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A NETWORK OF HOTSPOTS FOR POINTS OF INVINCIBILITY

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***Abstract* —** *The topic of this work is the realization of a network of hotspots. This work provides basic information about wireless communication technology (Wi-Fi) and its advantages, which ensure the rapid spread of hotspots across Points of Invincibility in Ukraine. A study of hotspots network of Points of Invincibility was carried out on the example of the Primorsky district of the city of Odessa to provide the use of Internet resources to citizens and internally displaced persons.*

***Keywords* —** *Hotspot, wireless network, Point of Invincibility, Starlink internet-terminal, peak hour.*

I.INTRODUCTION

In connection with the large-scale power outage in Ukraine due to russian shelling of the energy infrastructure in the country, the Points of Invincibility, which were previously announced by the President of Ukraine Volodymyr Zelenskyi, began to be opened. Thus, over 4,000 such points have been prepared throughout the country. The plan of the terrorism sponsor country is to leave the residents of Ukraine without electricity, light and heat. In the event of a long-term emergency power outage, Points of Invincibility become an island of safety, stability, and warmth, which operate around the clock and are free for temporary stay [1].

Now it is planned to equip Points of Invincibility with Starlink internet-terminals, but there are not enough of them [2]. Services to be provided in the Points of Invincibility, despite the power outage consists of:

Fig.1. Services at Points of Invincibility

II. LITERATURE ANALYSIS

The majority of such points are organized and equipped using the allocated resources of executive authorities and local self-regulation agencies in each territorial area. As for the

Points of Invincibility organized by responsible businesses (operating at the expense of the business), they provide an opportunity to warm up and recharge mobile devices. Other services may be at charge at the discretion of the owners. Currently, there are about 150 Points of Invincibility in Odessa, but only 55 of them provide Internet access [1].

The study examines twelve Points of Invincibility from the point of view of providing the possibility to get free Internet access in the city of Odesa. Points of Invincibility in Odesa are characterized by a large influx of citizens, guests of the city and internally displaced persons. All of them are in a great need of fast and high-quality communication with relatives and employees at working enterprises. In addition, in the central part of the city there is an opportunity to connect network equipment to the packet transport network.

Therefore, the topic of introducing a network of hotspots operating on the wireless Wi-Fi radio access protocol (Wireless Fidelity) in Points of Invincibility, is relevant to this day. According to the National Commission for State Regulation in the Field of Communication and Informatization, the state of the telecommunications services market for 2021 in Ukraine, excluding the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol, and part of the temporarily occupied territories in the Donetsk and Luhansk regions, covers services of mobile communication, fixed access to the Internet, fixed telephone communication services, provision of infrastructure facility channels, etc.

The main indicators of the industry for 2021 are as follows: the total annual revenue of the communications market amounted to UAH 81 billion, 91% of which is traditionally revenue from the provision of telecommunication services. In the structure of revenues from the provision of telecommunication services in 2021, the largest share was mobile communication - 66% and fixed Internet access - 19.5%. There is a noticeable increase in revenues from the provision of mobile communication services, which in 2021 increased by 14% compared to 2020 [3]. Below is an infographic of the state of telecommunications services in Ukraine. The state of the telecommunications services market according to the data of the annual report for 2021, received as of March 20, 2022, is presented in Fig. 2. The mass use of modern communication services using LTE technologies, which became possible after the launch of 4G networks in 2018 by the three largest telecommunications operators, gave a tangible impetus to increase a demand for the usage of mobile Internet by Ukrainians. In 2021, revenues from the provision of Internet access services increased by 14% compared to last year.

During 2021, mobile operators significantly expanded coverage on the territory of Ukraine with 4G networks, which made it possible to increase the share of the population that can receive mobile broadband access to the Internet, which significantly speeds up and facilitates all personal and business interactions. Behind the scenes, constant work on improving the quality of services and building networks continues. The ideology of the Internet network, which was initially developed at the initiative of the US Department of Defense in case of nuclear war, has now become an increasingly pervasive ideology on which the majority of information systems designed for widespread use are built.

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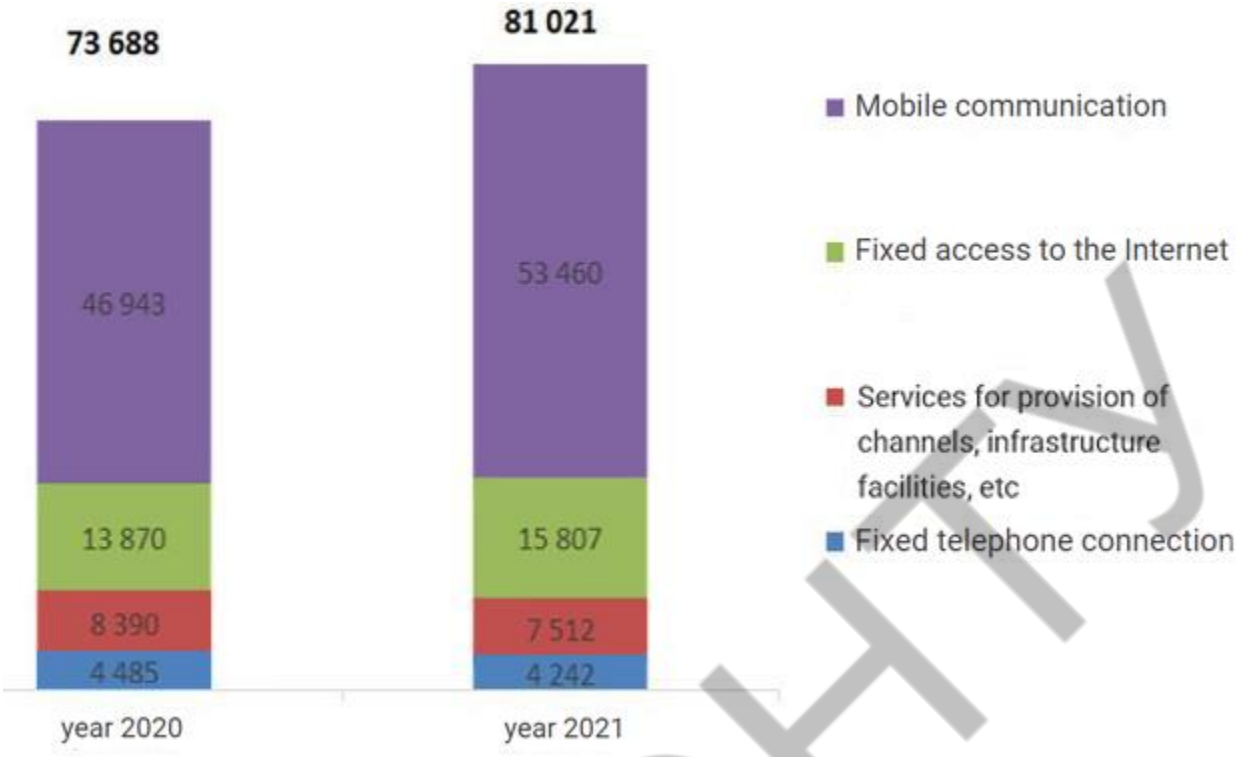

Fig. 2. Structure of revenues of telecommunication services, million UAH.

Today, the Internet unites many different networks, millions of computers, hundreds of millions of users from all continents, and according to various estimates, the number of such users increases by 50-80% annually. The Internet provides prompt access to information on any topic [4].

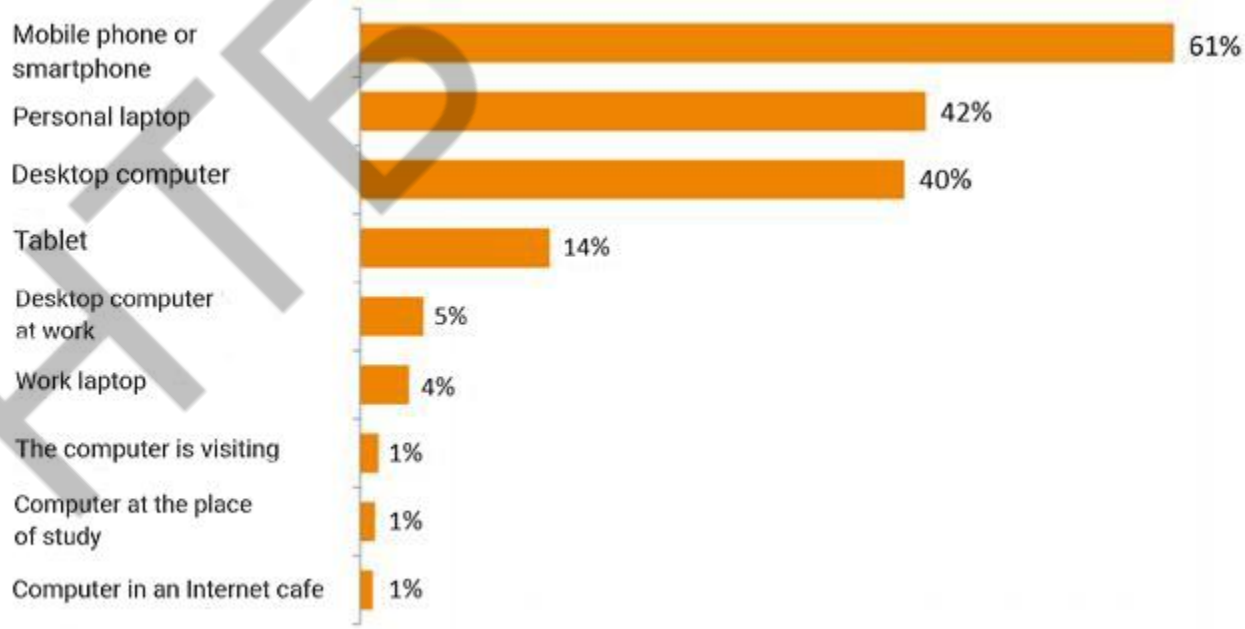

Fig. 3. Distribution by types of access of regular users to the Internet in Ukraine (according to Factum Group Ukraine) [5].

Mobile devices (pocket computers, smartphones and laptops) equipped with client Wi-Fi adapters can connect to the local network and access the Internet through access points - Hotspots.

This technology has a number of advantages that ensure its rapid spread. It allows you to deploy networks without laying cables, which reduces the cost of creating and expanding networks.

Places where it is not possible to lay a cable, for example, outside the premises of buildings of historical value, can be served by Wi-Fi networks. In addition, Wi-Fi devices are widely distributed on the market, and devices from different manufacturers can interact at the basic level of services. It is easy to add new equipment to a wireless network, which is a disadvantage of cable networks.

Wi-Fi is a set of global standards. Unlike mobile phones, Wi-Fi equipment can work in different countries around the world.

The availability of standards that provide different data transfer speeds allow you to choose the most optimal equipment to ensure the necessary functionality of the selected services.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The total number of subscribers with high-speed Internet access is constantly growing. The largest share is made up of subscribers who get access to the Internet through wireless communication channels - 66%. Thus, the use of Wi-Fi technology for the rapid organization of high-speed access networks is expedient and economically beneficial.

The object of this topic regarding the introduction of hotspots network in Points of Invincibility is the study of the literature on Wi-Fi radio access technology, the creation of a scheme of the network of hotspots, the calculation of network segment indicators.

The subject of the study is a network of hotspots for public access to the Internet in Points of Invincibility.

Research methods - analysis of Wi-Fi technologies, comparative analysis of Wi-Fi radio access network equipment, application of software for modeling network segment indicators.

Wi-Fi technology is most effective for building wireless local networks (WLAN) and for organizing so-called active zones (Hotspots) - access points in places where potential users are concentrated, who have terminals with Wi-Fi support (portable and pocket personal computers with appropriate hardware modules). Such points can be deployed in places of public catering, the client base of which consists of representatives of small and medium-sized businesses and wealthy sections of the population; in hotels, waiting rooms of airports, railway and bus stations.

The cycle of organizing wireless public Wi-Fi networks consists of the following stages:

1) creation of a project of the future Wi-Fi zone;
2) equipment selection and configuration;
3) organization of a local wireless network;

4) access settings and Internet connection
5) protection against unauthorized access.

The radio access network of Wi-Fi technologies is deployed quickly and with relatively low costs, due to the use of a significant amount of standard local area Ethernet network hardware. Access points (AP) are used on the network, which will provide access to the public data transmission network and a large number of subscriber stations. The access points provide interaction over the radio channel with subscriber stations through the radio interface of the 802.11 standard, and through the Ethernet protocol they interact with the public data transmission network. Access points and base stations (BS) have standard Ethernet interfaces. 10/100/1000BASE-T LAN port. Each access point provides coverage of the service area. The radius of the service area depends on the parameters of the physical level and depends on the generated load.

Access points of one active with the help of an Ethernet switch interact with each other, as well as with service servers.

Since the main use for the Wi-Fi network (IEEE 802.11 standard) is mass access to the Internet, lines with a significant capacity of Gigabit Ethernet are appropriate in the area of access to the transport network.

The MCE Y.1231 recommendation provides the following elements of a Wi-Fi access network (IEEE 802.11 standard):

1) SESM (Subscriber Edge Services Manager) server for managing services on the subscriber side for registering users and visitors to the network, which allows you to distinguish your own users of the radio access network from users of other networks that currently use this network, and charge them accordingly for the services provided.
2) the main and backup AAA servers (Authorization, Authentication, Accounting) for user authentication, access authorization and billing, the information and functions of which are duplicated; user authentication is possible using the common RADIUS protocol;

When organizing an active Wi-Fi zone, payment for the provided services should be organized by prepaid cards for mass Internet access. Hotels, public catering outlets etc. should have a possibility to receive a single bill for the services of the main activity together with telecommunication services received through the radio access network.

For the Wi-Fi hotspot, support for virtual local area networks (VLAN) is expected to ensure greater network security.

The following protocols SNMP, Telnet, SSH and WEB can be used to centralize maintenance and control of the Wi-Fi network.

Designing a Wi-Fi network (IEEE 802.11 standard) should include the following stages:

1) Planning of the nomenclature of multi-service services and the main parameters of subscriber radio access - load and required bandwidth of information transmission.
2) Determination of potential zones of concentration of radio subscribers and initial planning of capacities and placement of BS from the point of view of optimal coverage of the given territory.

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3) Choosing the physical topology of the radio access network, calculating its load and the required transmission speed, specifying the required number of BSs in the case of a cellular topology, and designing their connection to the packet transport network.
To build a Wi-Fi broadband network (IEEE802.11 standard), you need to choose a certain type of equipment. Among the most common manufacturers of wireless equipment, we can highlight: Cisco and D-link.

Cisco is a world leader in the field of network technologies. Unlike many other technology companies, Cisco does not make a firm choice in favor of one technology. The Cisco company discloses its solutions in the field of modern technologies, which include:
1) IP communications;
2) network security;
3) wireless LANs;
4) storage networks (SAN);
5) home networks;
6) video systems;
7) applied network services.

At the moment, the leader in the production of wireless equipment is the D-Link company. The company produces a new family of wireless devices that provide, due to a number of innovations (according to the specification), a high speed of data transmission.

Access points of D-Link equipment are chosen for the deployment of the hotspot network in the city of Odesa, namely: wireless dual-band unified AC2600 access points with Power over Ethernet (PoE) support that meet European and Ukrainian standards (Fig. 4).

Fig. 4. Wireless dual-band unified access points AC2600 DWL 8620AP [6].

The external wireless dual-band access point D-Link AC2600 is an ideal solution for creating hotspot zones that provide Internet access to users located on outside of the premises. The AC2600 provides a reliable wireless connection at a speed of up to 300 Mbps in the 2.4 GHz frequency band and up to 866 Mbps in the 5 GHz band. Thanks to this feature, as well as support for the Wi-Fi Multimedia ™ (WMM) Quality of Service (QoS) function, the access point is an ideal solution for transmitting audio, video and voice

applications. The included QoS function allows the AC2600 access point to automatically prioritize network traffic according to the level of interactive streaming, such as HD video or VoIP. The QoS feature can be adjusted through the AC2600 access point's web interface using a drop-down menu to select user-defined priority rules. In addition, the AC2600 supports load balancing to ensure maximum performance by limiting the number of users per access point. Thanks to the support of the 802.11ac wireless standard and powerful antennas, the access point can be placed almost anywhere convenient for the user, where it is necessary to organize a wireless network coverage area.

AC2600 allows network administrators to create a controlled and reliable wireless network with optimal coverage both in the 2.4 GHz frequency range (802.11b, 802.11g and 802.11n) and in the 5 GHz range (802.11a, 802.11n and 802.11ac). The AC2600 access point supports the 802.3af Power over Ethernet standard, which allows you to install this device in places where power outlets are not available.

Network administrators have several options for managing AC2600 access points, including a Web interface (HTTP), Secure Socket Layer (SSL, which provides a secure connection to the Web interface), Secure Shell (SSH, which provides a secure channel between the access point and remote computer) and Telnet.

For advanced network management, administrators can use D-Link Central Wi-Fi Manager, which allows you to configure and manage multiple access points from one computer. In addition to standard management options, D-Link Central Wi-Fi Manager allows network administrators to remotely check equipment, eliminating the need for personal control of any operations.

Consider the technical characteristics of the Cisco Catalyst 3750 series router. Cisco Catalyst 3750 series switches are stack multi-level switching devices designed for a Gigabit Ethernet network with performance of 10/100/1000 Mbit/s. The switches are intended for medium-level corporations and branches of large companies [7].

They are distinguished by ease of use and the highest fault tolerance among stack switches. For this project, we choose Cisco Catalyst WS-C3750-24FS-S.

The switches are managed via the web interface over a network connection or via the command line interface with the use of console port or Telnet network. The software has three execution options:

1) IP Base Image - advanced quality of service (QOS), traffic management, access control lists (ACL), multicast filtering (IGMP Snooping), static and dynamic routing based on RIP and EIGRP.

2) IP Service Image - extended set of 3rd level functions: multicast traffic routing, policy-based routing, extended set of routing protocols.

3) Advanced IP Service Image - IPv6 routing and advanced IP services.

The physical topology of the radio access network is determined by the potential zones of concentration of radio subscribers, their number and location in the Points of Invincibility.

Therefore, the installation of access points is considered from two points of view - optimal coverage of the given territory and places of concentration of potential users. The

designed network will have a loop topology, which is an alternative topology for deploying wireless broadband radio access networks.

This topology is the most effective for a wireless network, because the load between the nearest users can be closed using wireless means, and the access point will be accessed through the terminal of one of these users. Such a radio access network consists of the following levels: the level of users, at which load exchange is ensured between them; external access level at which users access the transport network. The "loop" topology provides high efficiency in the use of network resources and allows you to quickly increase its bandwidth and change its configuration imperceptibly for subscribers.

The radio access network, subject to the scalability of the IEEE 802.11a/b/g/n/ac standard, the so-called active zone (hot spot) of Wi-Fi technology in the city of Odesa, is formed on the basis of twelve access points located in the Points of Invincibility of Odesa.

An uninterruptible power supply (UPS) is installed for each radio access point in case of failures in the external power grid.

Three active zones are considered for the designed network, all access points of one active zone are connected to each other and to service servers using Ethernet hubs. All three load concentrators of active zones are connected by a switch in order to connect to the transport network through a telephone exchange.

In the area of access to the transport network, lines with a significant capacity of Gigabit Ethernet are used. The main and backup AAA servers and the SESM server located in the premises of the city automatic telephone exchange (ATE) are installed for the network.

For the Wi-Fi hotspot, support for virtual local area networks (VLAN) is expected to ensure greater network security.

The following protocols SNMP, Telnet, SSH, and WEB can be used to centralize maintenance and manage the wireless network.

Features of wireless network planning:

1) the location of access points depends on the required coverage area and building construction;

2) thick walls, or walls with metal structures, will block the signal more strongly. It is desirable to reduce the number of walls and partitions to a minimum - each wall can reduce the maximum data transmission distance to 30 or more meters;

3) office furniture, offices, can form "shadows" in the coverage area;

4) direct visibility is necessary to obtain a larger coverage area;

5) place wireless devices away (at least 1-2 meters) from electrical devices that can generate a radio signal.

Fig. 5 shows a plan-map with the topology of the network of hotspots in Points of Invincibility in Odesa.

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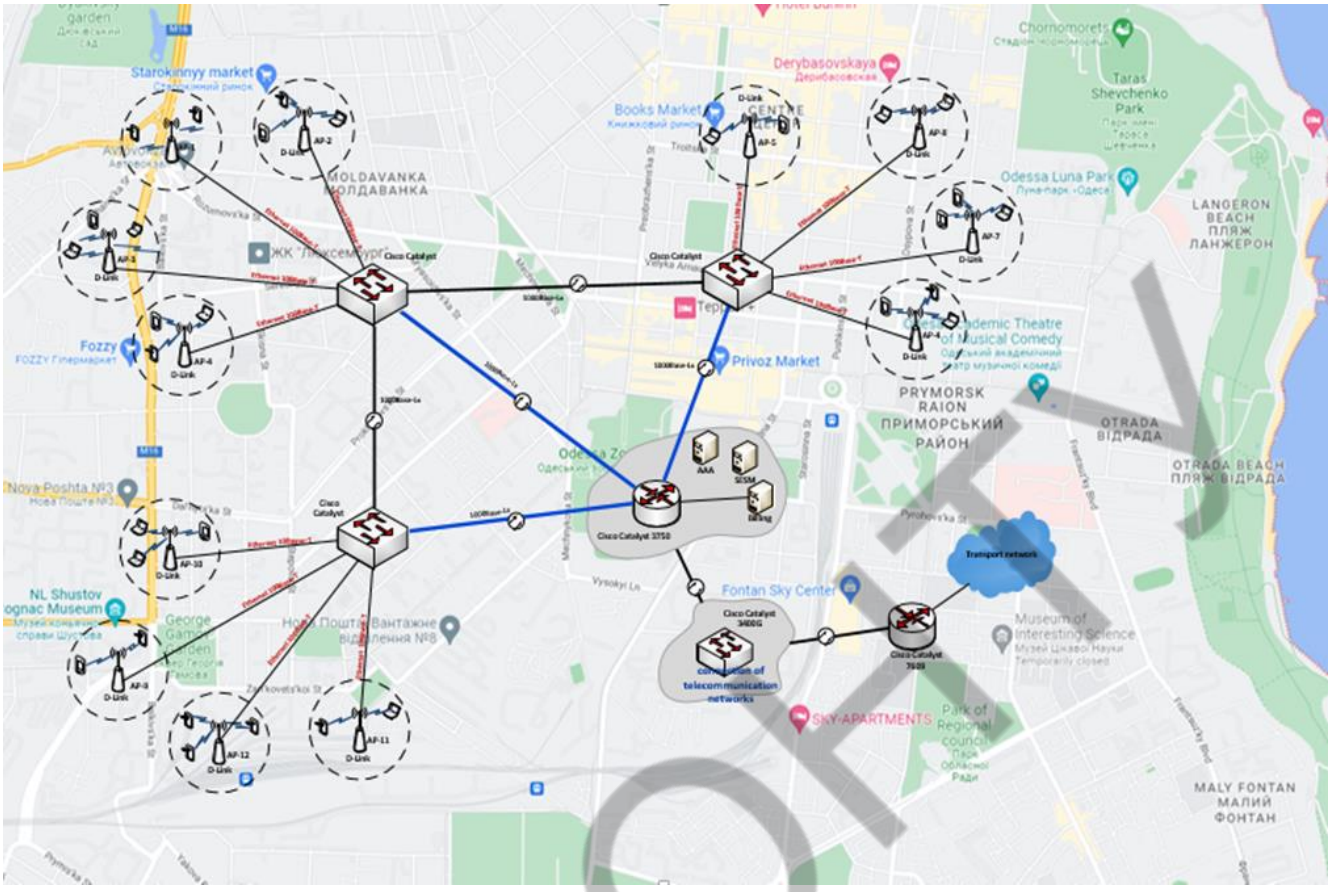

Fig. 5. Plan-map with the topology of the network of hotspots in the Points of Invincibility

Table 1 - Placement of access points in Points of Invincibility in Odesa

Numbering access points	Type of access point	Address of the Point of Invincibility
AP-1	D-Link AC2600 DWL 8620AP	Mala Arnautska, 2
AP-2	D-Link AC2600 DWL 8620AP	Pyrahovska, 3
AP-3	D-Link AC2600 DWL 8620AP	Seminarska, 1/5
AP-4	D-Link AC2600 DWL 8620AP	Staroportofrankivska, 103 a
AP-5	D-Link AC2600 DWL 8620AP	Spiridonivska, 12
AP-6	D-Link AC2600 DWL 8620AP	Spiridonivska, 18/24
AP-7	D-Link AC2600 DWL 8620AP	Bazarna, 85
AP-8	D-Link AC2600 DWL 8620AP	Tyraspolska, 13
AP-9	D-Link AC2600 DWL 8620AP	Tyraspolska,19
AP-10	D-Link AC2600 DWL 8620AP	Bryhadna, 56
AP-11	D-Link AC2600 DWL 8620AP	Sudnobudivna,11
AP-12	D-Link AC2600 DWL 8620AP	Komarova, 6

IV. RESULTS

Calculations were carried out for one segment per peak hour (PH).

It is planned to provide multi-service services (Triple Play Service) of high-speed data transmission, video images and multimedia in the broadband radio access network for Points of Invincibility.

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The number of subscribers in one service segment in the PH can range from 40 to 70 subscribers. Wi-Fi network services are mainly focused on data transmission, where the main category of subscribers are those who use laptops or smartphones. Therefore the most significant number of subscribers use medium-speed services, about 80% of users, video image transmission services are less popular up to 10%, high-speed services used by about 5% of users.

For the calculation, we will take the value of the number of NAP= 50 subscribers who will receive:

Medium-speed interactive multimedia (MSIM) services: Access to the Internet, Email, File sharing;

High-speed multimedia (HSM): Video conferences, Video surveillance, VPN services;

High-speed interactive multimedia (HSIM): High-speed Internet, AoD services, GoD services;

Over high-speed multimedia (OHSM): Access to IP TV, Tape video, VoD services.

The following data were used for the calculation:

$N_{MSIM\ AP} = 0.8 \cdot N_{AP} = 0.8 \cdot 50 = 40;$

$N_{HSM\ AP} = 0.10 \cdot N_{AP} = 0.1 \cdot 50 = 5;$

$N_{HSIM\ AP} = 0.05\ 50 = 3;$

$N_{OHSM\ AP} = 0.05 \cdot NAP = 0.05 \cdot 50 = 2.$

Each service is characterized by the following indicators:

1) R, upload Mbit/s - upstream transmission speed;
2) R, download, Mbit/s - downstream transmission speed;
3) Ti, s - average session duration;
4) Ci - the average specific total number of service requests;
5) Yi, Earl - the average specific total load.

To solve this problem, we choose an empirical model, choose receiving and transmitting equipment, use MS Excel spreadsheets and calculate the maximum speed of receiving services by users in the area of operation of one point of the hotspot network for Points of Invincibility in the PH and compare it with the capabilities of mobile Internet in Ukraine. The result of the MS Excel computer model calculations is presented in Fig. 6.

In 2023, Ukraine ranks 128th in the world in terms of mobile Internet speed, according to the Speedtest Global Index [8]. According to Speedtest, the average speed of mobile Internet in Ukraine is 11.97 Mbit/s per second when downloading information from the network to the user (download), and 7.84 Mbit/s when uploading information from the user to the network (upload).

The obtained research results correspond to average statistical data in Ukraine.

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	Expected intensity of receiving requests for the service download, Earl, Y	Bandwidth required, Mbit/s, R download	Expected intensity of receiving requests for the service upload, Earl,	Bandwidth required, Mbit/s, R upload	Bandwidth required, Mbit/s, R_S
MSIM	6	1,536	6	0,384	1,92
	10	2,56	10	0,64	3,2
	10	2,56	10	0,64	3,2
HSM	0,15	0,225	0,15	0,0192	0,2442
	0,15	0,225	0,15	0,0192	0,2442
	0,75	1,125	0,75	0,096	1,221
HSIM	0,9	1,8	0,9	0,23	2,03
	0,024	0,048	0,024	0,006	0,054
	0,9	1,8	0,9	0,23	2,03
OHSM	0,4	2,4	0,4	0,6	3
	0,4	2,4	0,4	0,6	3
	0,4	2,4	0,4	0,6	3
Total by segment of the network of hot spots			30,074		23,14

Fig. 6. Calculation of bandwidth of one segment of the network of ho spots for Points of Invincibility in the PH.

V. CONCLUSIONS

With the advent of the global Internet, society reached a new level, an information revolution took place. In connection with the rapid development of the information base, the market for providing high-speed and reliable access to the Internet is also developing rapidly.

The topicality of the subject is due to the fact that now there is a need to provide hotspot services in Points of Invincibility.

Wi-Fi technology has a large number of advantages, including: high speed of deployment, the possibility of gradual development of the network, starting with a minimal configuration, low operating costs, and high bandwidth.

The computer model for calculating the main parameters in MS Excel spreadsheets has been tested for the scenario of creating a radio access network based on D-LINK AC2600 DWL 8620AP access points that meet European and Ukrainian standards with the following qualities:

1) the network of hotspots (Wi-Fi) must provide visitors of Points of Invincibility with high-quality types of modern services, in particular, high-speed access to the Internet;

2) the network is able not only to withstand the load of one user with this service with a bandwidth of 23.14 Mbit/s, which is comparable to the capabilities of mobile Internet in Ukraine, but also has the possibility of further development.

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