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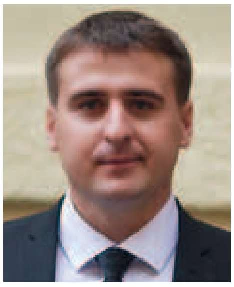

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# Perspective directions of development and research in the field of information and communication technologies

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*In den letzten Jahren sind sowohl auf dem Gebiet der Telekommunikation als auch in der Informationstechnik neue Technologien zur Anwendung gekommen. Dies beinhaltet zum Beispiel SDN (Software-defined Networking) und NFV (Netzwerkfunktionsvirtualisierung) im Bereich der Telekommunikation sowie Big-Data-Technologien in der Informationstechnik. SDN- und NFV-Technologien ermöglichen neue konzeptionelle Ansätze im Hinblick auf die zukünftige Architektur von Telekommunikationsnetzwerken. Die Entwicklung von SDN / NFV und Big-Data-Technologien verlief bisher parallel und ohne praktische Überschneidungen.*

*Aufgrund des wachsenden technischen Reifegrades und des Übergangs zur praktischen Anwendung dieser Technologien stellt sich die Frage nach deren gemeinsamer Nutzung. Kommunikationsnetzwerke der 5. Generation, sogenannte 5G, die Analyse großer Daten (Big Data) und das Internet der Dinge (IoT) sollen die Grundlage der digitalen Wirtschaft und die Antriebskraft für künstliche Intelligenz (AI) werden. Zusammen mit Big-Data-Mechanismen gewinnen IoT-Lösungen somit für den Benutzer an Wert. Auf lange Sicht werden AI-Tools für IoT-Lösungen Anwendung finden, bei denen Endpunkt und Anlagensteuerung auf künstlicher Intelligenz beruhen.*

*Die vorliegende Arbeit untersucht SDN (Software-defined Networking) und NFV (Netzwerkfunktionsvirtualisierung) als moderne Technologien zur Konstruktion von Telekommunikationsnetzwerken. Zudem werden Anwendungsmöglichkeiten in der Infrastruktur von unter Anwendung der Big-Date-Technology konstruierten Informationssystemen definiert.*

*For the last years in the field of both telecommunication and information technologies there appeared and found the application in practice new technologies, such as SDN (Software Defined Networking) NFV (Network Function Virtualization) in the field of telecommunications and Big Data technology in the field of information technologies. SDN and NFV technologies offer new conceptual approaches to the architecture of telecommunication networks, with which the future is connected. The development of SDN/NFV and Big Data technologies has been going on in parallel for these years and practically did not intersect.*

*However, as the level of their maturity grows and their transition to practical use raises questions about the possibility and expediency of their joint use. The „fifth generation" communication networks, the so-called 5G, together with the analysis of big data (Big Data) and the Internet of Things (IoT) are called upon to become one of the bases of the digital economy, the main driving force of which should be artificial intelligence (AI). That is, in combination with Big Data mechanisms, IoT solutions are more valuable for users. In the long term, there is the potential for AI tools to be applied to IoT solutions where endpoint and machine control is based on artificial intelligence.*

*In this paper modern technologies of construction of telecommunication networks SDN (Software-Defined Networking) and NFV (Network Functions Virtualization) are briefly considered. And possibilities of their use in an infrastructure of the information systems constructed with use of technology Big Data are defined.*

*Keywords: Cloud Computing, 5G, Big data, SDN, NFV, IoT, Artificial intelligence.*

## 1. Introduction

During the past decade, significant advances in the field of digital technologies, including artificial intelligence, robotics, cloud technologies, data analysis and mobile communications have been made. The technology of the near future will require powerful networks with high-speed data transmission and capacity to support QoS (Quality of service) for different applications. The next generation services featured here are currently in development, and coming to homes. We‘re already building the networks to be ready for the future. It‘s closer than you think. That is why we offer clear and well-organized coverage of five key technologies that are transforming networks: Software-Defined Networks (SDN), Network Functions Virtualization (NFV), the Internet of Things (IoT), 5G and Big Data [1-4]. Future communication networks based on SDN/NFV/IoT/Big Data is shown in the fig.1

Novel, emergent technologies are changing networks and services architectures. The main advantages of the future network include intellectual management of the network, higher speed of innovation, what promotes, first of all, the speed of technological progress and competition, increasing the reliability and security of the network, ensuring the quality of services and the consistency of access control policies.

## 2. Benefits of future communication networks

In „smart cities“ projects future communication networks will allow real-time transmission of information from a much larger number of sensors at different sites. It will be possible to deploy a thousand sensors instead of hundreds, which will be served by fewer base stations than the existing networks. These could be, for example, sensors to monitor the condition of public utilities facilities, „smart lighting“ sensors or sound sensors installed for safety and order in the city. In the latter case, the sensors may detect suspicious or too loud sounds, and this information will be automatically transmitted to law enforcement agencies.

New services using future communication networks can also be implemented in medicine. For example, to organize remote monitoring of patients‘ condition. The doctor will be able to promptly receive information from special sensors and monitor the condition of patients around the clock.

With very low data transfer delays, future communication networks also provides up more possibilities for remote operations using the robot. This service is especially relevant for small communities where there are no surgeons in the field: by controlling the robot‘s manipulations, the operation can be carried out by a specialist who is located in a completely different place. With future communication networks, this service can be deployed in wireless networks.

The low data latency that next-generation networks can provide is also important for the deployment of smart grids. The use of sensors will allow for the instant detection of power line faults and block the

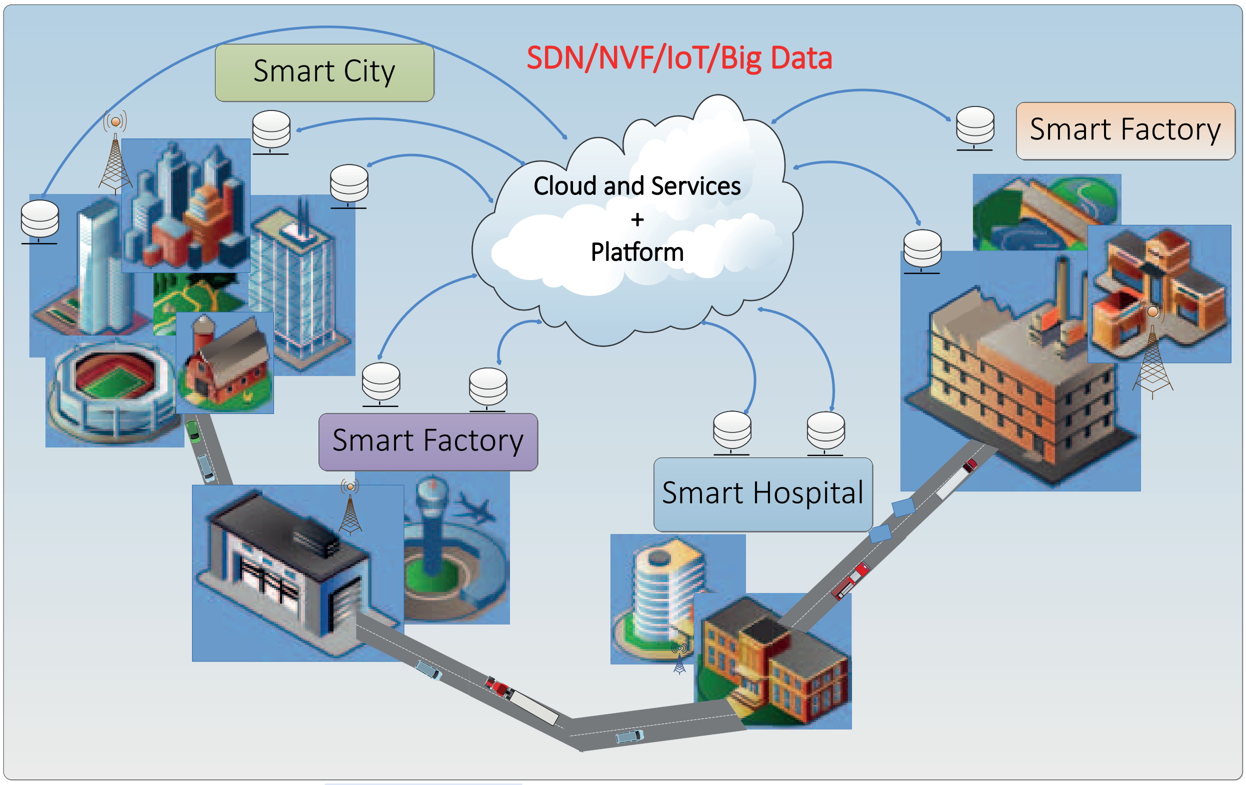


Fig.1 Future communication networks based on SDN/NFV/IoT/Big Data

propagation of the effects of the faults further along the line. Thus, the damage will affect a smaller number of power consumers.

In large manufacturing companies, in retail, future communication networks logistics, more industrial robots with different functions instead of people and drones can be used. The latter are already in use in some industries, but are most often controlled using Wi-Fi networks. 5G will allow you to cover a greater distance than Wi-Fi networks, and due to low delays - to increase the stability of such systems. Amazon, for example, has a drone delivery system deployment project.

An example of services for which future communication networks will have an advantage is urban video surveillance systems. future communication networks will help simplify their deployment and use. Now traffic from thousands of cameras in cities is mainly transmitted over fixed networks. Deploying such an infrastructure is not an easy task, as many wires have to be laid. With future communication networks, you can get terabytes of high-resolution video without using wires.

Operator believes that with the advent of the new generation of networks providers of this service, will be able to reduce its cost. This will be possible due to the fact that the cost of one 5G base station will be lower than the cost of stations for the existing networks, as well as due to the fact that one base station will be able to simultaneously serve more devices, respectively, for service will require fewer base stations.

## 3. State-of-the-art technologies for developing future telecommunication networks

One of the main technologies in the fifth-generation networks will be the Internet of Things. The internet of things is not just a multitude of different devices and sensors connected by leading and wireless communication channels and connected to the internet. it is a closer integration of the real and virtual worlds in which people and devices communicate. To achieve this, technologies such as wireless sensor networks and RFID will be used (method of automatic identification of objects).

Thus, the introduction of the „Internet of Things“ in the network of the fifth generation 5G will allow not only to interact in a single network in the circle of household gadgets (smart watches, VR devices, tablets and smartphones), but also will cover all areas of human activity (smart home and city technology).

The basic concept of IoT is the ability to connect to a network of various objects that people can use in everyday life, such as refrigerator, air conditioning, car, bicycle and even sneakers. All these objects should be equipped with sensors, which are able to process information coming from the environment, exchange it and perform various actions depending on the received information. An example of such a concept is the „smart home“ or „smart city“ system.

Internet integration is the use of an IP address as a unique identifier. However, because of the limited address space in IPv4 (which allows for the use of 4.3 billion unique addresses), IoT facilities will have to use IPv6, which provides unique network-level addresses of at least 300 million devices per inhabitant of the Earth. Objects in the IR will not only be devices with sensory capabilities, but also devices that perform actions (such as light bulbs or locks that are controlled via the Internet). To a large extent, the future of the IoT will not be possible without the support of IPv6, so the global adoption of IPv6 in the coming years will be crucial to the successful development of IoT in the future.

IoT can cause huge changes in everyday life, giving ordinary users a whole new level of comfort. But if the elements of such a system are not adequately protected from unauthorized interference, they will be damaged instead by a secure cryptographic algorithm, giving cybercriminals a loophole to undermine information security. Because things with embedded computers retain a great deal of information about their owners, including their exact location, access to such information can help attackers to commit a crime. The current lack of standards to protect such autonomous networks somewhat slows down the introduction of the IoT into everyday life.

Given that a significant amount of IoT traffic will be transmitted over the 4G / 5G network, it is necessary to ensure effective coding in the radio channel to minimize the possibility of information interception and network intrusion [5-7].

It is also worth noting that 5G technology plans to become a truly converged technology. Convergence is understood as the grouping of individual network components into a single optimized computing complex. Operators will organize virtual equipment for data processing and storage at the expense of a set of servers and DATA-centers, while physical equipment will be used only for transferring user traffic. Thus, there will be a reduction in the number of equipment for one base station, and taking into account that all this will be a cloud, the operator will have access to any point of the network for dynamic configuration of a particular network segment.

The 5G network infrastructure will be built on the basis of cloud technologies, which will be used in software-configurable radio access networks (Software Defined Radio, SDR), and in the basic software-configurable network (Software Defined Network, SDN). Network Function Virtualization (NFV), which is implemented in the 5G infrastructure, will cover QoS monitoring and management, as well as traffic maintenance and prioritization policies [8].

SDN - data network, in which the level of network management is separated from the devices of data transmission and implemented programmatically. NVF - a concept of network architecture, proposes to use the technology of virtualization of entire classes of functions of network nodes in the form of components that can be linked to one another or in a chain for the creation of telecommunications services (services). This makes it possible to organize a function such as „networks as needed“. 5G networks through virtualization and network technology „as needed“ offer to organize servers and DATA-centers for operators in advance, taking into account all requirements for the network [9-10].

Comparing traditional routing with virtual routing it is possible to

notice that in switches and routers special microcircuits provide transfer of packages from one port on another, and above the software carries out the analysis of packages and defines rules of such transfer. For definition of a route of transfer and avoidance of loops in the conditions of transfer of the traffic, the set of protocols, such as OSPF, BGP and Spanning Tree is developed.
According to the SDN concept, all control logic is transferred to so-called controllers, which are able to monitor the work of the entire network (fig. 2). The main element of the SDN concept is the OpenFlow protocol, which allows the controller to interact with network devices. On the north side, the controller provides Application Programming Interface (API), which allows the network owner or third-party developers to create applications for network management.
Such programs can perform various functions in the interests of business tasks (for example, to control access, manage bandwidth, etc.), and their developers do not need to know the details of the specific network devices. With the controller, the entire network, consisting of many different types of devices from different manufacturers, is for the program as a single logical switch. That is, the general implementation of SDN technology in mobile networks means the revision of the network architecture, separation of management from data transmission and automation of the administration of network equipment.
In addition to SDN technology, NFV virtualization technology plays a key role in the transition to network management software. These technologies complement each other in that they address different elements of the software-managed solution. SDN increases network flexibility with integrated network management, enables rapid innovation and reduces operating costs. NFV is designed to enable operators to reduce Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) operating costs by reducing hardware costs and power consumption.
The most important difference between NFV and SDN is the ultimate goal of the concept. If NFV plans to adopt specific network functions and implement them programmatically, and then manage them as software objects, SDN is the ideology of the entire network, where all management and responsibility for decision-making (routing, switching, etc.) is brought to a separate centralized level. That is, NFV are the concrete program components realising concrete network functions, and SDN - ideology of work of all network and interaction of its functional levels [11].

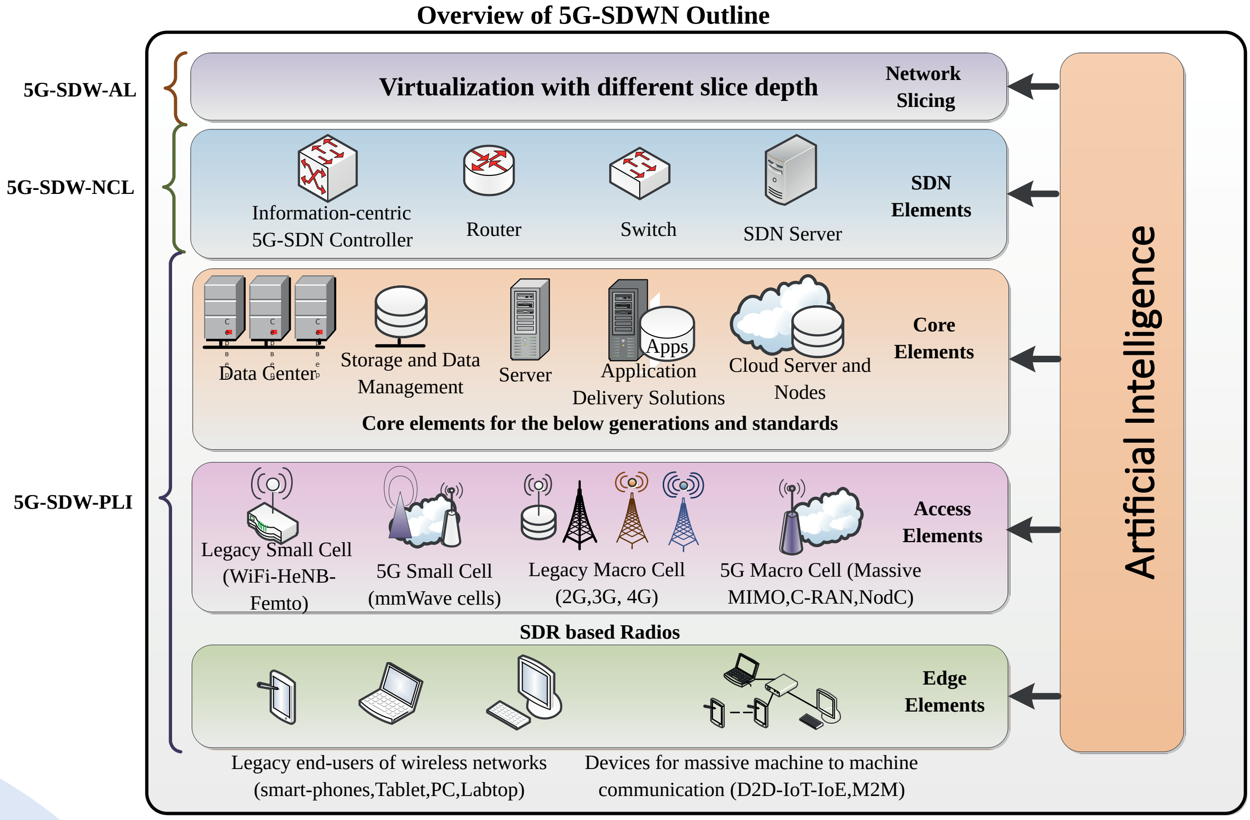


Fig.2 Future integrated communication network architectures

### 4. A new model for the future network architecture

The overall architecture of the proposed system consists of six horizontal planes: devices plane, access plane, core plane, network management and monitoring plane, network virtualization plane at the request of users, as well as a single vertical plane of artificial intelligence (fig.2).

**The plane of the devices** consists of various IoT sensors, mobile phones, tablets, laptops, tablets, M2M and D2D devices.

**The access plane** is responsible for directly providing services to end users using the physical network infrastructure of fixed and mobile subscriber access. The function of this plane includes the transmission of signals in physical communication channels, in particular signal processing, data coding, modulation, etc. Configuration of the physical network infrastructure is determined by synchronizing the parameters of physical devices with their virtualized abstractions.

**The core plane** covers the main aspects of packet traffic transmission in a heterogeneous network. It covers service gateways, routers and switches, and is responsible for traffic aggregation, user mobility management, and AAA (Authentication, Authorization and Accounting) functionality.

**Virtualization plane.** An important component of this plane is the virtualization of network functions (NFV), in particular: virtualization of network devices, virtualization of channel resources and virtualization of composite services. NFV technology is used to synthesize virtual abstraction of the physical network infrastructure, the configuration of which is synchronized with the configuration of the physical network infrastructure.

**The control and monitoring plane** is responsible for making real-time decisions regarding the main parameters of heterogeneous network functioning. It is based on the SDN controller, which performs the functions of resource management and monitoring, user mobility management, load balancing, control of network deployment for client-oriented service provisioning, routing of information flows and end-to-end control over the provision of objective and subjective service quality parameters (E2E QoS-QoE). Based on all of the above factors, the SDN controller adaptively determines the configuration of

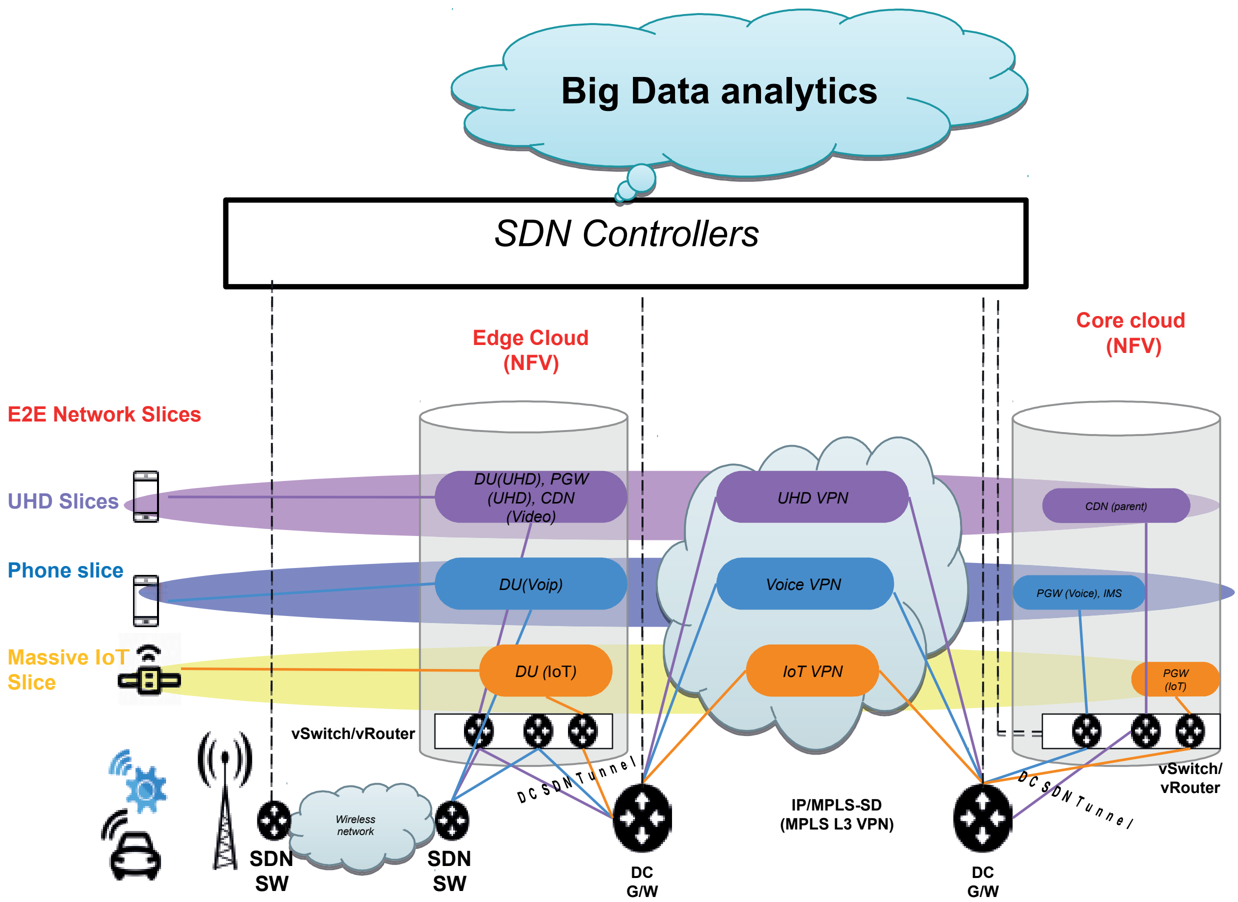


Fig.3 End-to-end Network Slicing for future network

the virtual heterogeneous network infrastructure for client-oriented service delivery to end users.

The monitoring system consists of high-performance servers and databases, which are used to collect and analyze large data from all levels of heterogeneous network operation SDN-IoT. The proposed monitoring system operates on the basis of cross-level asynchronous collection of data on the main parameters and characteristics of the functioning of network elements with reference to temporal and territorial metadata. The system allows collecting any data in text, numerical and graphical form. This feature opens up great opportunities for operators in terms of settings of the monitoring system in accordance with their requirements in the target area of network deployment and service provision. In addition, this system allows reducing the amount of service information in the operator's communication channels due to the small amount of data transferred.

**The plane of artificial intelligence** is responsible for the formation of the knowledge base on the main parameters and characteristics of heterogeneous network infrastructure functioning with the use of intelligent algorithms of machine learning. At this level, the information is obtained from the network monitoring system, in particular, the data on the quality of communication and satisfaction with the level of service by end users, information on the load of network nodes, malfunction of elements of the physical infrastructure, as well as long-term statistics of the behavior of end users and characteristics of heterogeneous network infrastructure functioning. The information obtained is transferred to the management plane, where it is used to make more effective decisions that would take into account the previous experience of the system.

## 5. Network Slicing concept for future networks

This means that the future network infrastructure can be logically sliced into „network layers" - „slices" - for different business applications and for different RAT radio access technologies. These networks can be separately optimized for different data rate requirements for different RATs. For example, the 4K video application requires high speed and is not critical to packet latency, while the NB-IoT application, on the contrary, does not require speed, but, in some cases, requires fast enough information delivery. The „tactile Internet" application almost always requires the least amount of delay. And these are only three of the many 5G applications.

Such requirements are difficult to meet within a single network, so the 5G network has to be logically divided into independent layers („slices"), each of which is managed by a separate BSS / OSS operator.

Network Slicing technology allows for logical separation of networks for different types of 5G services, which require different radio access technologies RAT (Radio Access Technology), with different characteristics of data transmission media, on the basis of a single volume (pool) of network resources.

These are, for example, services (fig.3):

- High quality UHD video
- Voice services (5G Voice)
- Internet of Things with many sensors, sensors and actuators (Massive IoT)

The Internet of Things for critical applications, such as unmanned transport (V2X), e-medicine (Mission Critical IoT) and many others.

All of these Network Slicing services run on a single physical infrastructure of data centers in the central and edge clouds, as well as the mist infrastructure (Fog Computing) required for Massive IoT and the Industrial IoT (IIoT).

This makes it possible to reuse the once created hardware and software infrastructure and flexibly reassign its available resources. In addition, this approach allows reducing not only the capital costs of network construction, but also the operating costs of its maintenance.

Additional technologies in future mobile networks:

- Low latency & high reliability - reduce latency and increase reliability
- Massive MIMO - Up to 8 data streams per subscriber. In Massive MIMO, the subscriber can operate with a large number of antennas at the same time, which will generate very sharp directional diagrams
- Novel Multiple Access - new access technologies
- New Full Duplex - allows you to use the same frequency in different cells for different tasks
- Flexibel Duplex - allows flexible traffic transfer
- Low latency & high reliability - reduce delay and increase reliability
- M2M / D2D - transfer of information directly between devices without human intervention. Expansion of coverage through subscriber devices. Creating a decentralized network.
- High frequency communication - frequencies below 6 GHz will be the primary bands for the 5G network. Frequencies above 6 GHz for universal access and backhaul
- Spectrum sharing - spectrum sharing at different levels by different access technologies.

D2D (device-to-device) - the principle of information transfer between devices, without human intervention. This technology makes it possible to expand the network due to the fact that mobile stations will perform the functions of transit, transmitting through themselves traffic from other mobile devices that are not in the range of base stations. This method of information transmission will allow to significantly relieve the network.

M2M - provides information transfer between devices using mobile network equipment, thereby reducing the load. However, with these technologies, data privacy may be compromised due to the fact that the radio channel between mobile stations is not controlled by the mobile network equipment.

## 5. Conclusions

SDN, NFV, Big Data, IoT technologies and their implementation through cloud services is an integral part of future networks have been described. SDN and NFV technologies offer new conceptual approaches to the architecture of telecommunication networks, with which the future is connected. The 5G wireless network has great potential for mass use and creates an entire ecosystem for the business segment, and is also important for the development of the sphere of connected IoT (Internet of Things) devices. Fifth-generation networks, coupled with Big Data and the Internet of Things, can be the basis for the future digital economy. The deployment of 5G networks will lead to the beginning of a new stage in the development of IoT. The main characteristics of 5G for connected devices are: high speed (over 100 Gbps); high number of connections; reliability and fast response (up to 1 ms delay). These advantages of furure networks will help the development of telemedicine, robotics, smart home systems, smart cities and the industrial internet of things. A new model for the future network architecture based on SDN/NFV/IoT/Big Data has been proposed.

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