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DEVELOPMENT OF 5G TECHNOLOGY AND ITS IMPACT ON THE TELECOMMUNICATIONS ECONOMY

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РОЗВИТОК 5G ТЕХНОЛОГІЙ ТА ЇХ ВПЛИВ НА ЕКОНОМІКУ ТЕЛЕКОМУНІКАЦІЙ

As part of the research, attention is paid to the fact that the development of 5G technologies provides for the construction of networks that are characterized by both a general acceleration of data exchange or transmission processes and a reduction in network latency (due to an increase in its capacity). These improvements will undoubtedly have a significant impact on the telecommunications industry. In particular, the deployment of a 5G network is currently contributing to a rapid increase in demand for telecommunications services in various countries while simultaneously raising expectations and requirements for the quality of services. Therefore, the article reveals the current specifics of the development of 5G technology and specifies its impact on the telecommunications industry. According to the results of the research, attention is drawn to the fact that while other types of networks (including 4G, 3G, etc.) allow for the use of mobile communication, Internet access, and other services with certain limitations, the development of 5G networks provides fast, stable, and uninterrupted communication with a high level of quality and wider data transmission capabilities. To avoid these problems, the authors concluded that in most countries, 5G technologies already have a significant impact on the telecommunications economy, which lies in creating opportunities for telecommunications equipment operators and providers of mobile and other communication services to: substantially transform the spectrum of classical private and public services towards increasing their convenience and accessibility, thanks to coverage, high data transfer speeds, and other advantages of the 5G network; introduce private and public services based on the Internet of Things; introduce support services for personalized "smart city" and "smart building" services that allow households to monitor their energy and other resource expenditures. The synthesis of the mentioned opportunities allows telecommunications companies to increase the number of mobile Internet users, and private and other communication services; increase the revenue of communication operators, expand the capacity of service sectors, increase the number of devices connected to the network, and increase the volume of data transmission, improving the quality of services for clients. The prospects for further research in the outlined area lie in the exploration of possible models for creating new services in the field of virtual and augmented reality, telemedicine, smart cities, etc.

У межах дослідження звернено увагу, що розвиток 5G технологій забезпечує побудову такого типу мереж, який вирізняє загальне прискорення процесів обміну або передачі даних та зниження затримки у мережі (що зумовлене підвищенням її ємності). Ці покращення, безумовно, матимуть значний вплив на економіку телекомунікацій. Зокрема, наразі розгортання 5G-мережі сприяє стрімкому збільшенню попиту на послуги телекомунікаційних компаній в різних країнах, при паралельному підвищенні очікувань та вимог, щодо якості послуг. Відтак, стаття розкриває сучасну специфіку розвитку 5G технології та конкретизує її вплив на економіку телекомунікацій. За результатами дослідження звернено увагу на той факт, що якщо в інших типах мереж наявна можливість користуватися мобільним зв'язком, доступом до Інтернету та іншими послугами з певними обмеженнями, то розвиток 5G мереж забезпечує швидкий, стабільний та безперебійний зв'язок з високим рівнем якості та ширшими можливостями передачі даних. Враховуючи вищенаведене, зроблено висновок, що в більшості країн 5G технології вже зараз мають вагомий вплив на економіку телекомунікацій. Цей вплив полягає у формуванні можливостей для операторів телекомунікаційного обладнання та провайдерів послуг мобільного та іншого зв'язку: значно трансформувати спектр класичних приватних та загальнодоступних сервісів у бік збільшення їх зручності і доступності, завдяки охопленню, високої швидкості передачі даних та іншим перевагам 5G мережі; ввести на ринок приватні та загальнодоступні послуги на базі інтернету речей; ввести на ринок послуги підтримки персоналізованих сервісів "розумного" міста та "розумних" будівель, що дозволять моніторити витрати домогосподарств на енергію та інші ресурси. Синтез наведених можливостей дозволяє телекомунікаційним компаніям збільшення кількості користувачів мобільного Інтернету, приватних та інших послуг зв'язку; збільшення прибутку операторів зв'язку; розширення ємності сервісних сфер; збільшення числа пристроїв, що підключені до мережі, та збільшення обсягу передачі даних; покращення якості послуг для клієнтів. Перспективи подальших досліджень в окресленій сфері полягають у дослідженні можливих моделей створення нових сервісів у сфері віртуальної та доповненої реальності, дистанційної медицини, розумних міст тощо.

Key words: 5G networks; communication networks; private 5G networks for industrial applications; public 5G networks; services; operator.

Ключові слова: 5G-мережі; мережі зв'язку; приватні мережі 5G з індустріальним застосуванням; загальнодоступні мережі 5G; послуги; оператор.

PROBLEM SETTING (DESCRIPTION OF THE PROBLEM BEING ANALYZED IN GENERAL AND ITS CONNECTION WITH IMPORTANT ACADEMIC OR PRACTICAL TASKS)

As of 2022, 5G networks are deployed in some form in developed European countries (with a range of public and private 5G networks for industrial applications). With an average coverage of 5G networks in Europe at 66% of the territory in 15 EU member states, this figure reaches approximately 40—45%. 5G networks are already deployed in the Asian and North American regions with coverage estimated at 66—75% (with the most extensive use of 5G networks in enterprises). 5G networks are already operational in Ukraine, albeit in the early stages of development. This is confirmed by the fact that in 2017, former President of Ukraine P. Poroshenko signed a decree on the introduction of 5G on the territory of our country, and in November 2020, the Cabinet of Ministers of Ukraine approved a plan of measures to release additional radio frequency bands in the ranges of 790—862 MHz and 694—790 MHz from television radio-electronic means for the full implementation of high-speed 5G communication in Ukraine [6]. In addition, from December 1, 2019, to May 31, 2020, testing of 5G technology was carried out in Ukraine by Ericsson and mobile operator Lifecell in the stores of the Lifecell network. It is already clear that the de-

velopment of 5G technology (or fifth-generation wireless communication, which is a direct successor to 4G) provides for the construction of such types of networks that are characterized by both general acceleration of data exchange or transmission processes and a decrease in network latency (which is due to an increase in its capacity).

These improvements will have a significant impact on the telecommunications economy. In particular, the deployment of 5G networks is driving rapid increases in demand for telecommunications services in various countries, while simultaneously raising expectations and requirements for service quality. The Ericsson Mobility Report shows that in 2020, the percentage of mobile internet users who used high-speed services for the first time exceeded 10% worldwide. Furthermore, the overall increase in network capacity and reduction in network latency is not only prompting telecommunications companies to actively update their services and service offerings, but also creating opportunities to create tariff plans with higher data transmission speeds, services related to connecting various devices to the internet for data retrieval and exchange. It is expected that the increasing number of connections to 5G networks will drive the popularity of IoT services (such as support for "smart home" systems and others connected to the internet), and by 2027, over 50% of all mobile devices in the world will have such support. The outlined realities of

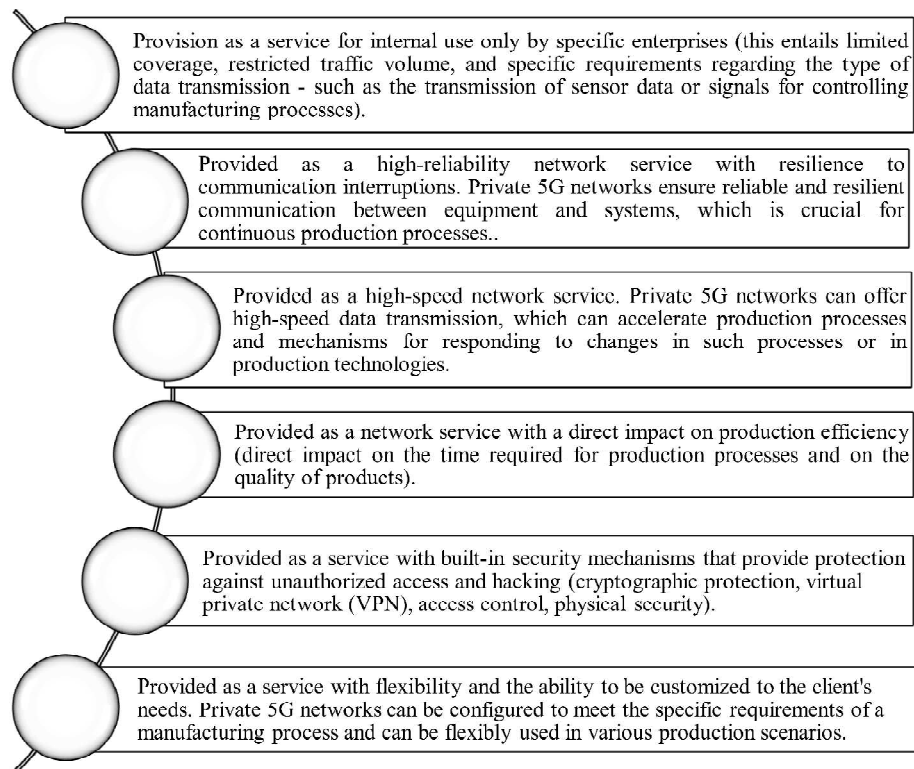


Fig. 1. Features of private 5G networks for industrial applications when provided as a service

Source: created based on [6].

5G technology development are leading to new opportunities for businesses in the telecommunications industry in many countries, which could result in the creation of new business models, increased profitability of telecommunications companies, and more.

THE ANALYSIS OF THE LAST RESEARCH AND PUBLICATIONS IN WHICH THE SOLUTION TO THIS PROBLEM IS BEGUN

The peculiarities of the development of 5G technology and networks based on them have been studied by such researchers as Teereshko Yu., Tardaskina T., Tolkachova H., Banket N., Alkhimova V., Bilous O. However, these studies mostly address specific issues that have arisen from the evolution of mobile telecommunications and emphasize the advantages of 5G technology over previous technologies. While these researchers acknowledge that 5G technology represents a new generation of telecommunications that utilizes high-frequency ranges and a large number of small data transmission stations to achieve extremely high data transfer speeds and low latency, they do not identify their impact on the telecommunications industry. These considerations underscore the relevance and timeliness of investigating the current realities of 5G technology development and its impact on the telecommunications industry's economy.

FORMULATING OF ARTICLE PURPOSES (THE PURPOSE OF THE STUDY)

The purpose of the article is to identify the current specifics of the development of 5G technology and to specify their impact on the economy of telecommunications.

THE PAPER'S MAIN BODY WITH FULL REASONING OF ACADEMIC RESULTS

According to the research content, the authors rely on examining the development of the telecommunications economy through the prism of improving and modernizing existing telecommunications networks to provide faster and more reliable connections between different devices and to improve the quality of telecommunications services. The basic thesis is that the introduction of 5G technology has a significant impact on the telecommunications economy. This 5G technology is the basis for building next-generation communication networks, and as such, it should be considered the next stage in the development of mobile telecommunications (after 4G technologies), which involves gradual transformations in data transmission, latency between the time of sending a request and receiving a response, and network capacity in the following directions:

— Private 5G networks with industrial applications in various industries (in this case, only cases

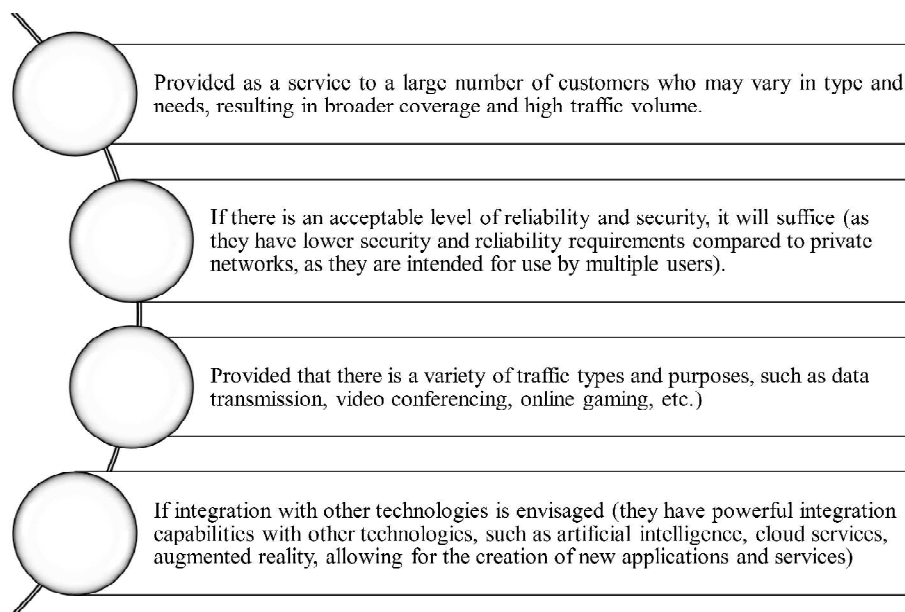


Fig. 2. Features of public 5G networks provided as a service

Source: created based on [2; 4—6].

where the network is provided as a service by telecommunications service providers or specialized telecommunications companies are considered). These networks have several features, including (Figure 1): being provided as a service for internal use only by specific enterprises (which results in limited coverage and limited traffic volume); high reliability and resilience to communication interruptions; data transmission speeds of 10 Gbps and above; built-in security mechanisms; flexibility and configurability; and direct impact on production efficiency.

An additional feature of a private 5G network with industrial applications, considering that we are focused solely on practice when it is delivered as a service by telecommunications service providers or specialized telecommunications companies, is its provision on a subscription or pay-per-use basis. Specifically, the network customer typically pays for the cost of equipment, network deployment, and configuration, as well as support and maintenance. Payment for network usage can be made for a fixed period or the use of network resources.

— Public 5G networks, or communication networks that support the 5G standard and are intended for general use and can be of different types and purposes. The main types of such networks include [4—5]: mobile operator communication networks (which are available to mobile communication users and allow voice and data transmission from mobile phones and other devices), Wi-Fi-based communication networks (which are used for wireless communication between devices and are installed indoors to

provide wireless Internet access for users), Small Cells-based communication networks (which are used to provide wireless coverage in areas with a high concentration of users, including on streetlights, poles, and other locations to provide better network access); satellite-based communication networks (which are used to provide wireless communication over long distances); virtual network-based communication networks (which are used to provide secure and fast connections between different computers and devices). Within the scope of this research, only cases where networks are provided as services by telecommunications service providers or specialized telecommunications companies are considered, and they have several features that distinguish them from private 5G networks for industrial applications, including (Fig. 2): 1) delivery as a service to a large number of clients who may vary in type and needs (resulting in wider coverage and large traffic volumes); 2) an acceptable level of reliability and security (as they are intended for use by different users); 3) diverse traffic types and purposes; 4) integration with other technologies. Taking into account that we are only focusing on the practical aspect of networks being provided as a service, the specificity lies in its provision based on subscription or payment for multifunctional use (which caters to a large number of clients who may have different types and needs).

Therefore, the use of 5G technologies within public and private 5G networks with industrial applications has great potential to improve the telecommunications economy, due to its targeted

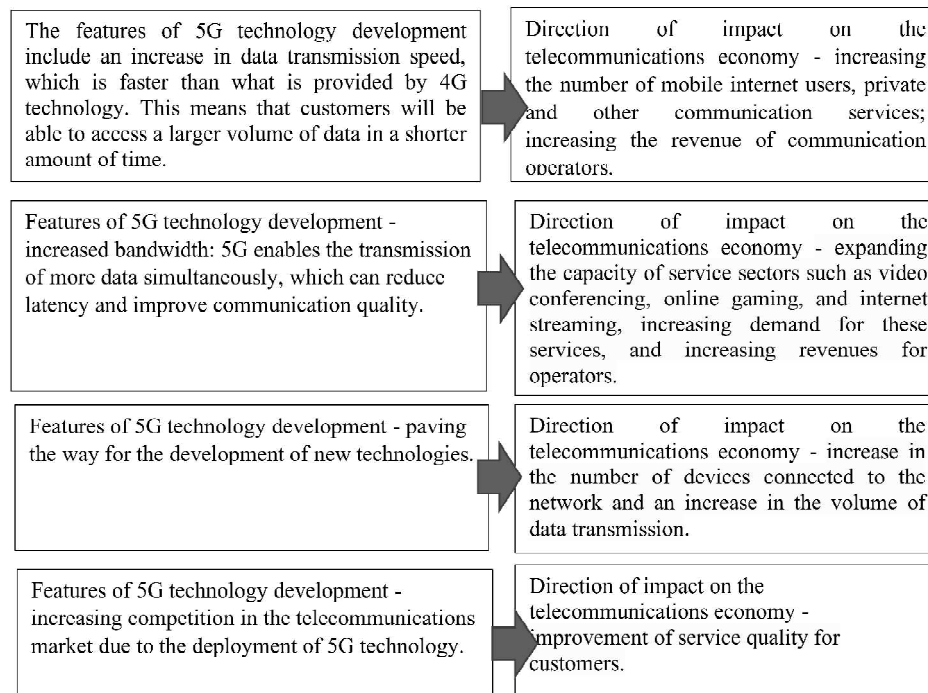


Fig. 3. Features of the impact of 5G technology development on the telecommunications economy

Source: created based on [2; 5; 4; 6], Fig. 1 and Fig. 2.

impact (shown in Figure 3), which increases the number of mobile internet users, private and other communication services, operator revenues, service sector capacity, number of devices connected to the network, data transmission volume, and improved quality of services for customers. According to analysts, global revenues from 5G services could reach approximately \$3.6 trillion by 2035, which is a significant resource for further development of the telecommunications industry [6]. In addition, the service sector capacity of the telecommunications economy has already expanded with support for mobile communication, SMS, and internet access, with support for video conferencing, online games, and internet broadcasts. Other impacts are currently fragmented. All of this will have a cumulative impact on the economy and technological progress of telecommunications companies.

The outlined impacts and features for both public 5G networks and their private configurations with industrial applications are formed in connection with the fact that they support the latest communication standard, which provides significantly higher data trans-

Table 1. Most notable projects for deployment of private 5G networks with industrial application

5G networks	5G network deployment experience	Advantages of private 5G networks
BMW company	The company has launched a private 5G network for automobile production at its factory in Leipzig, Germany.	Increased productivity and efficiency in the production process; high level of security and data confidentiality in the production process.
Ford company	The company has launched a private 5G network for automobile production at its factory in Detroit, USA.	Increased efficiency of production processes; reduction of costs for reconfiguration and monitoring of production equipment functioning.
Siemens company	The company has launched a private 5G network at its power plant "Elbe Station" in Hamburg, Germany (the network provides wireless connectivity to sensors, controllers, and other devices within a range of up to 1 km from the base station).	The optimization of data collection and processing processes to improve the efficiency and reliability of production processes, monitoring of the communication infrastructure at the station by the company's own means, and increasing production efficiency.
Deutsche Bahn company	The company has launched a private 5G network at a railway station in Nuremberg, Germany for monitoring and controlling train traffic.	Allows for safe and efficient railway operation using high-speed communication with low latency and high bandwidth capacity.
Ukkoverkot company	The company has launched a private 5G network for monitoring crop and livestock conditions on farms in Finland.	Allows to improve the quality and accuracy of monitoring the condition of crops and animals, more efficient data processing, which has reduced the time and costs of information analysis.
Dongfeng Motor company	Creation of a "smart" factory based on 5G technologies in the city of Wuhan, located in the Hubei province.	Allows robots and other devices in the factory to exchange data and communicate with each other seamlessly, increasing productivity and efficiency in the manufacturing processes.

Source: Compiled from official websites of BMW, Ford, Siemens, Deutsche Bahn, Ukkoverkot, and [3].

Table 2. Most notable projects for the deployment of public 5G networks being developed by mobile operators

5G networks	5G network deployment experience	Advantages of private 5G networks
Verizon in CIIIA	One of the leading mobile operators in the US, which began deploying 5G networks in some cities in the US in 2019, is Verizon. Currently, Verizon provides 5G services in more than 60 cities in the US, including New York, Los Angeles, Chicago, Houston, and Washington.	Increased data transmission productivity and the ability to connect a significant number of devices to the network within coverage areas.
SK Telecom in South Korea	The leading mobile operator in South Korea launched the world's first 5G network in 2019. Currently, the operator continues to deploy the network and provide services in various cities in South Korea.	Increased data transmission productivity and the ability to connect a significant number of devices to the network.
Vodafone in Europe	Vodafone was one of the first operators to launch 5G networks in several European countries in 2019. Currently, they have 5G coverage in more than 100 cities in Europe, including Ukraine (within the innovation hub 5G Lab, which was opened in UNIT. City).	Increased data transmission productivity, the ability to connect a significant number of devices to the network, and the ability to introduce new services and applications.
China Mobile in China	China Mobile launched its 5G network in China in 2019. They continue to deploy the network and provide services in various cities across the country.	Increased data transmission productivity, the ability to connect a significant number of devices to the network, the ability to introduce new services and application, and the ability to access high-speed internet anytime and anywhere.

Source: compiled from official websites of Verizon, SK Telecom, Vodafone, China Mobile, and [3].

mission speeds than previous ones (including 4G, 3G, etc.). Such a standard is created using new radio frequency bands technology, as well as more complex encoding and modulation algorithms, which provide data transmission speeds up to 20 Gbit/s, better network performance and reliability, network configurability, and other advantages outlined in Figures 1—2. Let's examine the above-mentioned features of 5G technology development and the specifics of their impact on the telecommunications economy in more detail.

So, private 5G networks with industrial applications are currently present in various industrial sectors (such as the automotive industry, electronics manufacturing, energy, and others), and their impact results in transformations in production systems. Specifically, in each point of the industrial space (located inside an assembly hall, logistics center, or administrative facility), there is the possibility of connecting to fast, reliable, and secure networks. Currently, there are approximately 300 successfully implemented projects for deploying private 5G networks in the EU [3]. Germany is leading in this area with around seventy functioning networks. In the Asian and North

American regions, more than 14,000 private networks based on 5G technologies have been deployed (for example, in China, there are over 6,500 private networks, the vast majority of which are based on 5G technologies) [3]. The most well-known projects for deploying private 5G networks with industrial applications are listed in Table 1.

In Ukraine, there are currently no large-scale projects for the deployment of private 5G networks with industrial applications. However, there are already some trials of the technology being conducted in various industries. For example, in 2021, Ericsson Ukraine in partnership with Kyivpastrans launched a test project using 5G technology to monitor traffic and ensure road safety [3]. However, this was not a full-scale deployment of a private 5G network with industrial applications.

However, according to the analysis of private 5G networks with industrial applications presented in Table 1, it's evident that such networks provide their owners with the ability to: 1) control communication infrastructure on their own; 2) increase productivity and

efficiency in the production process (due to more accurate monitoring and control of work processes, use of autonomous robots, increased mobility of the workforce, wireless connection to sensors, controllers, and other devices); 3) reduce costs for reconfiguration and control of production equipment; 4) improve data security and confidentiality (private 5G networks can be protected from external attacks and ensure high data confidentiality); 5) achieve more efficient data processing and reduce time and costs for information analysis; 6) increase production efficiency (by reducing equipment downtime, reducing the number of defective products, and reducing the number of workers required for production). According to the outlined advantages, we believe that Ukraine should strive for a maximum increase in projects that lead to the full deployment of private 5G networks with industrial applications. These networks are supplied as a service, so in the period of post-war recovery, this can help quickly increase the competitiveness of telecommunications companies (whose services may include design, deployment, and support of private 5G networks, as well as integration with other systems used in industrial processes).

So, public 5G networks are currently being developed primarily in the format of mobile operator networks, which offer 5G support services to their subscribers (in the form of various subscription plans that provide access to the 5G network, or separate services that work only with the 5G network). Today, there are a significant number of successfully implemented projects for the deployment of public 5G networks in the EU, developed by mobile operators. The 5G network is quite widely developed in the Asian and North American regions, where the development of autonomous car services, medical technologies, and other innovative technologies is currently being implemented based on these networks. The most well-known projects for the deployment of public 5G networks developed by mobile operators are listed in Table 2.

In Ukraine, there are currently no large-scale projects for the deployment of publicly available 5G networks being implemented by mobile operators. However, certain test projects are already underway, such as testing the capabilities of 5G at the innovation platform 5G Lab, which opened in UNIT.City (where successful 5G use cases from Huawei and mobile operator Vodafone Ukraine are presented [1; 6]). Although the big three mobile operators — "Lifecell," "Vodafone Ukraine," and "Kyivstar" have announced that investments and efforts are aimed at launching 5G no earlier than 2022, a longer period should likely be expected due to Russia's military aggression against Ukraine and its consequences. Ukrainian mobile operators do not yet see opportunities for monetizing 5G technology. Additionally, Vodafone Ukraine recently boosted its own 4G network to a record-high speed of 772 Mbps (thanks to the aggregation of four LTE carrier frequencies: LTE1800 20Mhz 4x4 + LTE2100 10Mhz 4x4 + LTE2600 10Mhz 4x4 + LTE900 5Mhz 2x2) and is currently in the stage of monetizing it. In addition, there are currently other companies involved in the development and deployment of 5G networks, such as equipment manufacturers, and cloud service providers, as well as individual organizations and institutions working on creating other types of public networks, including those based on Small Cells. Specifically, such networks are currently being created in areas with limited access, such as buildings, narrow streets, and gaps between buildings (for example, in Miami, USA, Small Cells have been installed that have allowed for an increase in data transmission speed and coverage in the city's central area [3]), as part of the expansion of the quality of Internet of Things services, to ensure stable connectivity of various

smart devices to the communication network (in particular, in San Francisco, Small Cells have been installed that allow for tracking the location of cars and transmitting data about them to servers in real-time [3]). However, sufficient data for studying the deployment projects of Small Cells and other types of public 5G networks are currently lacking [3].

However, the prospects for the development of 5G networks, which are being developed by mobile operators, will be after the normalization of the situation, as according to the analysis (see Table 2), it is obvious that such networks provide their users with the ability to: 1) increased productivity when transmitting data (this means that users will be able to receive and send information much faster than on previous networks); 2) the ability to connect a significant number of devices to the network (which means that users can use Internet services and various applications on their devices without limitations); 3) the ability to implement new services and applications that were previously impossible on previous networks; 4) the ability to use high-speed Internet anytime and anywhere. Based on the outlined advantages, we believe that Ukraine still needs to strive for the deployment of public 5G networks developed by mobile operators, as this will not only transform the circle of classic mobile operator services but also introduce qualitatively new services which, due to the connection to the network of various things, will have a cumulative impact on the economy and technological progress of telecommunications companies.

CONCLUSIONS FROM THIS STUDY AND PROSPECTS FOR FURTHER EXPLORATION IN THIS AREA

The study highlights the fact that while other types of networks (including 4G, 3G, etc.) offer limited access to mobile communication, internet access, and other services, the development of 5G networks provides fast, stable, and uninterrupted communication with high-quality and wider data transmission capabilities. Taking into account the above, the authors have concluded that 5G technologies already have a significant impact on the telecommunications economy in most countries, which lies in creating opportunities for telecommunications equipment operators and providers of mobile and other communication services, by:

1. significantly transforming the spectrum of classical private and public services towards increasing their convenience and accessibility, thanks to the coverage, high data transmission speed, and other advantages of the 5G network

(services for content delivery are already changing on the market, thanks to the addition of virtual reality, high-quality streaming video);

2. introducing private and public services based on the Internet of Things, which, by connecting various things to the network that can interact with each other and with humans, providing automation and optimization of various processes, will create opportunities for offering health monitoring services, energy management, automatic control of traffic flows, smart homes, and others;

3. introducing support services for personalized "smart city" solutions will allow monitoring of traffic, city infrastructure, and "smart" buildings, enabling households to track energy and resource consumption. Additionally, the large amounts of data collected from various devices can be used to develop personalized solutions that consider the needs and preferences of each user.

The synthesis of the mentioned opportunities enables telecommunications companies to increase the number of users of mobile internet, private and other communication services; increase the revenue of communication operators, expand the capacity of service sectors, increase the number of devices connected to the network, and increase the volume of data transmission, improving the quality of services for customers.

The prospects for further research in this area lie in exploring possible models for creating new services in the field of virtual and augmented reality, telemedicine, smart cities, and so on.

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