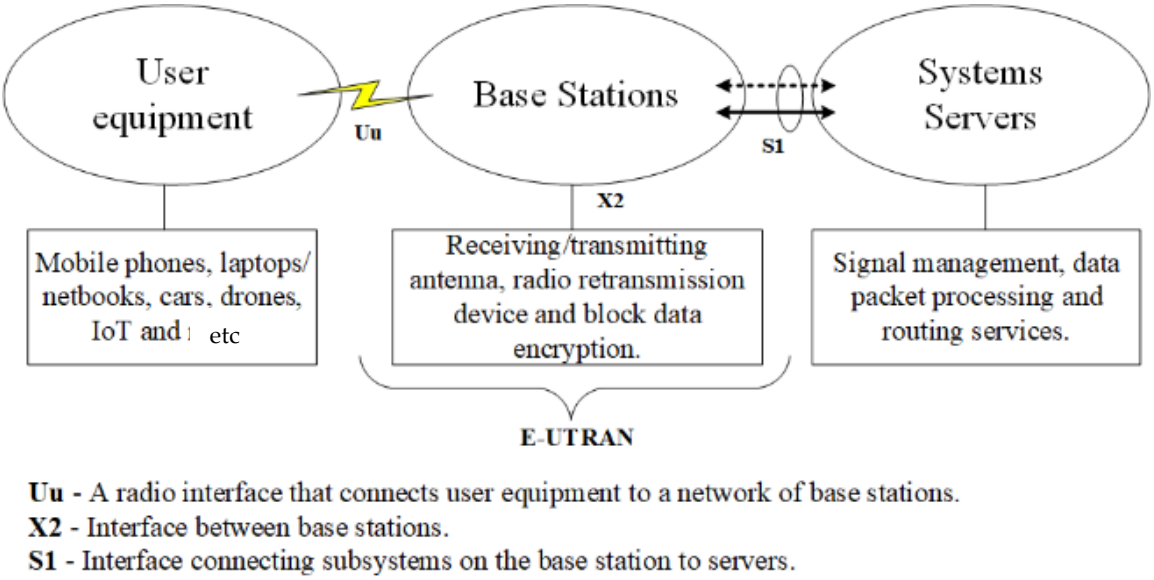

Fig. 1. General architecture of E-UTRAN

User equipment – mobile phones, notebooks, cars, drones, IoT and etc.

Base stations – receiving/transmitting antenna, device for retransmission of radio signals and data encryption block.

Service servers - signal handling, processing of data packets, and routing services.

Uu- Radio interface establishing communication between user equipment and base stations.

X2- Interface between base stations. These stations is connected to each other according to the "each other" principle.

S1 - Interface connecting the subsystems in the base station with the service servers.

3) ***Evolved Packet Core (EPC).*** EPC is an evolved extension of the GPRS/3G network core (4G). This layer hosts the internal and external packet data networks, as well as all IP network services. The EPC acts as an intermediary link between EUTRAN and the server for data transfer. It consists of four components, each of which has its own functions (Figure 2):

- EPC
- E-UTRAN User plane (U-plane) Serving Gateway(SGW)- Packet Data Network Gateway (PDN GW) – External network (Internet, IMS, and etc.)
- Control plane(C-plane) Mobility Management Entity(MME), Home Subscriber Server HSS, signals, traffic
- Serving Gateway (Serving GW, SGW) - acts as a bridge to send data between the base station and the PDN gateway. SGW processes and routes packets for base stations.

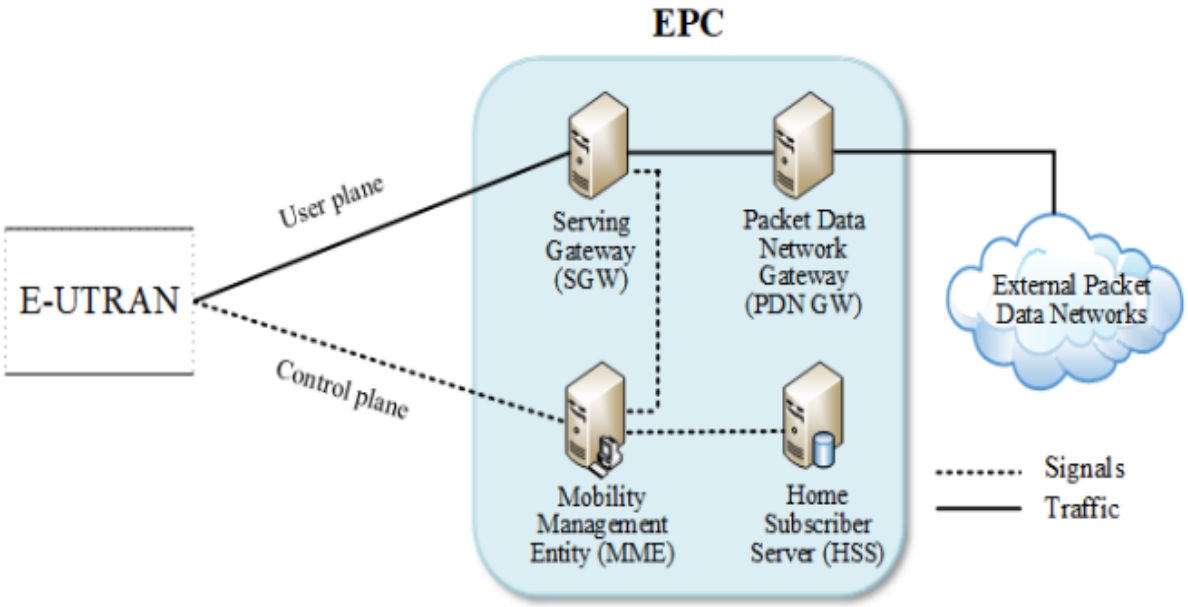

Fig. 2. General architecture of EPC

- Packet Data Network Gateway (PGW) performs the function of a bridge to transfer data between the SGW and the server. PGW ensures the subscriber's connection to external networks, performs packet filtering and billing.
- Home Subscriber Server, HSS subscriber database in the mobile communication network. It is a large database and is intended to store information about subscribers.
- Mobility Management Entity, MME supports the mobility of network users. It tracks the subscriber's movement and performs the transfers between base stations. The MME is mainly responsible for ensuring that the device connected to the network does not lose its connection while moving from one base station to another, and operating in roaming mode (Letaief et al., 2019; David, & Berndt, 2018).

4) ***Network servers transmitting data for general use (PDN, Public Data Network) -*** serve to forward data packets between mobile stations. The data from the transmitter is divided into packets and delivered to the server via EUTRAN and EPC and stored.
5) ***Servers Private Data Networks (SPDN).*** These servers mainly serve to store the data used to establish communication between objects.

4. Technologies to be used in 6G

Each generation of wireless technology uses various new technological concepts according to its trends. Similarly, 6G should differ from the previous generation in terms of the technology used. These technologies will make 6G the next generation of wireless communication technology. The 6G system will follow the trends of 5G by adding new technologies and incorporating new services. New services or technologies to be included in 6G are (Ni et al., 2019):

4.1. Optical wireless communication;

Optical wireless communication (OWC) is a form of optical communication that uses visible, ultraviolet, and infrared light (radiation) to transfer signals. Optical wireless communication uses visible light to transmit data. Thus, 6G should provide high data transfer rates. In addition to providing low-latency, longer-distance communication and security, optical wireless communication will also address the problem of data transmission speed existed in previous generations (Daukantas, 2014; Tomkos, Effenberger, & Kevin Rhee, 2016).

The advantages of OWC technology compared to radio communication are:

1) wide range;
2) high data transfer rate;
3) low latency;
4) high security;

5) affordable price;
6) low energy consumption.

The distance between the objects intended for communication can vary from a few nanometers to several thousand kilometers. In this case, effective inter-facility communication will be achieved by deploying different OWC systems (Ranaweera et al., 2022).

4.2. Communication frequency measured in terahertz (THs);

We live in an era of significant expansion of wireless data traffic. Although recently launched fifth-generation (5G) networks offer significant improvements over 4G LTE, they are inherently limited in supporting data and connectivity needs in the 2030s. Because these needs go far beyond the initial conditions of 5G networks. This prompts both industry and academia to move beyond 5G and conceptualize 6G networks (Saad et al., 2019).

In 6G wireless communication technology, a larger frequency range must be used to transmit signals. The 6th generation communications will use terahertz frequencies while the prior generation wireless communications used gigahertz frequencies. Due to this, 6G will expand the coverage several hundred times. For instance, communication will be possible under water, at heights and even in space. At this time, transmitters and other network equipment will have low energy consumption (Huq et al., 2019).

Terahertz ranges from 100 GHs to 10 THs. The frequency of electromagnetic waves applied in communication from 1G (0.9 Ghs) to 4G (1.8 Ghs) has also continued at an increasing pace. The higher the frequency, the more the permitted transmission capacity of the channel will rise, and the volume (amount) of data transmitted per unit time will also increase. This is often understood and emphasized as "increasing the speed of the network" (Akyildiz, Han., & Nie, 2018).

4.3. Wireless energy transmission;

Future wireless communication technologies pave the way for the concept of the Internet of Things, i.e., information sharing between a large number of devices with different functions (household, industrial, etc.) via wireless media. Many of these devices are portable with or without batteries. This necessitates charging them in a simple and efficient way. One of these technologies is wireless energy transmission (Lu et al., 2014). Thus, it will be possible to run or charge wireless devices without the need for a wired infrastructure.

Generally, wireless power transmission is carried out by three methods: inductive coupling, magnetic resonant coupling, and electromagnetic radiation (Zeng, Clerckx, & Zhang, 2017).

In wireless technology, there must be several base stations to establish communication and transfer data between objects. In order to transfer a data packet from one base station (transmitter) to another (receiver), it is necessary to realize the energy transfer between these stations. This new concept - wireless transmission of data and energy - should be applied to transmit data packets in 6G.

Using 6G towers, the transmission of energy must be implemented through radio waves of a certain frequency between the transmitting and receiving antennas. If these waves are maximally protected from external electromagnetic influences, they can pass through various complex barriers.

Furthermore, it will be possible to transmit electricity over longer distances, as in the case of classic power lines. Due to the new systems, it will be possible to provide energy while driving electric cars and charge mobile phones. At this time, there will be no need for an additional block or cable, it will only be crucial to organize their communication with the tower (Costanzo, Masotti, & Energizing, 2017).

4.4. Artificial intelligence

The combination of 6G communication and artificial intelligence could reshape aspects of our technological thinking and lead to revolutionary changes in our modern lifestyles.

The concept of artificial intelligence can be comprehended as a reproduction of human intelligence in a computer. In other words, artificial intelligence is a mathematical science and technology that aims to apply human logic to devices. Devices with artificial intelligence will capable to think, analyze the problem and find solution.

6G will be the first generation to present the concept of artificial intelligence among wireless communication technologies. While communicating between objects, many complex

situations emerge that can be solved by these objects themselves, using the concept of artificial intelligence. The rapid progress of artificial intelligence will drive the emergence of smarter networks for real-time communication in 6G technology (Shafin et al., 2020).

5. Advantages of 6G

1) Taking into the consideration the increased network throughput (data transmission capacity, frequency bandwidth), the biggest and most important advantage of 6G is the potential data transfer speed. While 5G offers speeds of up to 10 gigabytes per second, studies indicate 6G to have speeds of up to 1024 gigabytes per second. This is equivalent to a data transfer speed of 1 terabyte per second. Thus, 6G promises 100 times higher speed than available standards;
2) Increased frequency bandwidth, higher channel throughput, i.e., more information can be transmitted at any time. The application of new technologies such as mobile vehicles, remote surgery will increase gradually;
3) 6G will optimize the healthcare field by eliminating time and space barriers through remote surgery and simplify the processes in healthcare;
4) 6G is applied together with the Distributed Antenna System (DAS) to tackle the problem of traffic loading;
5) 6G can provide users with instant real time access to each other;
6) Online video broadcast will be possible in 8K/16K quality in real time over the Internet;
7) Wireless transmission of holographic images (3D, three-dimensional objects). These objects will be visible in the air and on transparent material. The goal here is to be able to join any meeting, dinner or exhibition as a hologram from any location of the world. In this case, the updated copy of the hologram should make the presence of the person at the other point fully felt. This is also called a digital copy;
8) Delays during robot control will be reduced to microseconds;
9) Virtual reality experiences will be further improved. Unlike virtual reality with a helmet, for example, it will be possible to create a room for an exhibition or art gallery that can host many participants remotely. This will enable to visit the Hermitage or walk the streets of London with friends who live in different countries;
10) Fast data transmission will allow continuous updating of the detailed 3D map in the modern car's computer. Due to this, the car will determine in advance all the turns and ups and downs on the route, as well as share information with other cars. This will protect the driver and transfer control functions to the autopilot (Banafaa et al., 2023).

6. Challenges of 6G

Currently, 6G communication cannot be assessed to have drawbacks since it has not yet been implemented, but it can be concluded that some challenges may appear in 6G (Saad et al., 2019):

1) 6G uses optical wireless as part of its communication. Thus, the disadvantages of visible radiation can be considered a problem in 6th generation wireless technology, because this type of radiation can be harmful to human eyes;
2) Terahertz waves have a frequency higher than the millimeter waves used in 5G, and their radiation effect can cause the growth of brain cells. These waves can couple directly to proteins, forcing them to resonate non-linearly;
3) Widespread wireless communication technology can become an integral part of the world's energy consumption;
4) The complexity of forming an effective structure for wireless technology by managing a large number of terminals;
5) The main problem for 6G is that the signal in the terahertz range (signals with a frequency above 100 GHz) can weaken faster in the atmosphere and even be lost due to small obstacles. This reveals the need to increase the number of base stations and install them more densely. As a result, the situation is much worse than 5G: we are talking about installing base stations at a distance of tens of meters and having to transmit data in the network through personal devices;

6) Since the Terabyte Internet requires huge traffic and, accordingly, hundreds of gigahertz frequencies, one of the main challenges of 6G is that its material part is developed on the basis of a completely new element base. The required range (called the "terahertz gap") is currently available and not even busy. However, since it lies between microwave and light frequencies, it is extremely difficult to absorb. Even the mass production of transistors intended for this has not launched yet. And the transistors will not certainly be made of ordinary silicon material;
7) Security defaults remain a major challenge in both 5G and 6G wireless standards.

Conclusion

6G technology is a relatively new technology, so it is in the premature stages of research and development. Although certain applications have yet to emerge, research regarding the potential of 6G networks continues. The expected features and capabilities of networks based on 6G technology, including high-speed data transfer capability, low latency, rich device connectivity and wide coverage, will revolutionize the industry and enable transformative applications. The Internet of Things will also further evolve with 6G, as it will enable a large number of devices to effortlessly connect and interact with each other. Autonomous systems such as self-driving cars and drones will greatly benefit from the low latency and high reliability of 6G networks. These systems will be able to share data faster and make real-time decisions, leading to safer and more efficient operations. Additionally, the implementation of 6G infrastructure will require significant investments and extensive research. Global initiatives, collaborations and standardization activities are already underway to ensure a smooth transition to 6G technology.

However, there are a number of issues to be addressed. Spectrum availability is a major concern, as identifying suitable frequency bands for 6G communication poses technical hurdles. Given the increasing data rates and device density, developing energy-efficient hardware and network optimization techniques are challenging. Additionally, given the proliferation of connected devices and data-intensive applications, ensuring security and privacy in 6G networks is crucial.

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