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PROBLEMS OF THE NETWORK INFRASTRUCTURE CONVERGENCE OF UKRAINE AND EU: DIGITAL ECONOMY AND SOCIETY INDEX

The network infrastructure is the basis for the effective functioning of the modern digital economy. The success of the Ukrainian economy additionally depends on the compatibility of its network infrastructure with the network infrastructure of the EU. Therefore, it is relevant to analyze the state of the network infrastructure in the EU, compare it with the state in Ukraine, in order to determine the challenges that Ukraine will need to overcome in the convergence of the Ukrainian digital economy with the EU digital economy. The relevance of the work is justified by the fact that the introduction of advanced digital network technologies, coordinated with European ones, is one of the ways to increase the future competitiveness of the Ukrainian economy.

The Digital Economy and Society Index (DESI) summarizes a number of indicators of the effectiveness of digital technologies in Europe and allows us to assess the state of the digital economy and society. This work is devoted to analyzing one of the DESI indicators, namely, digital infrastructure, both in the European Union (EU) and Ukraine. The analysis covers the defined DESI 2023 digital infrastructures, such as at least 100 Mbps fixed broadband take-up, at least 1 Gbps broadband take-up, fixed Very High Capacity Networks (VHCN) coverage, Fiber-to-the-Premises (FTTP) coverage, mobile broadband take-up, 5G coverage, and 5G spectrum.

We have shown that Ukraine currently has a good offer of FTTP technology, which can become the basis for the convergence of the digital infrastructure of Ukraine and the EU. However, according to our analysis, Ukraine urgently needs to accelerate the implementation of the 5G network, especially the 5G spectrum technology, which will contribute to the modernization and recovery of the national economy. The results of the analysis will be useful for the convergence of the digital economy of Ukraine with the European digital economy.

Keywords: network technologies, network infrastructure, telecommunication network, DESI, DESI digital infrastructure indicators, digital economy.

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ПРОБЛЕМАТИКА КОНВЕРГЕНЦІЇ МЕРЕЖЕВОЇ ІНФРАСТРУКТУРИ УКРАЇНИ ТА ЄС: ІНДЕКС ЦИФРОВОЇ ЕКОНОМІКИ ТА СУСПІЛЬСТВА

Мережева інфраструктура є основою для ефективного функціонування сучасної цифрової економіки. Успіх української економіки додатково залежить від сумісності її мережевої інфраструктури з мережевою інфраструктурою ЄС. Тому важлвою є задача аналізу станів мережевої інфраструктури ЄС та України з метою виявлення об визначити викликів, які Україні потрібно буде подолати на шляху конвергенції української цифрової економіки з цифровою економікою ЄС. Актуальність роботи обґрунтовується тим, що впровадження передових цифрових мережевих технологій, узгоджених з європейськими, є одним із шляхів підвищення майбутньої конкурентоспроможності української економіки.

Індекс цифрової економіки та суспільства (DESI) узагальнює низку показників ефективності цифрових технологій у Європі та дозволяє оцінити стан цифрової економіки та суспільства. Ця робота присвячена аналізу одного з індикаторів DESI, а саме цифрової інфраструктури, як в Європейському Союзі (ЄС), так і в Україні. Аналіз охоплює цифрові інфраструктури визначені DESI 2023, такі як щонайменше 100 Мбіт/с фіксованого широкосмугового зв'язку, щонайменше 1 Гбіт/с широкосмугового зв'язку, фіксоване покриття мереж дуже високої пропускної здатності (VHCN), оптоволокно до приміщення (FTTP), використання мобільного широкосмугового зв'язку, покриття 5G.

Аналіз показав, що Україна на біжучий момент має добрий стан з впровадженням технології FTTP, і, відповідно, вона може стати основою для конвергенції цифрової інфраструктури України та ЄС. Проте, згідно з нашим аналізом, Україні терміново необхідно прискорити впровадження мереж 5G, яка сприятиме модернізації та відновленню національної економіки. Результати аналізу будуть корисними для зближення цифрової економіки України з європейською цифровою економікою.

Ключові слова: мережеві технології, мережева інфраструктура, телекомунікаційна мережа, DESI, показники цифрової інфраструктури DESI, цифрова економіка.

Introduction

Technological progress and the widespread use of online communication platforms have transformed the digital economy into a global entity that is constantly evolving. Online business transactions have become a common and favorable strategy nowadays. A detailed analysis of key trends, advantages, and disadvantages of digitalization of the economies of various countries can be found in [1]. The digital economy success depends on many factors, including the implementation of advanced digital network technologies and services [2-4]. The success of the Ukrainian economy additionally depends on its compatibility with the technologies of the EU.

Therefore, it is relevant to analyze the state of the network infrastructure in the EU to identify challenges that Ukraine will need to overcome in the convergence of the Ukrainian digital economy with the EU digital economy. The relevance of the work is justified by the fact that the implementation of advanced digital network technologies, coordinated with European ones, is one of the ways to increase the future competitiveness of the Ukrainian economy.

Network infrastructure is a fundamental aspect of the modern economy and society. It is the basis of modern business operations and communications. The task of network infrastructure is to transmit data streams around the world to connect users, devices, and services. Now, businesses often need to adapt their network to global requirements in order to remain competitive and relevant, both within the country and beyond. So, network infrastructure is a large, complex, and dynamic system containing many physical and wireless components, hardware, software, and network support. In this sense, studying the state of the network infrastructure in this broad sense of the term is complex, important, and relevant [5, 6].

The characteristics of the current state of the network infrastructure in 27 European countries used for the analysis, were taken from the media portal digital-strategy.ec.europa.eu/en [7].

The main contribution of this paper can be summarized as follows:

1. We made a comparative analysis of Ukraine's digital infrastructure and the countries of the EU and identified challenges related to the network infrastructure on the way to converge the Ukrainian digital economy with the EU digital economy.
2. We showed specific Ukraine currently has a good supply of FTTP technology, which can become the basis for the convergence of the digital infrastructure of Ukraine and the EU.
3. Per our analysis, Ukraine needs urgent acceleration of the 5G network implementation, especially the 5G spectrum technology, which will contribute to the modernization and renewal of the national economy.

Materials and methods

Progress in digital technologies in EU countries is monitored using the Digital Economy and Society Index (DESI). To create an opportunity to monitor Ukraine's progress in the direction of the digital economy, as well as to compare it with the digital economies of the EU, in September 2023, the Cabinet of Ministers of Ukraine approved the list of DESI indicators, the procedure for their collection and data exchange based on the EU methodology. In addition, to compete with and be at par with other countries, Ukraine could consider integration into the European Statistical System (ESS) to provide its indicators. All of this determines long-term need to improve the existing network infrastructure of Ukraine, to develop the communications network across the country's administrative borders and to provide an assessment of the digital economy.

One of the DESI indicators, as shown in Fig. 1, is digital infrastructure.

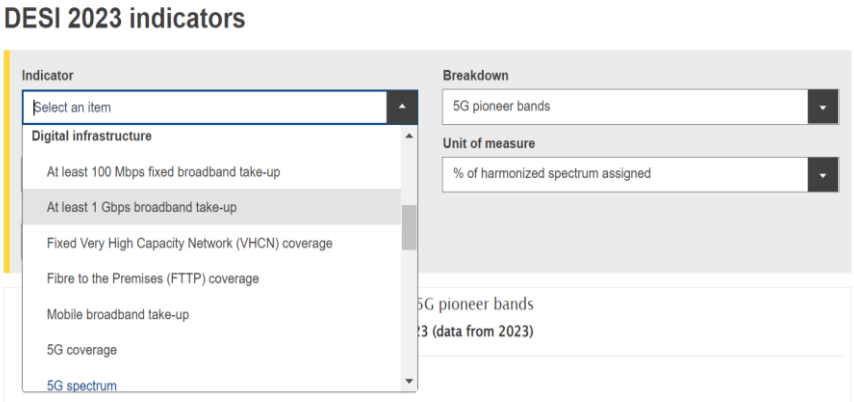

Fig. 1. Network technologies included in the DESI digital infrastructure list

The DESI 2023 digital infrastructure provides data on European countries performance with regard to network technologies. Below, for each of them, we present the results of our analysis, including EU countries data and, whenever possible, Ukraine data. Additionally, note that there are hybrid networks, which consist of communication line sections with the transmission of different physical nature signals on different transmission media [8].

Analyses and results

Below, we will sequentially analyze the state of various types of network infrastructure according to the classification used in DESI 2023 (Fig. 1).

At least 100Mbps fixed broadband take-up

Fixed connection with a speed of 100 Mbps has been used for telecommunication services for a long time. This technology cannot be considered novel. However, in many cases, such a connection can be successfully used for remote work and study.

According to DESI 2023, the 100 Mbps fixed broadband take-up for EU households is shown in Fig. 2. The coverage of this connection in different EU countries ranges from 20% (Greece) to 90% (Spain). At the same time, the indicator increases from 20% to 90% almost linearly from one country to another. The average value for the EU is 55%.

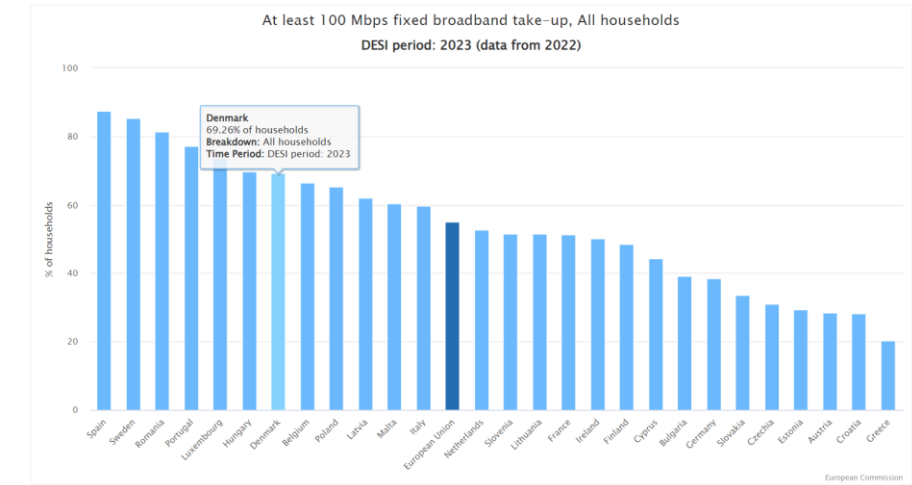

Fig. 2. Data on the use of fixed broadband with a speed of at least 100 Mbps

At least 1 Gbps broadband take-up

A broadband connection of at least 1 Gbps can provide significantly better quality of service than a 100 Mbps connection. However, DESI 2023 data (Fig. 3) show that the EU countries are much less provided with 1 Gbps connection, comparing to 100 Mbit/s connection.

The leader in providing technology with 1 Gbps connection is France (Fig. 3), although the indicator is only 40%. Note that this is almost twice lower than the best result for a 100 Mbit/s connection.

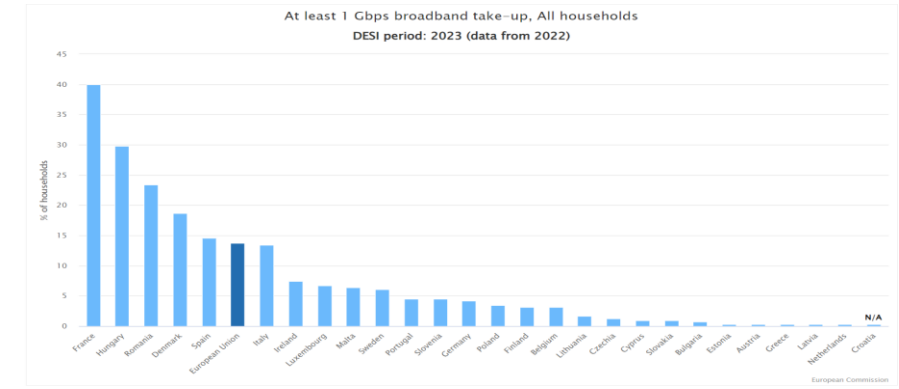

Fig. 3. Fixed broadband take-up with a speed of at least 1 Gbps

The distribution of the provision of 1 Gbit/s technology by country also looks different. There are only 4 countries with more than 15% coverage. Most countries (17 out of 27) have very low or low coverage of less than 5%. The worst-case coverage of less than 1% (Croatia) is 20 times worse than the worst-case scenario (20%) on 100 Mbps networks. For the EU, the provision of gigabit technology is 14%.

The Ukrainian market of telecommunications equipment offers a wide selection of equipment for fixed communication with a speed of 1 Gbps. We will be able to learn official data on its distribution after the integration of Ukraine into the European Statistical System (ESS).

Fixed Very High Capacity Network coverage

The next data transmission technology represented in DESI is a fixed Very High Capacity Network (VHCN). The term VHCN was introduced by the European Electronic Communications Code (EU) 2018/1972 (EECC). This is a network whose performance corresponds to an all fiber-optic network at least up to the distribution point at the serving place, for example, up to a multi-dwelling building or the base station in the case of wireless connection. Optical backbone networks today are the main foundational infrastructure that network operators use to deliver services to users [9].

Analysis of Fig. 4 shows sufficiently high VHCN coverage in the households of the European countries. VHCN coverage in 8 countries is very good (91%-100%), in 13 countries it is in the range of 71%-86%, in 5 countries - in the range of 53%-61% and only in one country (Greece) is 28%. For the EU, the coverage is 73.4%.

It should be noted that there is a gap in the provision of VHCN technology between rural and urban areas. Based on the results of the DESI 2022 Report, it is indicated that less than 40% of households in rural areas are covered by VHCN. This is twice lower than the urban areas coverage. To close this gap by 2025, Very High Capacity Network deployment in rural areas needs to be accelerated.

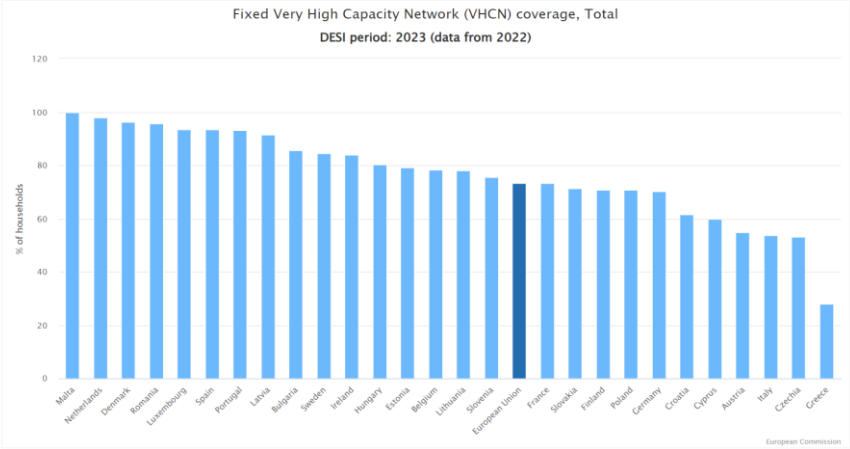

Fig. 4. Data on the use of Very High Capacity Network

Fiber to The Premises FTTP coverage

The next network technology from the DESI index is the Fiber to The Premises (FTTP) technology. FTTP is a modern technology that makes it possible to provide high-speed Internet access [10, 11]. FTTP Internet access based on optical fiber offers higher bandwidth, lower channel loss, and acceptable security in comparison with traditional two-pair or coaxial copper cables [12]. It involves bringing optical fiber from a central point directly to individual buildings of various purposes, such as enterprises, one- and multi-apartment buildings, and others. According to DESI 2023 (Fig. 5), the provision of this technology in 22 European countries is in the range from 50% to 95%, in the remaining 5 countries - in the range from 17% to 38%, and in the EU as a whole - 56%.

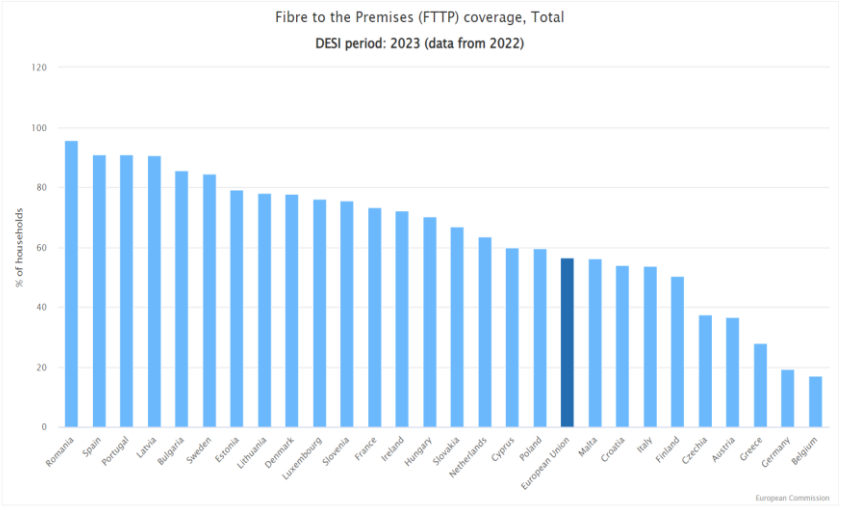

Fig. 5. Data on the use of Fiber To The Premises FTTP coverage

It should be noted that Ukraine takes a good place in Europe in the use of FTTP technology (Fig. 6). According to the data given in [13] provision of technology FTTP in Ukraine is 67%.

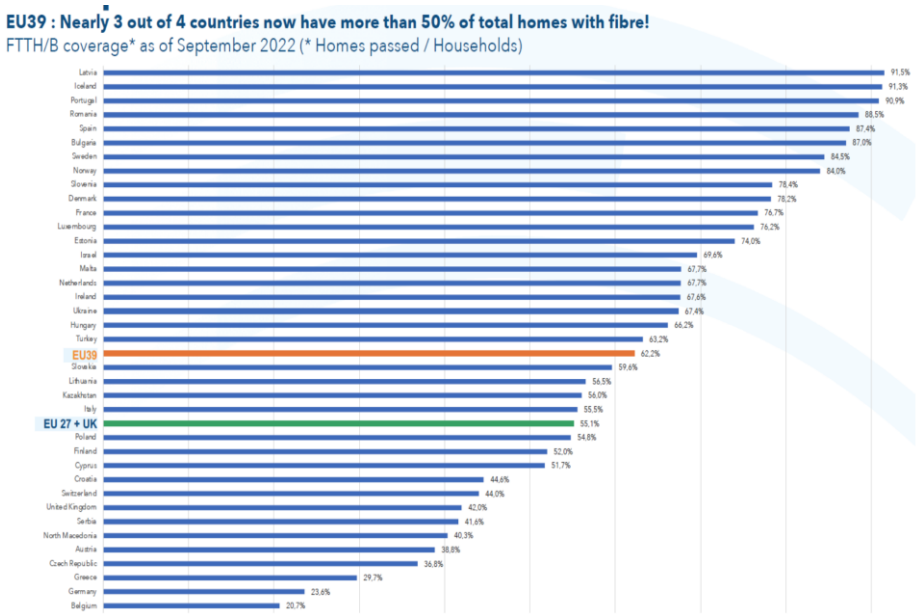

Fig. 6. 2023 Full Fiber Country Ranking

Mobile broadband take-up

Almost all the countries of the EU have a high provision of mobile broadband communication (Fig. 7). Coverage is in the range of 80% - 96%. Only two countries, Greece and Bulgaria, have lower take-up – 76% and 73%, respectively.

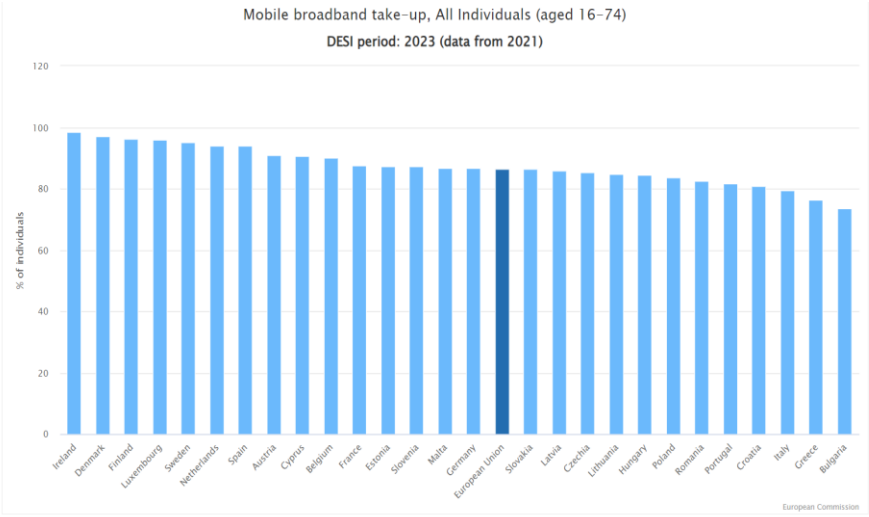

Fig. 7. Mobile broadband take-up in EU

5G Technologies

5G is a relatively new generation of wireless mobile broadband technologies that can provide the required quality of service for various types of traffic, including high speed, low latency, and high reliability. This enables the use of Massive-Machine-type communications (mMTC). Massive-Machine-type communications are considered one of the fundamental services in the digital world of the future, enabling a wide range of applications in current 5G networks and future Beyond 5G (B5G) networks, including industrial automation, intelligent transport, smart grid, etc. [14, 15]. The primary purpose of 5G is to transition industries that currently use wired infrastructure to wireless. The transition to fifth-generation networks allows faster and easier implementation of smart technologies in transportation, medicine, industry, agriculture, and smart cities [16-18].

Today, 5G technology has conquered the European telecommunications market, as evidenced by the data in Fig. 8 and Fig. 9. The 5G coverage using low and medium frequency bands is 80% - 100% in 16 countries and the EU as a whole. In 5 countries the coverage is less than 50%.

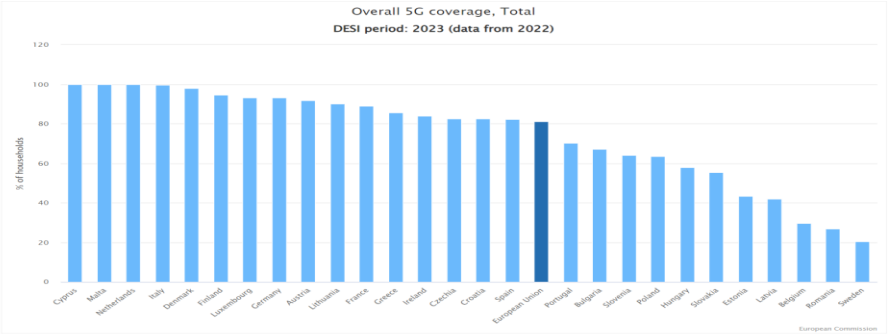

Fig. 8. 5G coverage in EU

Note that Sweden is ranked lowest with the 20% coverage. At the same time Sweden has 84% coverage with 5G Spectrum technology, focused on the so-called "pioneer bands" (Fig. 8). According to the media platform 5gobservatory.eu at the link https://gsacom.com/5g-spectrum-bands, the 26 GHz band was identified as the 5G pioneer band in Europe. Its use allows significantly higher speeds and better time indicators for real-time applications [19-21].

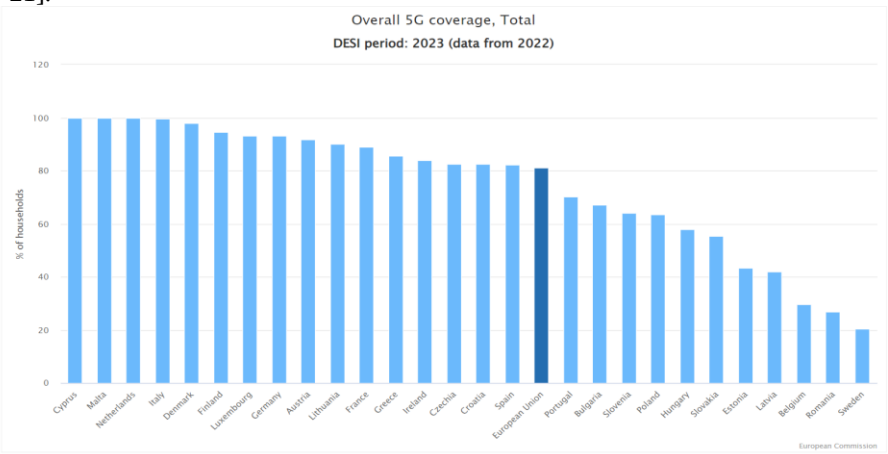

Fig. 9. Data on the use of 5G spectrum

The high network performance of the 5G Spectrum, and especially the extremely short response time, is the basis for a breakthrough in the time-critical areas of industry, especially, in autonomous transport, and telemedicine. As the DESI 2023 data illustrates, Europe is reasonably well equipped for this state-of-the-art 5G technology. The exception is Poland, which does not have high-speed 5G in the "pioneer bands" at all, although its 5G technology coverage is 62%.

Mobile operators in Ukraine recognize the 5G introduction as a strategic step of technological development. The National Commission of Ukraine, which carries out electronic communications regulation, considered the request of the Kyivstar company regarding the testing of the radio technology of the 5G standard and permitted to test the base stations of the 5G technology. Testing was conducted in February 2024. According to the results of a successful short-term test, Kyivstar confirmed the readiness of the core of its main packet network for the future rapid deployment of the 5G network with Non Stand Alone architecture for pilot or commercial operation.

Results and Discussion

The digitization of the Ukrainian economy depends on a number of factors, including the implementation of advanced digital network technologies and services. The digital economy and society index summarizes a number of indicators of the effectiveness of digital technologies in Europe and allows us to assess the state of the digital economy and society. According to DESI one of the indicators of the digital economy and society index is digital infrastructure. In this work, based on DESI 2023, we analyzed the following digital infrastructure indicators: at least 100 Mbps fixed broadband take-up, at least 1 Gbps broadband take-up, fixed Very High Capacity Networks (VHCN) coverage, Fiber-to-the-Premises (FTTP) coverage, mobile broadband take-up, 5G coverage, and 5G spectrum.

The article clearly illustrates the implementation of these technologies in different EU countries. Their comparative analysis by country, data on availability, technical characteristics, and prevalence of these technologies in Ukraine were conducted in parallel when considering each technology. Below we formulate the general results of the analysis and recommendations.

- Based on DESI 2023, we identified the challenges related to the network infrastructure on the way to the convergence of the Ukrainian digital economy with the EU digital economy.

- Currently, Ukraine is well equipped with FTTP technology, which can become the basis for the convergence of the network infrastructure of Ukraine and the EU.
- Our analysis revealed an urgent need to accelerate the implementation of 5G, and especially the 5G spectrum in Ukraine. This will have a significant impact on the modernization and renewal of the national economy. The paper analyzes the state of each of these technologies in different countries of the EU. In parallel, data on the availability of these technologies in Ukraine and their current status were presented.

Conclusion

The analysis showed Ukraine is currently in a good position with the implementation of FTTP technology. Therefore, this optical technology can become a good basis for the convergence of the digital infrastructure of Ukraine and the EU. However, according to the analysis, Ukraine urgently needs to accelerate the implementation of 5G networks, which will contribute to the modernization and restoration of the national economy. At the same time, as the results of testing conducted by telecommunication companies demonstrated, the technical possibilities for the implementation of 5G in Ukraine exist.

The results of the analysis will be useful for bringing Ukraine's digital economy closer to the European digital economy. The analysis results will be useful for the convergence of Ukraine's digital economy with the digital economy of the EU.

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