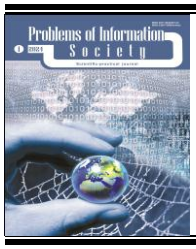

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Wireless mobile communication systems: current status, application fields and challenges

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ABSTRACT

The article analyzes the current state of mobile communication systems, and highlights development perspectives from the past to the present, vulnerabilities in security systems and application fields. At the same time, it provides information about the possible threats that may occur during an attack on the data entering the network from intelligent devices. For many years, numerous research centers have been conducting intensive research on the direct communication between various devices through mobile communication systems. These studies are realized to manage mobile communication systems and computers, mobile devices and other equipment. Therefore, special attention is paid to the development of mobile communication systems both in Azerbaijan and in the world, and it is considered one of the most promising fields of application of information technologies. The article also provides information about the fifth-generation mobile communication system, which is a new generation of wireless network technology for digital mobile networks. The results of research conducted on the fifth-generation mobile communication system in the world and the technological innovations to be brought to the healthcare and energy fields, agriculture, smart cities, smart villages and transport sectors are reported.

1. Introduction

In recent years, there has been a great progress in wireless mobile communication systems and this development has led to an increase in the number of subscribers. Unlike wired networks from the early 21st century to the present day, wireless mobile networks have caused changes in the structure and operation of telecommunication systems, providing voice and SMS services to users, leading to significant changes in the definition of infrastructure (Webster, J.G. and Larsson, T., 2017).

However, the emergence of wireless mobile communication systems has triggered significant changes in the telecommunications infrastructure and has enabled data to be transferred without connecting to wired networks. The main representatives of these technologies are 2G, 3G, 4G (LTE) and 5G technology, which has been used more in recent years (Leliopoulos, P., & Drigas, A., 2022).

Although wireless mobile communication systems were previously used only in military fields and for special purposes, today they have a direct effect on a large part of people. At the same time, the high achievements in wireless mobile communication systems in the world create new demands and needs in people's social, commercial and economic life (Andrea G., 2020). However, these demands and needs have led to the acceleration of the development of technologies over time. Consequently, technologies enabling mobile communication have become an increasingly important part of human life. This also allows users to access information from any device, regardless of location.

Wireless mobile communication systems are actively developed both in scientific centers and in countries where intensive research is conducted. In general, advances in wireless mobile communication technology will increase the efficiency of mobile communication so that people can build wider

connections and access information using mobile devices (Alenoghena C.O at al., 2023). Mobile operators highly appreciate these improvements and work to provide more efficient and quality services to customers.

This article mainly aims to study the current situation of wireless mobile communication systems and identify the problems we face. It also describes the advantages of wireless mobile communication systems, development stages, security issues, application innovation and other topics.

2. Current status of wireless mobile communication systems

There are many important and completed works in the field of wireless mobile communication systems throughout the world. Research, development and experience in this field have led to significant progress in the development of wireless mobile communication technologies. The Internet of Things (IoT), 5G, industrial applications, military applications, and security are just a few of the advances made internationally in the field of wireless cellular communication systems. Research and development in this area laid the foundation for increasing the efficiency and details of future communication technologies (Quy Vu Khanh at al., 2022).

Research on wireless mobile communication systems (WMCS) began in the 90s of the last century. With the development of technology, wireless mobile communication systems, which occupy more and more places in our lives, have become an indispensable need for people, starting with the first communication by Guglielmo Marconi through radio waves using Morse code, and going through an incredible path to this day (Bondyopadhyay PK & Sir JC Bose., 1998). WMCS development involves 1G, 2G, 3G and 4G generations. Currently, extensive research is being conducted in the field of 5th generation mobile communication technology, which is already being used and developed in many countries (S. Shukla at al., 2013).

First generation mobile communication systems (1G). With the emergence of new technologies, scientists began research on wireless cellular communication systems in the early 1970s. As a result of research, the development of mobile communication systems has led to the most important advances in Wireless Mobile Systems technology. It is the rapid expansion of mobile communication technologies that in the late 1980s, the first generation (1G) mobile communication system, which was analog, began to enter our lives with only voice-based services (Anand Vardhan Bhalla and Mudit Ratana Bhalla., 2010).

Second generation mobile communication systems (2G). Analog systems are designed for voice services only. Nevertheless, due to the difficulties experienced in the service quality and security in the analog system, the use of the first-generation mobile communication system has decreased significantly, and the second-generation mobile communication system, which is now a digital system, began to be widely used. The main difference of the second-generation mobile communication system from the first-generation mobile communication system is that the information obtained here is transmitted rather digitally, and the application of this different method instigated the emergence of the Short Messaging Service (SMS) (Henri Hodara & Edwin Scaljo., 2021).

Third generation mobile communication systems (3G). Third-generation mobile communication systems are wireless networks based on new technologies and international standards, and were created by the Japanese company NTTdocomo in 1988 to increase the productivity and efficiency of wireless mobile networks (R. Yallapragada at al., 2002). 3G wireless mobile communication system, unlike its predecessors, was not based only on voice communication, but at the same time, internet service was also preferred. The use of these services has led to the emergence of new demands and needs (Heikki Karjaluoto., 2006).

In the first releases of the Universal Mobile Telecommunications System (UMTS) standard, the switching subsystem did not differ in structure from the same subsystem of the second-generation networks. The UMTS standard includes a switching center, as well as a set of Home Location Register (HLR), Visitor Location Register (VLR) and Authentication Center (AUC) designed to store subscriber data. In later releases, MSC functions are split between two devices: MSC server and GMSC. The MSC was responsible for establishing server connections, sending bills, and performing some authentication functions. GMSC is a transition area subordinate to the MSC server (H. Holma and A. Toskala., 2004).

Base station subsystems in UMTS networks have undergone significant changes compared to GSM networks. The main elements included in the subsystem of base stations are as follows

(Fragkiadakis, A. G., Askoxylakis at al., 2011):

Radio Network Controller (RNC) is the center of the base station subsystem and performs many functions such as radio resource management, encryption, connection establishment through the base station subsystem, and resource allocation among subscribers (Payel Mukherjee et al., 2021).

NodeB-UMTS is the main base station for mobile communication systems. The main function of the NodeB is to convert the signal received from the RNC into a broadband radio signal sent to the phone. The base station resource allocation does not change the subscriber's speed, but acts as a bridge between the controller and the subscriber equipment and is completely subject to the RNC (Ishtiaq Ahmed Choudhry & Nazir Ahmad Zafar., 2012).

User Equipment (UE). Unlike previous standards, UMTS man involve not only an ordinary phone, but also smartphones, laptops, desktop computers, etc. Packet data in the UMTS network is transferred from the Media Gateway (MGW) to the Serving GPRS Support Node (SGSN) element known from the GSM system, and then to other external data transmission networks, such as the Internet, through the Gateway GPRS Support Node (GGSN) of the GPRS gateway. In general, SGSN and GGSN GSM networks are used for the same purposes in the UMTS network. Only software updates are made for these elements (Jonne Soininen., 2000).

Fourth generation mobile communication systems (4G). The first 4G mobile communication system in the world was commissioned by Telia Sonera company in 2009. Users and subscribers have used this service for the first time, which allows them to get the information, music, video they want in real time through mobile applications running on smart mobile devices and using broadband infrastructure, regardless of location, space and time. The data transfer speed of 4G mobile communication system reaches 300 Mbit/s, which provides distance education, mobile commerce and other socially oriented services easily and with high quality. Moreover, this technology creates great opportunities for users operating in private sectors (Ahmed, T., Ahmad, W. & Ahmad, B., 2022).

The 4G mobile communication system supports the basic WiMax and LTE standards. The LTE network structure significantly differs from the 2G and 3G standards, and substantial changes are made by both the base station subsystem and the switching subsystem. Furthermore, the data transfer protocols between network elements are different. Here, all information (voice, data) is transmitted in the form of packets. The LTE network can be divided into the following main elements (Fig. 1), (Ashish Kumar et al., 2013):

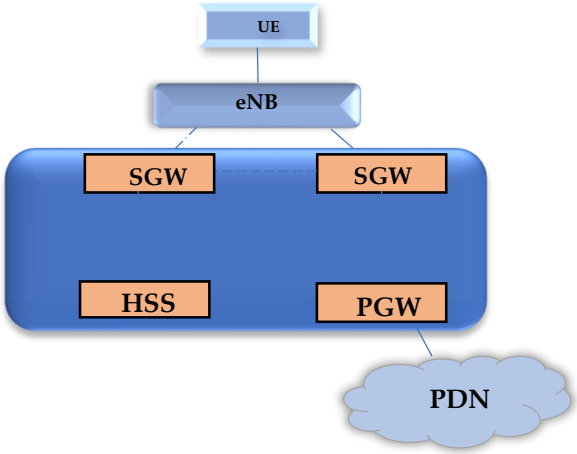

Fig. 1. LTE Technology

User Equipment (UE) includes any device with communication capabilities such as mobile phones, tablets, computers, etc. (Anastasios N. Bikos at al., 2013).

Evolved Terrestrial Radio Access Network (E-UTRAN) controls the radio communication between user equipment and the enhanced packet core (EPC). LTE network can connect to only one mobile network and one base station at the same time (Anastasios N. Bikos at al., 2013).

Evolved Packet Core (EPC) manages connections between base stations and the network and ensures their correct formation. Besides, EPC supervises the user facilities of communication operators. EPC includes a packet data gateway (PDN-GW), a mobility management device (MME), a serving gateway (SG), a policy and charging rules feature (PCRF), and a home subscriber server (HSS) (Anastasios N. Bikos at al., 2013).

Serving Gateway (S-GW) processes user data traffic, but is not responsible for the signaling data used, and transmits IP data from the UE to the underlying LTE network. At the same time, it directs incoming and outgoing IP packets to improve system interoperability and acts as a link for UEs when switching from one eNodeB to another eNodeB (Anastasios N. Bikos at al., 2013).

Packet Data Network Gateway (P-GW) is a network node connecting the EPC to the external IP network. The P-GW forwards packets to one of the external IP networks. Moreover, it allocates one IP address to all users and applies different policies against user IP traffic as a packet filter (Anastasios N. Bikos at al., 2013).

Wimax is an IP-based wireless broadband technology designed for "metropolitan networks" known as IEEE 802.16, providing Wi-Fi-like performance with the coverage and quality of service (QoS) of cellular networks. Wimax technology can provide broadband wireless access (BWA) over 30 miles (50 km) for fixed stations and 3-10 miles (5-15 km) for mobile stations (Omendri kumari and Dr. Sanjay Kumar., 2014). The Wimax network architecture includes three main components as follows: Access Service Network (ASN), Connectivity Service Network (CSN) and Mobile Station (MS).

Access Service Network (ASN). WIMAX is a set of network elements designed to organize network access for subscribers. ASN also provides Wimax and IP connection services to its users in accordance with Service Level Agreements (SLA) approved with the Network Access Provider (NAP) (Ahmadi Sassan., 2011).

Connectivity Service Network (CSN). The WiMax core network is primarily responsible for user authentication, roaming services, network management, and providing interfaces to other networks. A network administration system provides the functions of monitoring and managing all base stations and subscriber stations in the network, downloading software and setting system parameters (Ahmadi Sassan., 2011).

Mobile Station (MS) refers to a general term applied to radio stations installed on mobile objects and designed to work while on the move, as well as all types of mobile and portable radio terminals running in wireless networks. Furthermore, it is a combination of all software in the user equipment (mobile phone, SIM card, memory card, etc.) required to connect to the GSM network (Ahmadi Sassan., 2011).

Fifth generation mobile communication systems (5G). The fifth-generation mobile communication systems are already replacing the fourth-generation mobile communication system in many countries of the world. The fifth-generation technology has 10 Gbit/s speed, which is higher compared to the fourth generation, as well as high throughput and very low latency, and is also aimed at connecting billions of objects using the Internet of Things (IoT) technology (Hashimov M.A., 2020). Mobile systems enable the creation of new network services and technologies such as in-car communications, smart grid, smart parking and blockchain-based services through the Internet of Things (IoT) (Sankaran, K. S., Ramprabu, G., & Prakash, V. R., 2020).

Over the past decade, many cities have made significant progress in implementing 5G technology. Below are the countries where the 5G mobile communication system concept has been successfully implemented:

China. By the end of 2022, China will have installed 2.312 billion 5G base stations and 561 million 5G users, accounting for more than 60% of the world's population. China's data output grew by 22.7% annually to 8.1ZB (zettabytes) in 2022, accounting for 10.5% of the global total and ranking second in the world. China is leading for the technology, industry, network and deployment of 5G and accelerating 6G research and development. The number of Chinese internet users has reached 1.067 billion people, and the country's internet access level is 75.6% of the total population (Ivy Huang., Digital China Summit 2022).

South Korea. South Korea's Fifth Generation communication technology research is jointly conducted by the South Korea Academy of Electronic Communications, some mobile communication manufacturers such as Samsung, LG and Ericsson, as well as the Ministry of Development and Science of South Korea and telecommunications operators. On June 28, 2013, South Korea's Ministry of Future Investment and Science and the Chinese government signed bilateral agreements with the IMT-2020 group in China for South Korea's 5G Form Five generation development. Moreover, the China National Computer Emergency Response (CNCERT) and the Korea Computer Emergency Response Team (KRCERT) signed cooperative network security agreements between the two organizations (Andy Hira, 2012).

Azerbaijan. Azercell Telecom, the leading mobile operator of Azerbaijan, has first launched a pilot project for the implementation of 5G wireless mobile communication technology in the country. The project was implemented in the Customer Service Center in Fountains Square in the center of Baku in cooperation with Ericsson. During the trials, the project recorded a download speed of more than 1 GB/s, which meant the implementation of the 5G network in the most crowded and busy areas of urban life for the first time in Azerbaijan and in the region. The pilot project, in which Azercell Telekom will play a leading role, will enable states, telecommunication companies and users to better prepare for the development of 5G wireless mobile communication infrastructure and the transition process to this technology (Azerbaijan State News Agency, 2019).

3. Implementations in the field of wireless mobile communication systems

Wireless mobile communication systems are one of the most significant areas of technology with extremely dynamic development in the field of technology and are widely used in our daily life. These systems enable the emergence of useful applications and projects in different fields, leading to changes in communication, data sharing, technological development and lifestyle. The research conducted in the field of wireless mobile communication systems gives remarkably positive results in terms of the integration of technology with a large and independent structure and leads to radical changes in our lives. The main implementations in this field are as follows (Osseiran, A at al., 2013):

Self-Driving Cars: wireless cellular communication systems provide secure communication and sensor systems for automated vehicles. This enables vehicles to interact with each other and with the infrastructure to ensure safe driving (Alhabib, Mustafa et al. 2023).

Smart City Projects: wireless cellular communication systems are used in "Smart Cities" projects, for example to increase safety in cities, optimize traffic management and improve energy efficiency with IoT sensors and devices (Garcia, L., Jiménez, J. M., Taha, M., & Lloret, J., 2018).

Telemedicine and Health Technologies: medical technologies such as telemedicine platforms and remote monitoring are used in wireless cellular communication systems. This enables patients to provide remote medical services and share various medical information (Mammadova M.H., Jabrayilova Z.Q., 2020).

Cloud Computing and Edge Computing. Cloud computing and Edge computing technologies play an important role for the effective operation of wireless mobile communication systems. Both technologies are used in the field of mobile communication, especially within the framework of 5G and Internet of Things (IoT) projects, to ensure high performance and security (Alakbarov R.G., Hashimov M.A., 2016).

Industry 4.0 Applications. Wireless mobile communication systems comply with the principles of industry 4.0 in the field of technology and automation. This includes the application of remote control, sensor systems and automation technologies in enterprises and business processes (Bonavolonta, F., Tedesco, A., Moriello, R. S. L., & Tufano, A., 2017).

Azerbaijan has experienced serious development in the field of telecommunications in recent years, and one of the bases of this development is the wireless mobile communication system. The implementations in this field in the country are aimed at strengthening the telecommunication infrastructure and introducing technological innovations (OECD., 2022). Although almost half of the population of Azerbaijan lives in cities, it is also important to provide communication services to people who work and live in rural areas and agriculture. To this end, mobile operators are developing wireless communication infrastructure in residential areas, which allows people working in agriculture to use communication services effectively.

Wireless cellular communication systems are increasingly used in urban areas. This means faster, safer and better communication services for city residents and business people. Such applications occupy an important place for companies operating in the field of business and tourism in the country. The government of Azerbaijan is taking serious steps towards the development of the country's state telecommunication infrastructure. As a result of these steps, the country's telecommunication network will be more modern and secure, further strengthening the country's leading position in the telecommunications sector (Azerbaijan - Country Commercial Guide., 2023).

The development of a wireless mobile communication system in Azerbaijan is a strategic priority for strengthening the country's telecommunication infrastructure, providing leading positions in the field of technology, and improving communication opportunities for people living and working in remote regions. The implementations in this field prove that Azerbaijan is a country moving forward and adapting to rapid changes in the field of telecommunications and technology. Accordingly, the results obtained in practice around the world clearly show how wireless mobile communication systems assist our lives and contribute to the development of society. These systems enhance our experience by targeting the bright and dynamic future of the developing world. The importance of wireless mobile communication systems in these areas promises further interesting and innovative developments, along with global communication, technological development, infrastructure efficiency and security improvement (Toghrul Fattahov, 2019).

4. Application fields of wireless mobile communication systems

Wireless mobile communication systems have a wide range of applications and are used in various fields, from efficient communication to data sharing, from technical applications to innovative solutions. Mobile communication is an ideal tool for fast and accurate data sharing in different fields, in different documents and platforms. These wide applications show how important role wireless mobile communication systems play in various areas of our lives (Liu, Y., Kashef, M., Lee, K. B., Benmohamed, L., & Candell, R., 2019).

Application fields of the first-generation mobile communication systems. They were developed in the early 1980s to provide easily applicable voice communication in telecommunications. In the early days of mobile phones, being able to talk to each other by voice became the most basic function. Due to this connection, people could join a voice chat using their mobile devices anywhere. One of the main features of 1G was the ability to send voice messages. This innovation allowed users to send voice text messages to other mobile device users. Correspondingly, in the 1G era, mobile phones and devices were simple and easy to use. This has made access to mobile communication easier and more accessible to users who are not familiar with the technology. As the first generation of mobile networks, 1G not only laid the foundation of mobile communication, but also took the first steps towards technological development and the creation of a new generation of mobile networks. The experience and achievements of this period led to the creation of larger and more sophisticated systems in the field of mobile communication and created the necessary conditions for the development of technology (Ahmad, Norlia and Methe, David T., 2021)

Application fields of second-generation mobile communication systems. The second-generation mobile communication network, 2G, launched in the mid-1990s, was a technology developed mainly for providing voice communications. During this period, 2G created a direct experience for users by providing better sound quality and advanced features unlike the first-generation analog systems. The main goal of 2G was to create secure and efficient audio communication. This helped to introduce mobile telephony standards and new technologies to improve the quality of communication. Multimedia messaging services (MMS), including shot text message service (SMS), were introduced alongside 2G to enable users to send a variety of information including text, images, audio and video. Another feature was that 2G was best suited for voice chats and text messages, unlike next-generation mobile networks that offered a wider range of services. This, in turn, made 2G a productive platform for voice communication and short texts. In addition, it provided the possibility of maintaining mobile communication in foreign countries with the "roaming" service for users traveling abroad. The fact that 2G was based on the worldwide GSM standard allowed for secure and standardized mobile communication in many countries. Consequently, it helped create global standards in the field of mobile communications (Kireet Muppavaram et al., 2023).

Applications fields of third-generation mobile communication systems. Third-generation mobile communication technology (3G) aimed to increase data speed and provide a more efficient platform for a wider range of applications. 3G has a very wide range of applications and provides many services and features to offer users fast and efficient data connections. This technology increases the speed of the mobile Internet, ensuring more efficient and high-quality use of websites, video streams, online games and other network applications. Higher speeds allow users to easily access high-quality video and multimedia content on their mobile devices. 3G also makes available a convenient connection to various information platforms such as e-mail, news, weather forecasts and other information services. 3G technology also offers speed and efficiency for GPS applications ensuring a mobile device to determine its location as it moves. Mobile banking and financial apps eases operations with banks through mobile phones and these apps use 3G for secure and efficient connection (Heikki Karjaluoto., 2006).

Application fields of fourth-generation mobile communication systems. Fourth generation (4G) mobile communication technology opens up a new stage in the development of mobile communication in terms of speed and efficiency and has a wide range of various application fields. One of the main advantages of 4G for users is fast Internet connection and high-quality voice communication. Another important benefit of 4G is that it provides fast transfer of large amounts of data. It enables users to quickly download and display video and graphics files. High-speed 4G also provides high-quality online video and HD or ultra-HD images on mobile

devices. The technology is designed not only for smartphones, but also for smart watches, "smart home" devices, cars, sensors and a number of other devices connected to the Internet. 4G is also independently applied in several fields such as distance education, health monitoring and telemetry. Travel agencies, travel platforms and other travel and tourism sectors are also using 4G capabilities to provide fast and reliable communication, which has also extended to the tourism sector and uses 4G to provide more efficient and convenient travel for customers through mobile services. These developments are constantly expanding the possibilities of using available 4G capabilities to expand mobile communication technologies and meet modern demands (Dr. Vidyaa Thulasiraman, Mr.G.Manikandan, 2016).

Application fields of fifth-generation mobile communication systems. 5G mobile communication system has been one of the most popular topics in modern times and there is enough information about the scope of this technology. Moreover, the 5G mobile communication system is applied in various fields that are very significant for people:

The Internet of Things. This concept includes smart homes, smart industry, smart farmland and smart city infrastructures. 5G mobile network technology is an infrastructure designed to overcome connectivity challenges caused by a large number of connected devices. The speed and higher capacity of 5G mobile network technology will allow networks to process more data, thus helping the development of the Internet of Things. One of the important topics discussed in the field of Internet of Things is smart cities. There are various areas such as vehicle and traffic monitoring and management, street lights, waste, pollution and urban environment management (Attaran Mohsen., 2021).

Energy Field. Energy is a very important factor in production and one of the main indicators representing the country's economic and social development potential. Renewable wind and solar energy systems are currently being explored in the new energy system. Even since 2017, the use of coal energy has decreased in Europe and energy production from renewable sources such as solar and wind has started (Michael Taylor., 2016).

The fifth-generation mobile communication system aims to provide efficient use in the energy sector through smart grid, smart lighting, smart sensor devices and energy metering technologies. Through the devices used in the fifth-generation communication systems, it will help to collect data, efficiently plan the energy infrastructure and take action to reduce the resulting downtime. During a severe hurricane in Chattanooga, Tennessee, USA, a mid-sized city used smart grid technology to reduce power outages by more than 50%, reducing operating costs by $1.4 million (Katherine Tweed., 2016).

Agriculture. Global climate change and water scarcity continue to increase their effects over the years. The only way to fight these challenges is through human-made technologies. In industry and intelligent agriculture, IoT technologies have also gained great advantages in agriculture. Here, the sensors collect information such as soil structure, fertilization, weather forecast and transfer it to the central server or cloud environment through gateways over 5G networks and store and analyze information about the conditions of farmers' fields, crops, livestock, and equipment. After analyzing the data collected from these sensors, farmers can use this data for further research to increase productivity (Dhanaraju M at al., 2022).

Smart Irrigation Method. Irrigation method in agriculture is one of the most used methods by farmers. Through the fifth-generation IoT and communication technologies, in order to effectively use the irrigation methods, where to direct the water source, what volume and how long it will be used, as a result of the data collected from the water source, it can be monitored and analyzed instantly from smart devices (Wie Xiang at al., 2022).

Smart Livestock Method. By using fifth-generation communication systems, with the help of sensors placed on animals, it is possible to monitor and develop real-time biomedical information such as animal movement, body temperature, pulse, and tissue resistance (Richard Gray., 2020).

Healthcare Sector. 5G mobile communication technology is widely used in the field of healthcare and even has introduced new opportunities and new services for this field. The main goal is the widespread use of technological applications in the healthcare industry that enable more data collection and management, such as smart medicine, remote diagnosis and remote surgery, to reduce costs during remote medical care and examination of patients. In healthcare, 5G mobile network technology has significantly affected the quality of healthcare for hundreds of millions of patients and brought about noteworthy changes in healthcare delivery (Anne Y. Ning., 2021).

Smart clothing. Ranging from e-textiles to "smart" fabrics, these garments, unlike traditional clothing, are equipped with sophisticated sensors, hardware and textiles to collect, analyze and track personal data. With this clothing, the level of oxygen in the human blood, heart rhythms and similar signals of the body can be constantly monitored centrally. The data obtained through these clothes are collected by IoT sensors and transmitted to the cloud environment or relevant cloud healthcare services via the 5G mobile communication system. Wearable smart health clothes will be constantly used during diagnosis and monitoring of chronic diseases by analyzing data from sensor devices (M. Chen at al., 2017).

The global smart clothing market was estimated to be worth 4.5 billion USD in 2022 and is projected to reach 20.6 billion USD by 2030, representing an average annual indicator of 21.1% for the analyzed period. This indicates that the demand for smart clothing is growing rapidly and is predicted to continue (Grand View Research, 2023).

Robotic Therapy and Surgery. For the first time in China in 2019, doctors performed a remote operation using the 5G mobile communication network. Surgeons from Mengchao Hepatobiliary Hospital, Fujian Medical University and China Unicom Fujian Branch operated the animal in a laboratory about 30 miles away. The delay of the Internet connection was 100 ms, that is, 0.1 seconds. Animal liver removal was successful with this remote surgery (Yang, T at al., 2016).

The biggest advantage of using 5G cellular communication system for remote surgery is the low latency it offers. The lower the latency, the more the surgical robot will be able to respond to the surgeon's actions from tens or hundreds of miles away. This reduces the probability of mistakes and enables the surgeon to work as in own room (J. Ding et al., 2014).

5. Challenges of wireless mobile communication systems

The development and application of wireless mobile communication systems, in addition to providing significant advantages to the modern communication infrastructure, faces some serious problems. The security, privacy and reliability issues of these technologies can be observed in four main areas. Security issues are one of the biggest challenges of wireless cellular communication systems. Potential hacking attacks and data breaches can threaten the privacy of technologies and put users' personal data at risk. Privacy breach is another problem. Security measures to ensure reliable data transmission may be of greater concern. It can be difficult to take adequate and effective measures to protect data important to users and companies. The implementation of appropriate security standards, protocols and innovative measures is essential for the efficient, secure and stable operation of wireless mobile communication systems. This will help create a wider and more developed communication infrastructure and increase the trust of technology users.

Problems arising in the first-generation mobile communication systems: There used to be many difficulties in transmitting data through the first-generation mobile devices. 1G is a mobile device with an analog system invented for voice calls only, and some special capabilities (Chi-Chun Lo and Yu-Jen Chen., 1999). Moreover, at that time, the price of a minute of conversation was high, consequently only financially satisfied people could afford mobile communication.

Here, it can be concluded that obviously the collected data was not safe for analog systems (Jyhi-Kong Wey at al., 1995). Finally, the rapid development of technology and the inability of 1G technology to meet the increasing user requirements such as voice quality, voice level, coverage, brought the development of the second-generation mobile communication system to the fore (Munip Geylani et al., 2016).

Problems arising in the second-generation mobile communication system: as a result of the development of the second-generation mobile communication system, Internet services, corporate mail services for operators and mobile commerce applications have been developed and widely distributed. With the development and spread of these programs, various types of data security attacks have occurred. These attacks included base station attacks, attacks on wired and wireless communication lines, and mobile communication viruses;

Dangers from wired lines include threats that put mobile devices and user data at risk. These threats include attackers using it to steal user personal information, hack into bank accounts, private message seizing, and access other information. In addition, attackers can target mobile devices through viruses and malware to disable the device, delete data and destroy the device (Sağıroğlu Şeref & Mohammed Murad., 2010).

Dangers to base stations. Data transmission to GSM infrastructure users is performed through base stations. Since there is no identification between base stations, data can be intercepted by attackers (criminals) by creating fake base stations (Samet, Refik & Çelik Ömer Faruk., 2016).

One-way authentication and Man-in-The-Middle Attacks. This attack is realized through the user's authentication network. An attacker, as a subscriber, starts the attack process by accessing the mobile network code between the user and the base station. Here, the attacker presents himself as a base station. Therefore, the attacker can enter between the user and the base station and change and capture all the necessary information (Meyer Ulrike & Wetzel Susanne., 2004).

Problems arising in the third-generation mobile communication systems: the results of the analysis show that data-oriented attacks are also emerging as the demands of users to obtain information through mobile phones are increasing. The most hazardous data attacks are described below:

Denial of service (DoS) attack. It deliberately attacks a computer network or service. Its main goal is to disrupt or disable the regular operation of a system or service. These attacks are realized by using resources, overloading network traffic or abusing system resources (Fabio Ricciato at al., 2010).

Redirection attack. This is a type of attack on several mobile networks. The attacker here uses devices capable of simulating base station systems, intercepting data transmission and traffic between mobile stations and base stations. Here, the attacking fake installed mobile stations capture the personal information of users redirecting the traffic from the base stations (Y. L. Huang at al., 2011).

International Mobile Subscriber Identity (IMSI). A unique number, typically fifteen digits, assigned to mobile phone users on the Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) networks. IMSI involves two parts.

The first part consists of 6 or 5 digits according to North American or European standards. This part identifies the GSM operator of the subscriber and represents the GSM operator of a certain country.

The second part constitutes the unique identification of subscribers and is assigned by the network operator. This part shows the unique and individual identifier for each subscriber.

The IMSI is stored in the subscriber identity module (SIM card) in the mobile phone and sent by the phone to the relevant network. In base service centers such as home location register (HLR) or visitor location register (VLR), IMSI is used to retrieve mobile device information (Khan, M at al., 2008).

Problems arising in fourth-generation mobile communication systems: Along with the development of 4G mobile communication system, in addition to attacks on communication systems, SIM-cards or base stations, many types of attacks that threaten the security of mobile devices have also appeared. Attacks on communication networks and mobile devices are shown below:

Attack on EU mobile devices. Mobile devices are used to provide data transmission instead of voice data transmission. Location-independent information is easily accessible through mobile devices. In 2021, the number of active mobile devices worldwide was approximately 15 billion, up from 14 billion in the previous year. By 2025, the number of mobile devices is estimated to reach 18.22 billion, which means that there are 4.2 billion more devices at risk compared to 2020 (Federica Laricchia., 2023). Mobile devices are equipped with operating systems such as IOS, Android, Ubuntu, Windows Phone. Types of attacks on mobile devices may include:

Malicious programs: Virus, Worm, Trojan, Spyware are the names given to malicious programs (UKŞAL Mesut., 2015). The aim of malware is to intrude the operating systems of the user's mobile devices, access user data, encrypt data and disrupt the device's operation by destructing the operating system. This malware intervene mobile devices using free apps downloaded from the operating system's app stores.

Direct Attacks: Direct attack aims to obtain information through unauthorized access by using vulnerabilities in downloaded applications or mobile device operating systems. Unlike malware, it exploits vulnerabilities without installing software (Yanxiang He at al., 2005).

Problems arising in the fifth-generation mobile communication system: The fifth-generation mobile communication systems (5G) represent a major development stage in the history of wireless mobile communication systems and enable billions of devices to be connected to the network. However, there are some hidden dangers of this development. Along with 5G, billions of devices will be connected to the network, making data security more complex and problematic. In addition to security risks in the wireless structure of mobile networks, this raises security issues for other devices that will use the fifth-generation mobile communication system. This will lead to application failure and data capture by

malicious attacks. Common threats at the application level are as follows (Seongmin Park, 2021):

Malicious code attacks. Such attacks can pose a serious threat to cars, smart home systems and other integrated devices. Devices infected with malicious code can become potential targets for hacking and stealing important data. It is important for users and technical control organizations to take security measures to protect their systems and devices from these attacks (Aashi Singh Bhadouria, 2022).

The Internet of Things and fifth generation communication systems (5G) enable "smart" cars to connect directly to the network and share information. Attacks using malicious code provides direct access to vehicles to control and direct its movement, or eavesdrop on information.

Smart meter and network attacks. This type of attack targets the devices in the transport infrastructure. This interference attacks and negatively affects the ability of smart meters to connect to the grid and interact with other smart grid devices.

Smart meters are automated devices used to regulate activities such as managing energy and water supplies, traffic control, parking systems and other transportation services. Network attacks, on the other hand, aim to attack or negatively impact these devices.

Man-in-the-Middle Attack: In this type of attack, an attacker secretly intercepts the information sharing between two trusted parties in the network and transmits the information to both parties by altering it. Since there is no inspection capability between the communication channels in a Software-Assisted Network, an attacker with a Man-in-the-Middle attack can get all the details within the network by eavesdropping on the data (Danish Javeed at al., 2020).

The development of technologies such as fifth-generation wireless cellular communication systems can lead to significant changes in the field of data protection. Many factors must be taken into account in the field of data protection, the most important of which are legal frameworks and legislation.

Internet, information technology and data protection laws and appropriate measures play an imperative role in protecting personal data. They may include implementing additional measures and certain security protocols to combat the illegitimate use of personal data and protect people's privacy rights.

Conclusion

The rapid development of wireless mobile communication technologies meets the ever-increasing technological needs of users. Definitely, this development is an important issue in reviewing the history of mobile communication technology and understanding the current challenges. Indeed, the rapid development of mobile network technologies has increased the importance of data security and privacy, meanwhile exposing vulnerabilities in the technologies.

Despite the development of previous mobile communication technologies, the emergence of 5G in the field of wireless mobile network technologies is accompanied by a number of changes and offers. This article focused on the security aspects of 5G, as well as the performance, pros and cons of the different generations. In addition to the security challenges observed in previous generations, new security challenges are emerging with the advent of 5G. This can lead to serious threats, although it becomes more widespread and complex with billions of devices connected to the network.

The greater data volume and speed of 5G potentially enables different cyber threats to be targeted and damaged. This article emphasized the need for independent measures and advanced security protocols to control security risks. Furthermore, 5G technology is used to integrate all types of wireless networks, which allows to get the necessary network infrastructure.

Consequently, the advent of 5G brings great advancements in mobile wireless technologies, however raises new security issues. Taking measures and implementing protocols is essential to effectively manage security risks. Additionally, the integration of all types of wireless networks helps to optimally manage the infrastructure and ensure security. This article can be very useful for researchers working in the field of mobile wireless technologies.

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