Analysis of Facing Developers Problems of Modern Telecommunication Technologies

Ruslan Politanskyi[1[0000-0003-0015-7123]], Andrij Veryga[1[0000-0002-2616-3057]], and Mariya Vistak[2[0000-0001-5192-4017]]

[1] Yuriy Fedkovych Chernivtsi National University, Ukraine
[2] Danylo Halytsky Lviv National Medical University, Ukraine
r.politansky@chnu.edu.ua

Abstract. The development of modern telecommunication technologies is accompanied by a significant amount of theoretical research. We can identify three most important areas that precede the introduction of new technologies in specific solutions made by the largest manufacturers of modern telecommunications equipment: (1) research in signal theory; (2) research of routing algorithms; (3) convergence of telecommunication technologies. We briefly analyze all three areas, indicating the main trends and problems of further development of information and communication technologies.

Keywords: Telecommunication, Signal Theory, Routing Algorithms, Internet of Things.

1 Introduction

The development of mobile communication began in the early ’80s of the last century. Currently, it is possible to identify 5 generations based on fundamentally different access technologies for subscribers and base stations. These are AMPS technology using analog signals, GSM and UMTS technology, and at least LTE and 5G technology, which are transnational corporate technologies. The use of LTE and 5G technologies has made it possible to unify data transmission standards in mobile networks and the Internet. The rapid growth of traffic transmitted by mobile networks has led to an increase in such transmission system performance as the maximum data rate and the density of the number of connected devices. The ability to provide the characteristics of each new standard was achieved both by moving to higher frequency bands with more channels in each band and by improving the technology of modulation and encoding of digital data. A significant increase in transmission rate without increasing the total power consumption resulted in the transition from code division multiplexing (CDMA) in GSM and UMTS technologies to orthogonal frequency division multiplexing (OFDM) in LTE and 5G technologies.

2 Research in Signal Theory

Increasing the data rates declared in the 5G standard requires the development of directional phase antennas, the development of new data routing standards that enable the implementation of point-to-point connections, as well as the development of new technologies for free frequency band search [1], to efficiently use bandwidth and prevention of collisions of users using fixed frequency bands [2].

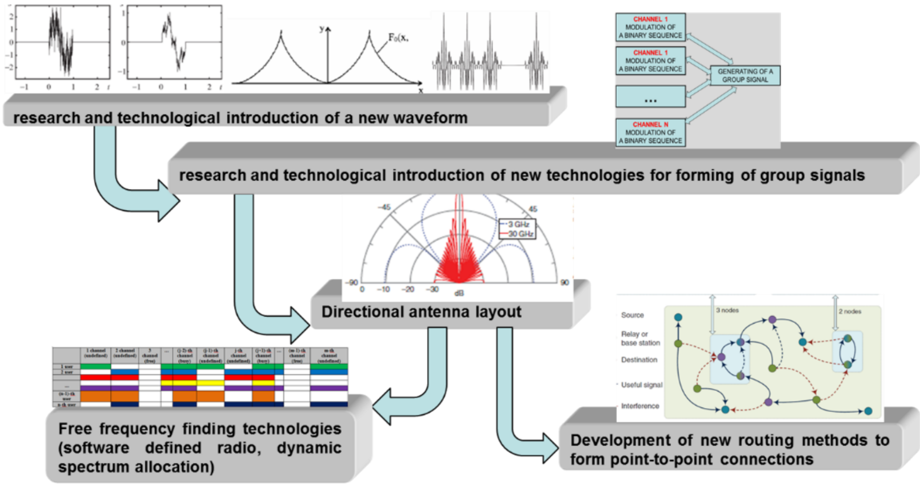

Fig. 1. Development of mobile communication technologies.

The growing demand for the number of devices that can simultaneously transmit information within one cell, causes a significant increase in the problem of inter-channel interference. Solving the problems of inter-symbol (ISI) and inter-channel interference (ICI) requires solving the problem of protection against interference that has the properties of non-stationary random processes. The importance of this problem is noted in the classic work of the famous engineer of telecommunication systems B. Sklar [3], who divided wireless channels into three groups as for statistical properties of noise acting in the channel:

- Channel with additive white Gaussian noise.
- Relays channel.
- Channel with a high probability of a bit error.

The methods of prevention of white Gaussian noise which is present in most wireless channels are widely used and are well known. The most common of these are correlation detection and digital filtering methods based on discrete Fourier transform algorithms and the use of a matched filter with a transient response determined by the waveform that forms the channel symbol.

To prevent non-stationary noises, which both include inter-symbol and inter-channel interference, several adaptive methods are applied based on:

- The transverse line filters.
- The equalizer with feedback.
- The Viterbi equalizer.

B. Sklar also noted that most traditional methods of removing channel interference are ineffective against little-scaled fading. This fact is greatly enhanced with increasing frequency of signals, as this significantly increases the number of possible paths of propagation. Such characteristic as the number of simultaneously connected end-point devices also becomes significantly non-stationary, as the maximum possible number of simultaneously connected subscribers significantly increases in new types of networks (5G standard) [2].

The current state of development of digital signal filtering is a fairly effective means of combating stationary interference, which in most cases can be modeled by white Gaussian noise. From a theoretical point of view, the possibility of such approximation is a consequence of the central limit theorem. Another non-stationary type of interference is conventionally divided into two groups: pulses-shape noise present in the channel and more regular types of interference acting both in time and frequency domain (Fig. 2).

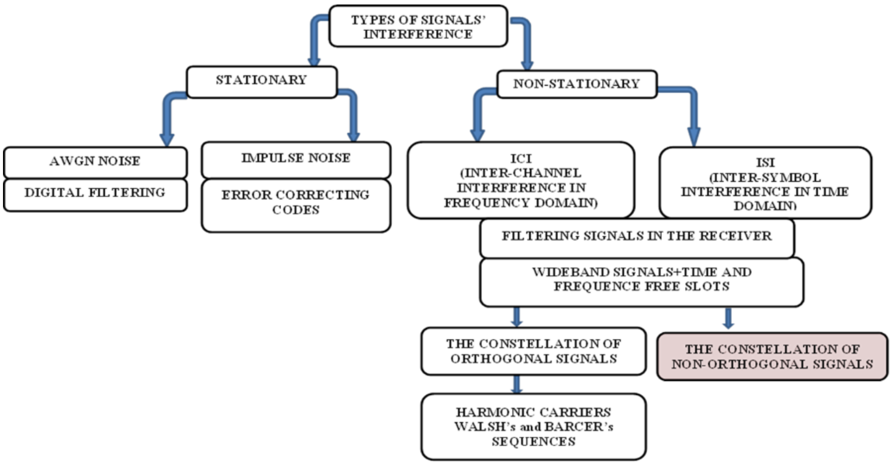

Fig. 2. Types of noise and methods of combating them.

Based on the data on the search for new modulation methods that can be used in the 4G and 5G standards [2], we can conclude that many new solutions are based on the use of non-orthogonal signals [4].

An effective means of combating interference owing to pulse-shape noise is the use of redundancy codes which is a usual practice. More complex types of interference are inter-channel and inter-symbol interference. The cause of inter-symbol interference is the overlap of signals transmitting neighboring channel symbols in the time domain due to multipath signal propagation. There are two reasons for the overlap of signals in the frequency domain: the finite duration of the signals, and the blurring of the signals due to the Doppler effect. In present, it seems that the most potentially effective method for elimination of inter-symbol and inter-channel interference is the use of broadband signals. These channel symbols could be both orthogonal and non-orthogonal. Thus, the task of finding complex signals with a high base, which was a classic among specialists in the field of telecommunications, becomes relevant again. This is the well-known optimization problem of signal modeling which consists of determining signals having a given spectrum width in conditions of limited signal duration.

The use of signals with some special shape could be effective against both inter-symbol (ISI) and inter-channel interference (ICI), while traditional signals, like OFDM, usually prevents only one of them.

Moreover, the transition to a high-quality spectrum area and the increase in the number of users will be designed with this problem in mind. Finally, the number of signal propagation paths increases due to the decrease in pulse duration, which leads to an increase in the power of the interference due to the inter-symbol interference. Increasing the number of users leads to a greater variety of this value during this time, not only increasing the power of migration barriers, but also fundamentally changing the statistical properties of a random process that uses migration barriers, and it becomes significantly non-stationary, which may be a major factor.

In this case, the traditional methods of redundancy coding and the use of optimal filtering are not more effective, because they are designed for known statistical characteristics of the channels, which in the case of non-stationary interference is very difficult to establish. Therefore, the methods of adaptive filtering are also becoming less suitable, because they are designed to be able to some extent to predict the characteristics of the channels over some time. This problem was appointed before providing modern communications by B. Sclar [3], who emphasized that in the case of deviation of the characteristics of the channel first from Rayleigh, and then from Gaussian, any traditional methods of noise control lose their effectiveness. And the fact that this problem can be solved by using complex broadband signals, say modern developers of 5G technologies [2].

We conducted a comparative analysis of the most common modern signals and modulation methods and so far little known, which are under development. The results of this analysis are shown in Table 1, where the most important in our opinion characteristics of signals and modulation methods are indicated: orthogonality of carriers, method of protection against interference of both types, presence of direct and inverse Fourier transforms in signals present in signal processing.

Table 1 shows the characteristics of the following signals and modulation methods: OFDM (Orthogonal Frequency Division Multiplexing), FBMC (Filter-Bank MultiCarrier), GFDM (Generalized Frequency Division Multiplexing), BFDM (Biorthogonal Frequency Division Multiplexing), TFP (Time-Frequency Packing). Also, we add a chaotic carrier as it is potentially the most suitable for preventing both ISI and ICI.

Table 1. Characteristics of complex signals and modulation methods

Method of modulation	Orthogonality of subcarriers	Protection from ISI	Protection from ICI	DFT	IDFT
OFDM	+	Cyclic prefix	Guard band	+	+
FBMC	–	Additional coefficient between the FFT coefficient (overlapping factor)		+	+
GFDM	–	Adding a CP between all subcarriers in the frequency domain and they become to be not contiguous		–	–
BFDM	+	The same as in OFDM and filters with different characteristics in transmitter and receiver sides		+	+
TFP	+	The use of an optimal receiver in the assumption that controlled interference between contiguous signals in the time domain has the Gaussian white noise statistics			
Chaotic carriers	–	Narrow time domain correlation. Ability to apply the phenomenon of the synchronous response of systems with dynamic chaos	Almost uniform spectrum in the frequency domain. Ability to apply the phenomenon of the synchronous response of systems with dynamic chaos		

3 Research of Routing Algorithms

The increase in integrated characteristics of telecommunication networks the volume of traffic, data transfer speed, and the total number of end-point devices has led to a significant complication of both the network structure and transport layer algorithms. Also, the development of telecommunications technologies has led to the possibility of new telecommunications services (cloud computing, mobile services, Internet of Things, Tactile Internet, Internet of All) and the merging of networks into a single global system. As a result of the above trends, technology convergence is becoming increasingly important, as it makes it possible to get rid of inconsistencies in platforms developed by different vendors and at the same time prevent the undesirable monopolization of the telecommunications technology market.

Therefore, as in the case of research of new methods of formation of channel signals caused by fundamentally new characteristics of channels, the importance of finding new methods of the simulation of the distribution of traffic at the transport level of the network is growing again. From the theoretical point search and researches of algorithms of transport-level for networks with a time-variable structure (Fig. 3) become more important.

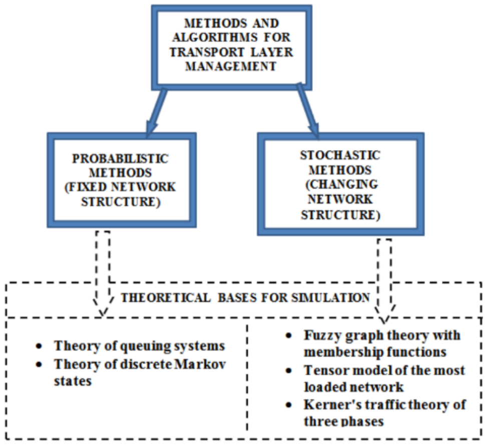

Fig. 3. Transport layer methods and algorithms.

Methods of modeling networks with a static structure and constant speed of request processing have been used since the emergence of networks with a packet type of information transmission. These methods used well-developed theories of queuing systems, Markov chains, methods of diacoptics, the theory of graphs with unchanged structure. But such methods are no more possibly applicable to networks with complex especially changeable topologies, which take place in modern mobile networks. This is evidenced by at least a comparison of one of the most common results for networks of both types: the average number of nodes connected directly with each other for achieving the best network bandwidth: for networks with a static structure there are only three such nodes, and form networks with variable structure, this statement needs to be proved.

For networks with variable structure, other methods of theoretical research are used: graph theory with fuzzy logic of connection between pairs of nodes, tensor models of fully loaded networks [5], Kerner's theory of three-phase traffic flow [6], modeling of networks with variable topology (the content approach) [7].

According to the tensor model, a transport network can be described as an oriented graph, with given sets of vertices V and arcs E. Each arc corresponds to a real information transmission channel, and each vertex is a transport node of the network. The set of all nodes is divided into two subsets: the set S, which generates flows, and the set D, which absorbs them. The tensor model can be the basis of multithreaded routing (MPTCP), which allows data to be transmitted on several routes simultaneously for one connection.

4 Methods and Algorithms of Convergence of Data Transmission Technologies

One of the main trends in the convergence of technologies for storage, processing, and transmission of information. The consequence of convergence is the achievement in three main areas: cloud technology, information transmission channels, and the manufacture of electronic devices of the final link of the information transmission system.

To date, the convergence of info-communication networks has led to the emergence of three main concepts: virtualization of network functions (Network Function Virtualization), cloud computing (Cloud Computing), and software-controlled networks (Software Defined Network).

The increase in integrated indicators of telecommunication networks the volume of traffic, data transfer speed, and the total number of subscribers has led to a significant complication of both the network structure and transport layer algorithms. Also, the development of telecommunications technologies has led to the possibility of new telecommunications services (cloud computing, mobile services, the Internet of Things, tactile Internet, Internet of All) and the merging of networks into a single global system.

The increase in the number of mobile devices connected to the Internet (the Internet of Things) has led to intensive research in the field of mobile cloud computing (MCC). This area includes several important technologies used in MCC, namely [8]:

- The strategy of unloading traffic from cellular networks to other available wireless access technologies (for example, Wi-Fi).
- Migration of services and data caching.

The most common convergence technology is network virtualization. The essence of this concept is that many isolated logical networks with significantly different addressing algorithms and mechanisms for redirecting information flows have the same physical equipment. This is achieved by developing more flexible software and by duplicating network equipment components. This technology makes it possible to avoid the use of programmable hardware, such as FPGAs or network processors.

There is a clear analogy between network virtualization and computer hardware virtualization. Computer virtualization provides hardware abstraction and hardware distribution between different operating systems, and everything looks as if each operating system has its hardware. Thanks to virtualization in computer technology, it becomes possible to install software platforms from different manufacturers on a hardware platform manufactured by the world’s most famous brands, thus realizing the “many-to-many” relationship (Fig. 4).

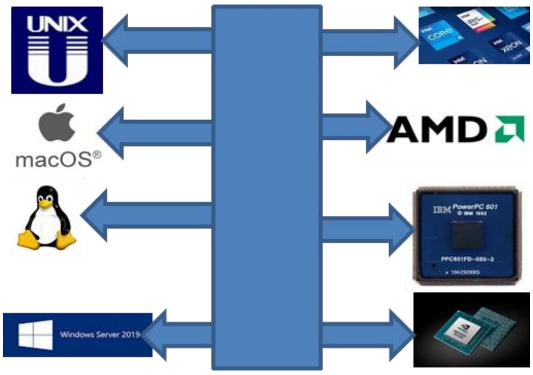

Fig. 4. Scheme of computer technology virtualization.

Thus the many-to-many relationship between software and hardware vendors is realized through virtualization of network functions.

A specific mechanism that provides virtualization is different sets of instructions for different hardware platforms implemented in one software shell. The purpose of the virtualization of network functions as well as the virtualization of computer hardware is also the convergence (convergence) of different hardware and software platforms. By analogy with computer hardware, network software should also include a level of hardware abstraction.

Virtualization of network functions means the division of five different resources:

- Bandwidth.
- Topologies.
- Traffic.
- CPU resources.
- Redirection tables.

Due to this, Cloud Computing technology becomes possible to use instead of corporate networks. Cloud Computing technology has become an advanced technology in the design of info-communication networks, and today it is used to build their info-communication structure by such giants of the IT industry as Google, Amazon, Axios System, Salesforce, Microsoft, Yahoo, Zoho. Three of them share a significant share of the info-communication services market by providing services in almost 40 geographical regions, competing with the Chinese telecommunications giant Huawei.

5 Conclusions

The main directions of theoretical researches directed on the search of new technologies of data transmission taking into account growth of volume of traffic and speed of data transfer and convergence of all existing telecommunication network technologies are considered in the work. It is concluded that an important area of research at the physical level is the search for new channel broadband signals that are resistant to both inter-symbol and inter-channel interference. At the transport level, the main search for data routing methods takes into account the convergence of networks, which results in the transition from the most common Ethernet protocol, which is based on the 7-layer OSI model, to a simplified 3-layer SDN network.

Despite its great practical importance, the implementation of software-controlled networks is a major science-intensive problem, which confirms, in particular, that much of the current SDN standards have been developed at Stanford University.

To date, active research is being carried out to find new convergent technologies that ensure the effective use of the latest advances in the processing of information-carrying signals—fully optical networks that do not use optoelectronic and electro-optical transformations [9]. The all-optical network is a promising technology for FN, which is also associated with the rapid development of optical technologies. This optical packet and integrated network (OPCInet) offers a variety of services that increase functional flexibility along with energy efficiency with high switching speed in the SDN packet system in the metro/core network.

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