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PROBLEMS OF ORGANIZING THE 5G NETWORK INFRASTRUCTURE

Abstract. Trends in the development of the network infrastructure of future wireless networks have been established. The interrelation between the construction of a network information infrastructure and technologies to reduce the environmental impact in 5G networks is noted. The use of vRAN technology, which allows to reduce total carbon dioxide emissions, is considered. 5G network services are presented, leading to an increase in total energy consumption in these networks. The limitations of the 5G network infrastructure associated with the use of slicing technology are shown.

Keywords. Infrastructure trends, efficient energy use, energy consumption, technological advancement, limitations of 5G technology, vRAN, Distributed Radio Systems

Introduction.

According to the UN (United Nations) advanced ICT (infocommunication technology) - 5G-based solutions offer the tools to reduce greenhouse gas emissions by 20% by 2030. Today, the relationship between the construction of a network information infrastructure and the effect of reducing carbon emissions has not been sufficiently investigated. Assessing the impact of broadband wireless infrastructure is essential for the national digital economy and digital transformation [1]. In this regard, the problems raised in this study are very relevant.

Huawei's research has shown that 4G base stations consume 80% of the total energy consumption of the network, while almost half of the electricity consumed goes to cooling the transmitting equipment.

And a study conducted by Nokia and Telefonica showed that 5G networks per unit of traffic are 90% more energy efficient than legacy 4G networks, which clearly confirms cost savings [2]. One kilowatt-hour (kWh) of electricity is needed to download 300 high-definition movies in 4G, and with 5G, 5000 ultra-high-definition movies can be downloaded per 1 kWh [3].

However, it should also be noted that the wider use of faster streaming, artificial intelligence, cloud services (including more efficient data uploads to the cloud) provided by 5G networks leads to an increase in total energy consumption [4]. In [5], the factors of reducing and increasing the overall power consumption at the network level for the implemented 5G mobile technologies are discussed, some methods for improving the energy efficiency of the 5G network are noted (for example, sleep strategies and cell scaling). Many sources describe various approaches to improving energy efficiency in 5G networks, in particular, by using Beam Forming (BF) directional radio beam technology, which allows you to automatically orient the maximum radiation of the transmitter towards the subscriber terminal [6]. However, network infrastructure factors are discussed indirectly in most studies.

Materials and methods.

The exponential increase in information traffic of data, of which a significant part is media data, as well as the massive growth of device communications, which generate a variety of requirements, services, standards - for all this it is necessary to ensure a smooth transition from existing 3G/4G technologies to 5G technologies.

With the introduction of 5G technologies, the load on the transport infrastructure, especially on the fronthaul (transport between the central office and radio sites (base stations)), increases. Fronthaul optimization - communication between the digital signal processing unit BBU (Baseband Unit), which processes user and control data, and radio heads (Remote Radio Heads, RRH) (or remote radio units RRU (Remote Radio Units)), antennas - is of dominant importance. In a 5G environment, fiber serves as an ideal front-end carrier for: handling large volumes of traffic; ensuring data transmission delay; network uptime [7].

To meet changing RRH needs, hardware resources can be dynamically allocated to virtual BBUs at a specific location, enabling energy savings (better utilization of hardware resources) and lower O&M costs (reducing number of BBUs and less equipment complexity at base stations). Virtualization of BBU resources makes it possible to dynamically distribute them between base stations depending on user activity and, in addition, disable unused BBUs (and under certain conditions even RRH) to significantly save electricity and reduce other operating costs [7]. In particular, to ensure the quality of 4K video, cloud gaming, VR (and in the future - 24K video for VR (virtual reality) and AR (augmented reality)) operators will use services for traffic distribution [8].

In [9], four different ways are noted (energy efficiency improvement; smart water smart buildings) in which 5G can combat climate change by significantly reducing emissions.

In 5G, it is possible to monitor energy consumption and manage this process using smart meters and smart power grids, more efficiently than ever. For example, the Flex5Gware project is aimed at improving performance and reducing power consumption of hardware and software platforms, on top of which all communication-related functions are implemented and performed [10].

For the telecommunications industry itself, 5G networks are estimated to be 40% more energy efficient due to technological development that has significantly increased energy efficiency, especially in chipsets. The use of the latest "system-on-chip" SoC (System-on-a-Chip) technologies increases productivity and energy efficiency, as well as provides more bits per kWh. Note that SoC is an autonomous non-disassembled chip that performs the functions of an entire device (for example, a computer)).

5G processors and radio modules are closely connected to each other, which provides intelligent, integrated and energy- saving functions [11]. In addition, telecom operators can use artificial intelligence (AI)-based analytics to digitize deployments and operations, and optimize existing networks [2].

Management, traffic management Fujitsu's new 5G SA (Standalone) vRAN (Virtualized radio access networks) software-virtualized radio access network technology, which complies with ORAN (Open radio access networks) specifications, provides high performance with low power consumption. ORAN is a radio access network, the main principles of which are: virtualization of network elements; use of hardware platforms with a standard open architecture; standardization of all interfaces for radio access network equipment [12]. A Virtualized Radio Access Network (vRAN) is a virtualized base station created using specialized software that provides base station management functions hosted on a general – purpose server.

Fujitsu estimates that the vRAN technology approach makes it possible to reduce the total CO2 carbon dioxide emissions in the system by 50% or more compared to conventional base station systems by 2025, offering users high-quality and stable communication [13].

To ensure high-performance communication with high bandwidth, software management methods are being improved, which allowed, for example, Fujitsu to increase communication speeds and communication coverage areas from two to four times. Fujitsu has also created its own dynamic resource allocation technology that reduces excess resources and power consumption due to the possibility of flexible configuration/optimization of server computing resources (using Digital Annealer technology) required for operation and depending on the state of use (traffic volume) of base stations, which depends on the region and time of day [1].

5G technology significantly expands the 3G, 4G and LTE cellular infrastructure, provides low latency and high bandwidth, which provides better support for real-time applications and mobile applications with a large amount of data, which leads to an improvement in the overall UX (User Experience). However, 5G has four limitations that 5G enterprise network teams may encounter when using 5G technology [14]: to get the best 5G connection, the subscriber needs to be in close proximity to the 5G infrastructure. This problem is especially aggravated when 5G networks operate in the millimeter range. To overcome this limitation, operators: deploy a much larger array of antennas to provide sufficient coverage; use beamforming technology with these large arrays of antennas to help the 5G system overcome more obstacles, allowing packets to travel multiple routes to reach the customer;

Most of the 5G deployment is done on top of the existing 3G/4G spectrum, which ensures backward compatibility with older devices. One of the ways in which 5G overcomes the bandwidth limitations of modern systems is the "network slicing" technology, which allows 5G operators to make better use of their networks, serving more users and transmitting more data at the same time.

Expanding 5G deployment in rural and remote areas if cable backhaul already exists there.

The security required for both operators and businesses. The overall 5G architecture makes it possible to improve security capabilities on the operator's side. Security is primarily addressed on the latest platforms, so it is assumed that 5G largely provides better security than 3G and 4G because it includes new security features.

The need to modernize/expand existing network Note that prior to 5G networks, previous mobile networks provided a uniform service based on a shared resource, regardless of the type of traffic. In a 5G network, all created network slices (network slicing) are supported by a single physical infrastructure, which serves as a limiting factor. In the 5G network, a single physical infrastructure does not allow creating an infinite number of slices, since at some point the resources of the physical network will be depleted and new slices will not be able to provide the required quality of service QoS (quality of service).

Infrastructures in buildings causes the need for an active DAS (Distributed Antenna System) infrastructure. Legacy DASs face problems working in 5G bands and increasing capacity. In this regard, many mobile operator’s MNO (mobile network operators) are beginning the transition from traditional embedded DAS to digital distributed radio systems DRS (Distributed Radio Systems) "5G-Ready" for a smooth transition to 5G [15], which will find mass use in public mobile networks and in the corporate sector.

The 5G network architecture will evolve along with the concept of cloud, edge network and Network as a Service NaaS (Network-as-a-Service) to meet the requirement of rapid deployment of network functions. 5G-Advanced network capabilities will be strengthened in the aspects of artificial intelligence, convergence, and enablement (figure 1) [16].

5G (API - Application Programming Interface; NaaS -Network-as-a-Service):

- artificial intelligence will improve the capabilities and quality of services at all levels, starting with the network management function, and will also reduce operating and maintenance costs;

- convergence of various access modes and networks (IIoT (industrial internet of things), Wi-Fi, fixed networks, etc.) will lead to an increase in the versatility of 5G networks, which will help the coordinated development of the 5G network with industrial networks, home network and the cosmos-earth network;

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- the Enablement feature will support a 5G network serving the vertical industry, which will provide the industry with customizable networks characterized by proactivity, flexibility and resource isolation;
- the NaaS network model makes 5G systems highly efficient, flexible and able to adapt to various individual solutions for the needs of the vertical industry.

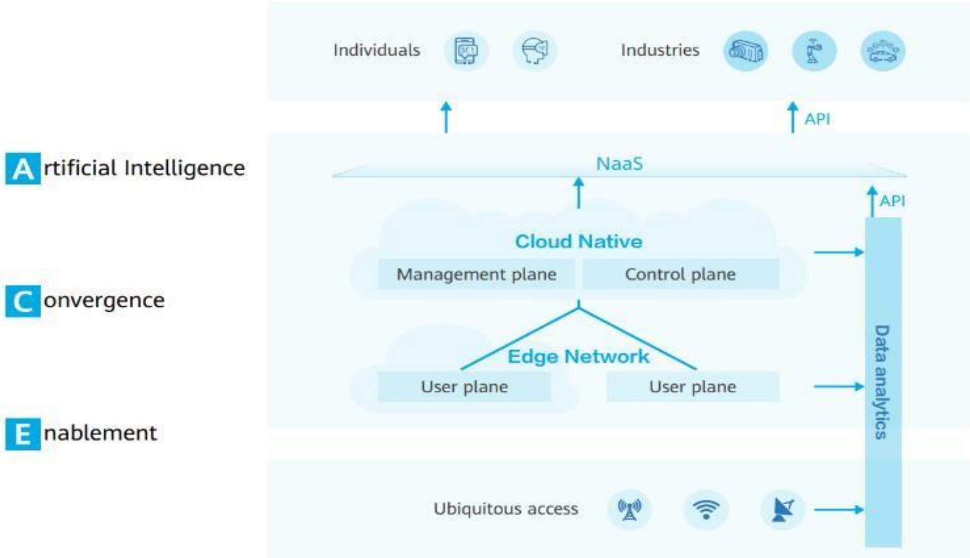

Figure1 – 5G-Advanced network architecture

Results and discussion.

The problems of organizing the 5G network infrastructure arising from the introduction of 5G are significant.5G technology has a high data exchange rate with low latency while maintaining low power consumption (this guarantees the environmental friendliness of 5G technology) and provides a very large bandwidth. To meet the growing demand of Internet users and connected devices for traffic, 5G networks use innovative technologies such as infrastructure consolidation and others. In the 3GPP standards related to 5G, the architectures of the radio access network RAN (radio access network) and the core network (CN, core network) are described in terms of services and functions.The main function of the RAN is to establish a connection between subscriber equipment and CN communication systems of various standards. In real-world optimization problems of 5G systems, the spaces of states and actions are huge. 5G usage scenarios (ULC (Ultra-Reliable and Low Latency Communications), MBC (Massive Machine Type Communications), eMBB (Enhanced Mobile Broadband)) place high demands on RAN in terms of performance, latency, reliability and efficiency. Meeting such requirements will require adjusting the parameters of the RAN control in space, time and frequency.The main optimization tasks can be divided into three domains (table 1), which are characterized by the type and number of network objects, and the frequency with which updates usually occur [16].

Table 1 – Three domains of RAN performance improvement

Domain	Network objects	Update frequency
Network design	Basebands, cells, RAM configurations, etc.	Monthly/Weekly
Network optimization	Cell clusters / individual cells	Weekly/Daily/Hourly
RAN algorithms	Cells and user equipment	Seconds/milliseconds

In 5G, there are also many problems that need to be solved in the field of cloud computing, which are related to the allocation and management of cloud computing resources. The study of resource allocation and 5G management strategies is important to achieve a high level of network efficiency. Virtualization of network functions (NFV, Network Functions Virtualization) and SDN (Software Defined Networking) are important technologies in 5G that provide effective network management and allow for open, flexible and programmable inclusion of new services. The network architecture of mobile edge computing (MEC, Mobile Edge Computing) allows to place computing and storage resources in a radio access network (RAN), which allows to process data in real time closer to the data source, which will significantly reduce latency, increase the efficiency of mobile networks. However, providing energy-efficient computing and obtaining low latency are considered the most important challenges facing the application of MEC.The deployment of super-dense cells will increase the capacity of the cellular network thousands of times, and small cells will significantly reduce the physical distance between base stations and user devices to enhance energy efficiency. Frequency bands up to 3 GHz will be used for macrocell coverage, and a higher frequency range will be used for picocells.Existing radio access technologies continue to evolve.Virtualization will play a key role in 5G technologies in order to efficiently use resources in mobile systems where several tenants own the network, since the mobile operator will not need to own a full set of specialized network equipment.

Technological indicators of the 5G network infrastructure expand the range of services provided by increasing the speed indicators for data transmission channels, as well as improve the quality of data transmission and allow implementing design solutions dependent on high data transfer speeds of 1Gbit/s.

The complex infrastructure of the 5G network depends on the correct location of telecommunications equipment to create optimal network coverage. To organize a dense high-quality radio coverage, a large number of base stations should be installed that will be able to form cells.Extended coverage affects the overall performance of the 5G system and the convenience of end users. An increase in the number of base stations may increase the coverage area, but this leads to interference between users at the cell boundary, which, in turn, affects the radio coverage area.

Extended coverage is one of the most difficult tasks in cellular networks, and the arrangement of network equipment is the main phase in creating a technological model of any network complex. The radio coverage area depends on the transmission power of the cell, the type of antenna used, the carrier frequency, the location of the cell (the location of user equipment and base stations, environmental conditions). Gaps in coverage are mainly due to the lack of line of sight, poor planning of the radio frequency network and multipath fading.5G uses the concept of small cellular nodes (femtocells, picocells and microcells) to: reduce delays, improve spectral efficiency, and ensure high data transfer rates.

Artificial intelligence (AI) technology provides intelligent methods for creating dynamic strategies and managing resource operations in a 5G network. However, it faces some factors (for example, setting up a new platform and data-based products) that affect their use in 5G networks.

Conclusions.

In order to meet the requirements for future 5G wireless systems, many technical problems need to be solved. It is possible to reduce total CO_2 emissions by 50% or more compared to conventional base station systems by updating the software functions of 5G networks and improving technologies to reduce environmental impact (smart water management, traffic management, smart buildings, etc.). Energy efficiency will increase significantly due to technological development, especially in chipsets. However, the increased use of faster streaming, artificial intelligence and cloud services provided by 5G networks leads to an increase in overall energy consumption. One of the main limitations of 5G technology that are possible in corporate networks is the use of "network slicing" technology, which relies on a single physical infrastructure, which will require the use of appropriate dynamic allocation of slice resources.

The introduction of 5G networks requires new approaches to building mobile communication networks based on open standards. The introduction of vRAN, consisting of general- purpose servers that do not require expensive development of specialized equipment, can serve as a good alternative to conventional base stations.A huge amount of data in the exchange of information is required for high–speed transmission of data traffic: in order to use the Internet in a new aspect with minimal delay (for example, the addition of virtualization of the human reality of the surrounding world; the provision of immersion services: holographic call; installation of XR - augmented reality (VR (Virtual Reality), AR (augmented reality), m (mixed reality)).This will solve the problems of local data storage, as well as the widespread use of global "cloud" storage on an ongoing basis.Reducing the size of mobile terminals and computer devices, reducing battery consumption, connecting millions of devices at the same time – the trend of 5G technologies.5G communication is nominated as the main means of providing Internet of Things systems. The infrastructure of the Internet of Things is constantly in development and in search of new algorithms for object communication, which makes it possible to distinguish IoT systems on a par with actively developing processes on the scale of digital transformation. 5G-Advanced networks should have ACE (Artificial Intelligence, Convergence, Enablement) properties [17], which will bring closer to the creation of heterogeneous global communications, and the infrastructure trend (integration of satellite, air, terrestrial and underwater networks) will provide tremendous connectivity.

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5G ЖЕЛІСІНІҢ ИНФРАҚҰРЫЛЫМЫН ҰЙЫМДАСТЫРУ ПРОБЛЕМАЛАРЫ

Аңдатпа. Болашақта сымсыз желілердің желілік инфрақұрылымын дамыту үрдістері белгіленген. 5G желілерінде қоршаған ортаға әсерді азайту үшін желілік ақпараттық инфрақұрылымды құру мен технологиялар арасындағы өзара байланыс атап өтілді. Көмірқышқыл газының жалпы шығарындыларын азайтуға мүмкіндік беретін vRAN технологиясын пайдалану қарастырылды. Осы желілерде жалпы энергия тұтынудың өсуіне алып келетін 5G-желілердің қызметтері ұсынылған. 5G желілері инфрақұрылымының slicing технологиясын пайдалануға байланысты шектеулері көрсетілген.

Түйінді сөздер. Инфрақұрылым үрдістері, энергия тиімділігі, энергия тұтыну, технологиялық даму, 5G, vRAN, Distributed Radio Systems технологияларын шектеу.

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ПРОБЛЕМЫ ОРГАНИЗАЦИИ ИНФРАСТРУКТУРЫ СЕТИ 5G

Аннотация. Установлены тенденции развития сетевой инфраструктуры будущих беспроводных сетей. Отмечена взаимосвязь между построением сетевой информационной инфраструктуры и технологиями для снижения воздействия на окружающую среду в сетях 5G. Рассмотрено использование технологии vRAN, которая позволяет сократить общие выбросы углекислого газа. Представлены услуги 5G-сетей, приводящие к росту общего энергопотребления в этих сетях. Показаны ограничения инфраструктуры сетей 5G, связанные с использованием технологии slicing.

Ключевые слова. Тенденции инфраструктуры, энергоэффективность, потребление энергии, технологическое развитие, ограничения технологии 5G, vRAN, DistributedRadioSystems.

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