

# Development and Interaction of the VTF Concept with IoT Platforms on the Example of the 5G Standard

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**Abstract**—The main prospects of development and interaction of mobile telecommunication networks are given, taking into account the potential opportunities for the realization of scenarios for the implementation of virtual technical functions on the platforms of the Internet of Things with the appropriate quality of service. The advantages and disadvantages of individual scenarios for the implementation of the concept of virtual technical functions are considered. An attempt is made to describe the principles of interaction of the 5G mobile network standard with Internet of Things platforms. Some aspects of the development of mobile communication systems are recognized, taking the promising technologies and recommendations of the ITU into consideration. The basic principles of construction of mobile communication networks are given, including the potential implementation possibilities of any realization scenario of virtual technical functions with set requirements for a given quality of service. The advantages and disadvantages of individual scenarios for the implementation of the concept of virtual technical functions are contemplated.

**Keywords**—5G Standard, IoT Network, Mobile Communication, SAE / EPS Project, VTF concept.

## I. INTRODUCTION

Communication between processes is defined as a method of interaction and data exchange between telecommunications and information systems. These systems typically process large amounts of information and are able to interact with each other regardless of hardware and software implementation [1]. They are relatively complex and require significant technological and economic resources to develop, upgrade, and improve mobile network standards [2]. To simplify the structure of large-scale application systems, it is necessary to develop and implement modern means of interaction in the overall complex of telecommunications and information networks, that could meet the needs of potential users. During the twenties of the 21st century, the system of mobile telecommunications, which had already acquired tens of billions of users, developed rapidly [3]. According to various sources, the number of connected devices in 2021 reaches around 50 billion and it is still constantly growing (Fig. 1).

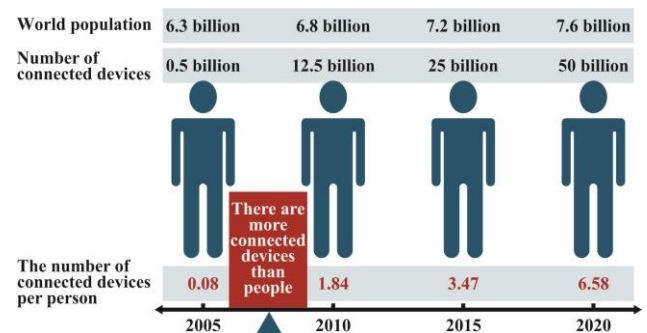


Fig. 1. Quantitative indicators of population growth and the number of connected devices [3]

With the growing demand for mobile telecommunications networks, there is a constant need to expand their capabilities. Meeting the needs for traditional and new services leads to an increase in traffic flow, and thus the depletion of radio frequency resources [4]. Given that the traffic is constantly increasing due to the emergence of additional services, such as remote control of automated processes, control of long-distance complexes, etc., this factor contributes to the fact that the number of various connections to mobile network systems will continue to grow.

The modern Internet consists of large-scale corporate, scientific, governmental, and home computer networks. The connection of networks of different styles of architecture and topologies is carried out using the IP protocol. Each network member (or group of participants) is assigned a specific IP address, which can be either permanent or temporary (dynamic). The increase in connections of various components has exceeded the number of subscribers, so the number of things already exceeded the number of users. IoT today consists of many neutrally interconnected networks, each of which deals with and solves its own problems. For example, in an office building, several networks can be deployed at once: to control air conditioners, heating, lighting, security, and so on. Each element that connects to the network needs a unique IP address, so due to the rapid growth of IoT, the problem of lack of addresses can be a limiting factor. The sixth version of the IPv6 Protocol will

help to radically solve this issue, which will enable every inhabitant on Earth to use a huge number of IP addresses. As shown in (Fig. 1), it is expected that by the end of 2021, there will be more than 50 billion networked things in the world, and IPv6 addressing capabilities will allow for virtually no restrictions to identify any element in the network. It is clear that such processes significantly affect the quality of functioning of global transport networks. Hyperautomation, blockchain, artificial intelligence security, distributed cloud, and autonomous systems create new opportunities in strategic technological trends, however, in turn, reduce the bandwidth of telecommunications systems and global networks [5]. Today, the number of devices and users connected to the 5G network is growing rapidly, and telecommunications equipment developers and operators are trying to respond to new challenges and continue to improve the architecture of mobile networks and regulate their interaction. Fourth-fifth generation networks (4G-5G) have become the next stage in the evolution of such networks. The 5G mobile communication system has significantly improved the quality (QoS) of customer service in the context of increasing data reception / transmission in the network, but with the growth of traffic, the quality of service has gradually begun to deteriorate. Increasing the number of different devices connected to the mobile network, based on 5G technologies, provides data transfer speeds of more than 10 Gbps, but no longer satisfies a certain category of users. The problem of improving the efficiency of mobile traffic flows therefore remains relevant.

## II. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Mobile generations of several standards have now entered the market that has begun to affect many aspects of our lives [1]. The ability to receive, modify, and transmit information and to store a large amount of memory for any object included in the network (transponder), various applications have expanded their number of new features, such as security, vehicles, personal access control, tracking objects (luggage, containers, animals), production control, timing in sports, document authentication, etc.

The potential of RFID (radio frequency identification) as an important means of communication is widely discussed, especially in the retail market [6]. It is clear that the rapid accumulation of connectivity elements has necessitated further development of the transport network, but its expansion also requires significant financial costs and the use of radiofrequency resources, which are limited and distributed by relevant ITU-T recommendations among states. In different regions of the world, the corresponding central executive bodies control and regulate the distribution of the radio frequency spectrum [7]. The demand for traditional and new services is forcing operators to develop the latest telecommunications systems, the key points of which are the further development of Internet networks and mobile systems with stable growth of end-user access devices [8].

To increase profits, operators are constantly encouraging the demand for intelligent services by providing a transformation of the rapid creation and implementation of the new terminal elements' segment. Operators who have organized a comprehensive mobile network platform have been able to evolve in the NGN network [9]. The main task of each mobile network operator should be to provide any user (subscriber) with the required service while roaming, ie.

to provide 100% support for the relevant functions, despite the fact that such functions may be "virtual", ie. uncharacteristic for a separate mobile network [10]. The number and variety of services that can potentially be implemented using such systems are very large, which is attractive for both mobile telecommunications subscribers and mobile operators.

Today, there are two concepts of providing additional services in mobile telecommunications networks: based on service nodes (Service nodes) and the classic intelligent communication network IN [10, 11]. The first will be used for the organization of services: SMS, EMS, MMS, call center services, etc. The main significance of the second concept for mobile telecommunications networks is not in the list of CS services (Capability Set), but in the idea to separate the processes of traditional switching from the procedures to providing new services that form the IoT [12].

The relevance of this idea has made it attractive for mobile telecommunications networks already in the SAE / EPS project, focused on providing the subscriber with additional services [13, 14]. This situation requires the participation of international regulation based on the developed ITU-T Recommendations, which government agencies in different regions of the world use to regulate the allocation of the radiofrequency spectrum. It should be noted that the development of new generations expands the capabilities of individual systems and standards, their technical and operational characteristics, methods, and new functions that differ significantly from previous developments.

The introduction of the latest technologies provides an opportunity to expand the segments of new applications with high bandwidth, and to administer any growth of users of mobile platforms and IoT connections. The mobile station must have access to communication services, ie. the MS must be served by any project of the MSC network (Mobile Switching Center - the mobile switching center), in the service area of which it is currently located [15, 16]. The system approach means that the mobile station (MS) is not included in a specific switching node, but directly in the network system in which it is located. This feature significantly complicates the organization of the subscriber database, which is the main component in some scenarios of the concept of VTF (Virtual Technical Function - virtual technical function) [10, 17].

## III. MATERIAL AND METHOD

The authors will analyze the prospects for the development and interaction of the VTF concept with IoT platforms based on the 5G mobile network standard, which increasingly encompasses the coverage of areas with the provision of various services and applications. One of the main advantages offered and implemented by mobile telecommunications networks is the ability to freely move the subscriber from its own zone to one or another zone served by mobile telecommunications networks of other operators [18, 19]. In this case, the subscriber must maintain his personal profile of services in other networks, ie. be able to roam services [20]. But unlike fixed networks, in mobile telecommunications switches trigger points and service profile are not provided in the form of static data, but are determined during registration.

Each of the three SAE / EPS project systems shown in Fig. 2 has its own set of services:  $S(i)$ ,  $S(j)$ ,  $S(k)$ , which are shown by rings. The intersections of such rings are services that are the same for these networks.

As the number of SAE / EPS project systems increases, the overall service platform  $S(i,j,k)$  decreases. In accordance with ITU-T ETS1, 3GPP standards in the mobile telecommunications networks of the SAE / EPS project enable their subscribers to use the functions of the home network while outside it, i.e. in the visiting network, the introduced concept of Video Home System (VHS) was to some extent limited and declarative [21].

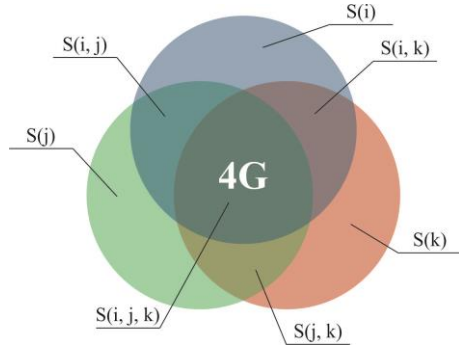


Fig. 2. Service coverage model in 4G project networks (SAE / EPS)

The fifth generation 5G network, which is defined as the next stage in the evolution of the fourth generation LTE 4G, forms the basis in which the proposed VTF concept can meet the actual needs of subscribers, namely can be quite voluminous and depend only on the degree of cooperation between operators and their technical capabilities, compatibility of user equipment [22]. In this case, SAE / EPS project systems that offer their subscribers a global roaming service must support VTF, if these systems have the capabilities of a subscriber service of a similar VHS service from the beginning, taking into account IoT traffic [23, 24]. In 5G networks and its modifications, routing in the data transmission mode is carried out in the packet switching mode. These types of traffic (traffic of classic mobile networks and IoT traffic) are abrupt in nature, because the data is transmitted by pulsations rather than a continuous stream [25]. It should be noted that such pulsations differ significantly from each other, so it is necessary to consider them both individually and as a whole.

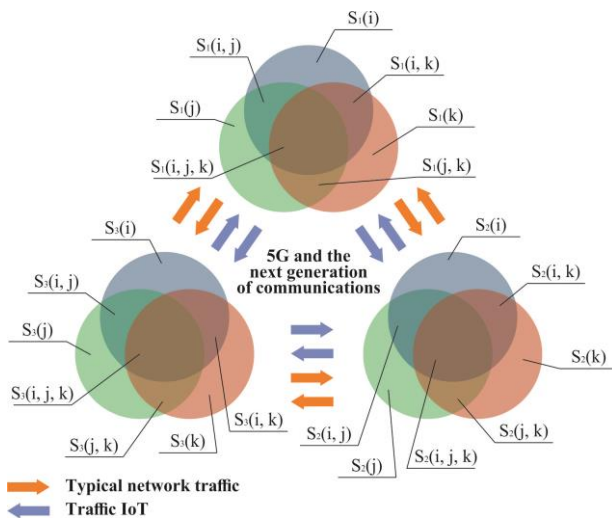


Fig. 3. Model of service coverage in 5G, 6G, 7G project networks

One of the main advantages offered by mobile telecommunications networks is the ability to freely move the subscriber from its zone to one or another zone served by mobile telecommunications networks of other operators. The capabilities of home and business networks may be different, which will affect the list and characteristics of the services that can be offered to the user who has moved to the business network. Fig. 2 shows abstract models with three systems of mobile telecommunications of the fourth generation, and in Fig. 3, a model of coverage by mobile networks of a certain plane by different standards based on technologies 5G and above is displayed [26].

Thus, each of these SAE / EPS project systems shown in Fig. 3 has its own set of services:  $S(i)$ ,  $S(j)$ ,  $S(k)$ , which are shown by rings. Increasing the number of SAE / EPS project systems increases the overall service platform  $S(i, j, k)$ . The degree to which the VTF concept is proposed, which will meet the actual needs of subscribers, will be quite extensive and will depend only on the degree of cooperation between operators, their technical capabilities, and compatibility of user equipment. In addition, SAE / EPS project systems that offer global roaming services to their subscribers must support VTF, if these systems have the capabilities of a subscriber service similar to the VHS service [27].

#### IV. RESULTS

Now, the authors will analyze the methods of joint functioning and evolution of the 5G and IoT standards. The 5G standard is taken as a basis, because it practically satisfies the requirements of standards both current and those under development. It is expected that 5G networks will be able to connect many devices necessary to make billions of connections, making it possible to create new services in segments that may be in demand by users. As an example, such segments will be the traffic of "typical" networks, "tactile Internet", IT and telecommunications sector, unmanned vehicle management, entertainment industry, education, and agriculture. Thus, the fifth generation networks in the first stage will meet almost all the requirements of traditional users and the IoT system. The degree to which the proposed concept of VTF can meet the actual needs of subscribers will be extremely large and will depend only on the degree of cooperation between operators, their technical capabilities, and compatibility of user equipment.

In addition, SAE / EPS project systems that will offer global roaming services to their subscribers must support VTF, if these systems have the capabilities of a subscriber service similar to the VHS service from the very beginning. The 5G mobile standard has been evolving since 2015, with 5G data capacity exceeding 1 Gbit/s. 5G is a relatively new technology that should provide all possible applications using a single universal device, integrating most of the existing communication infrastructures. 5G technology has a bandwidth of up to 40 MHz, it is a wireless technology with certain limitations, and it can be supported on the WWW (Wireless World Wide Web). 5G provides high speed data transfer with greater capacity. The main services are its dynamic access to information, devices with artificial intelligence capabilities, and a wide range of different applications.

One way to solve this issue is to quickly manage the structure of the switching network with long variable

components of the flow values. It is proposed to apply some methods of operational management of the mobile network by adjusting the flows (branches) of the system, which can improve the quality-of-service load between base stations, to another extent, spatio-temporal methods of processing information embedded in wave fields and radio signals received simultaneously in spatially spaced mobile reception points using both active and passive radio reception methods.

Analyzing the rapid development of telecommunications, it can be concluded that an important trend in different countries has been and remains globalization, ie. the joint efforts of telecommunications network operators and manufacturers of telecommunications equipment to solve grand problems of international nature. Globalization can take many forms and standards; creation of transnational corporations, joint implementation of information infrastructure projects by developed countries, etc. The avalanche-like state of accumulation of various devices connected and connected to the Internet requires the creation of a mobile network with the obligatory prospect of redundancy in several stages in advance. These stages will be the 6-7-8G standards, which will have to adapt to different challenges and standards with a certain power reserve.

In (Fig. 3), a model of service coverage in the networks of projects 5G, 6G, 7G, 8G is shown, where, depending on the increase or decrease of flows, their redirection is performed. By exchanging data, things "communicate" with various elements of the connection and, if necessary, "go" to the transport and global networks. It is the concept of communication of objects (things) that use technology to interact with each other and with the environment. Also, this concept requires devices to perform certain actions without human intervention. Thus, IoT is a system of interconnected computing devices, mechanical and digital machines, objects, animals or people, which are provided with unique identifiers and the ability to transmit data through a network without requiring human interaction with machines or computers. Along with the benefits of using IoT technology, the security and privacy issues of IoT are exacerbated. This is primarily due to the fact that IoT connects billions of devices to the Internet and involves the use of billions of data points, which must be protected from unauthorized intrusions. Hackers use poorly secured IoT devices when gaining access to the network. Because IoT devices are closely interconnected, all a hacker needs to do is exploit one vulnerability to manipulate all data. This is why users who do not update their devices regularly, or do not update them at all, leave them vulnerable to cybercriminals, and connected devices often ask users to enter their personal information, including IoT. Thanks to cheap processors and wireless networks, everything from a pill to an unmanned vehicle can be included in the IoT. This process adds a level of digital intelligence to devices that would otherwise be meaningless. Devices can transmit real-time data without human intervention, combining typical traffic and IoT traffic (see Fig. 4).

It should be noted that the structure of IoT is considered dominant, and the structure of transport and global networks that perform the functions of long-distance information transmission, is often considered a secondary component [10]. However, the functions of the transport network are gaining more and more weight as IoT traffic will continue to grow rapidly, so the quality of QoS will deteriorate. Figure 4

shows an approximate schedule for the implementation of 5G and IoT mobile services during the day. The curves of typical traffic and IoT traffic may coincide or differ, especially at night, when the presence of staff is almost leveled. In this case, the technologies of operation of both the equipment itself and the needs of energy capacity change.

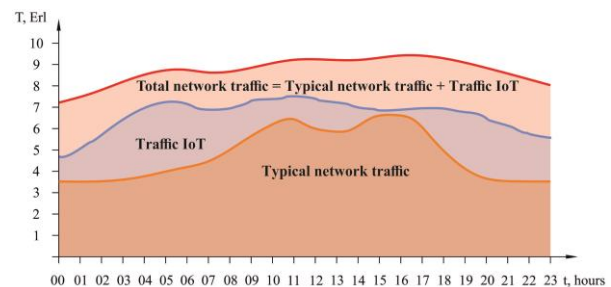


Fig. 4. Approximate schedule of 5G, 6G, 7G, and IoT mobile services during the day

The main obstacle to building large LANs with switches alone is the non-linear growth of broadband traffic due to the growing number of devices connected to the network.

The quality of work will be relatively stable with the allowable number of devices from 500 to 2000, and will depend on the network topology of the class and the defined tasks. As the volume of devices increases, broadband traffic will increase dramatically, so adding new devices will reduce the performance of such a network. With the growth of shared traffic, it is advisable to divide the typical network traffic and IoT traffic globally into separate streams. The concept assumes that IoT can seriously affect the development of modern society, as it will allow many processes to take place without the need for human intervention. Thus, IoT today consists of many interconnected networks, each of which deals with and solves its problems. For example, in an office, you can deploy a certain number of local networks at the same time, depending on the task. In this case, the end devices will be regulated and redirected in different streams of total traffic using VTF functions, which was the first attempt to take steps towards the creation of IoT. When transmitting information over long distances, IP packets pass through a large number of switches independently of each other and in any order, without prior preparation of existing equipment and their location is tracked.

IoT was originally more interesting for business and manufacturing, where its application is sometimes called Machine-Machine (M2M). Now the emphasis is on equipping homes and offices with smart devices that are functionally relevant to each of us and can also perform tasks independently. As a basis, one of the paradigms of development of the 5G infrastructure can be taken as a concept of functional units of QoS control and monitoring, implemented as part of the cloud infrastructure of the core SDN network using virtual functional modules VTF. As an example, the European 5G development strategy aims to give the subscriber an opportunity to choose what to connect to their TV by 2025: a 5G modem or a terrestrial antenna with DVBT (HDTV), and this requires appropriate quality management mechanisms. Thus, the efforts of developers to improve quality management mechanisms will focus on traffic to video and M2M services, on improvement of control algorithms and on creation new methods of quality

assessment. It is clear that in this case, the traffic will increase rapidly.

Analytical processing of existing mobile telecommunication network construction projects made it possible to highlight remarks of technical characteristics of mobile telecommunication network construction projects, which testify to the potential possibility of implementing any scenario of VTF implementation with a given quality in telecommunication networks and the telecommunication networks concept. Full virtualization of network functions will be implemented in the infrastructure of the following mobile standards, will include control and management of QoS, policy of maintenance, and generalization of traffic of mobile networks and IoT. The networks will have new solutions in the field of infrastructure: mobile nodes (Base Stations) of communication (Moving Node) and mobile transport networks (Moving Backhaul), which will be dictated by the need to implement different technologies in creating intelligent transport networks with virtualization of control and management function networks. It is safe to say that the interaction between mobile systems and the IoT will continue to grow and radically change the development of the social order on the planet.

## V. CONCLUSIONS

The stages and prospects of the development of mobile communication systems in the concept of VTF and interaction with IoT platforms are considered. Definitions of multiple concepts and separate scenarios of their realization have emerged as a result. Abstract models with different fourth-fifth generation mobile communication systems belonging to different operators are shown. It is concluded that in the implementation of the concepts, it is advisable to organize a centralized subscriber database for the classic network and the IoT network, which participates in the operation of virtual technical functions.

The general picture of harmonization of mobile communication standards for the next generations is formed. The general purpose of the research and partial tasks that need to be dealt with for further elaboration of the concept of virtual technical functions in solving the issues of development of telecommunication networks of mobile communication and their interaction with IoT are worked out. The peculiarity of IoT is that it can be formed in different conditions: in the conditions of the ultra-high-density network, for example, in the city; and in low-density networks with limited interconnection, for example, in low-density environments with no coverage by wireless networks.

The stages and prospects of the development of mobile communication systems in the concept of VTF are considered, the definition of concepts, and separate scenarios of their realization results. Some aspects of the advancement of mobile communication systems are given, taking into account the promising technologies and recommendations of the ITU. The basic principles of construction of mobile communication considering the potential of any realization scenario of virtual technical functions with the set requirements to the quality of service are described. Further research is planned to highlight the problems of the VTF project, namely the organization, monitoring, and management of the subscriber database, which can usually have different technologies and speeds.

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