Research of the Performance Multiservice Telecommunication Networks Based on the Architectural Concept NGN and FN

B. G. Ibrahimov[1(✉)] and A. D. Tagiyev[2]

[1] Department of Radioengineering and Telecommunication, Azerbaijan Technical University, Baku, Azerbaijan
i.bayram@mail.ru

[2] Department of Radioengineering and Telecommunication, Azerbaijan Technical University, Baku, Azerbaijan

Abstract. The quality indicators functioning multiservice communication network, built in accordance with the architectural concept NGN (Next Generation Network) and FN (Future Network) based on the technology building distributed communication networks, are analyzed. The performance multiservice communication networks using SDN (Software Defined Networking), LTE (Long Term Evolution), 5G New Radio, IMS (Internet Protocol Multimedia Subsystem) and NFV (Network Functions Virtualization) technologies was chosen as a system criterion. Based on the study, a new approach to constructing a method for calculating the performance network is proposed, taking into account the self-similarity property of the transmitted traffic. On the basis calculation method, analytical expression is obtained to evaluate the indicators channel resources, bandwidth and probabilistic-temporal characteristics of the communication network in the provision multimedia service.

Keywords: Nnetwork performance · SDN · Technologies for building distributed communication networks · NFV · Channel resources · QoS · Traffic self-similarity · LTE · Throughput · QoE

1 Introduction

The rapid development of the infrastructure digital economy, the formation strategic plans for the creation of a single information space based on advanced technologies require the construction multiservice telecommunication networks based on the architectural concept of the next NGN (Next Generation Network) and future FN networks with an increased performance indicator that support a wide range multimedia services and applications [1–3].

The studies have shown [4–7] that the problem of the digital economy and the development of a single info communication space directly depends both on the introduction of the latest technologies for building distributed communication networks, quantum technologies, nanotechnologies, biotechnologies, technologies complex energy systems, and

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on methods and artificial intelligence tools. Such technologies for the creation and development four targets for future FN networks primarily include technologies for building distributed communication networks [2, 8]: SDN (Software Defined Networking) and NFV (Network Functions Virtualization), optical WDM & DWDM (Wavelength Division Multiplexing & Dense WDM), 5G/IMT-2020, mobile LTE (Long Term Evolution), 5G New Radio (5G NR), IoT (Internet of Think) and IMS (Internet Protocol Multimedia Subsystem) multimedia communication technology, quantum technology and artificial intelligence.

It was established in [8–10] that the dynamics of the implementation FN architectural concept based on four target settings for creating future networks with increased operational efficiency and the introduction advanced SDN, NFV, LTE, NR and IMS technologies requires improving the performance of networks while providing various basic, additional and intellectual services. Therefore, the tasks choosing the performance indicator multiservice telecommunication networks built in accordance with the concept NGN and FN when establishing a connection and when providing multimedia services are the most relevant.

Based on the analysis, it was revealed [4, 5, 7, 9, 11, 12] that among the above technologies in multiservice telecommunication networks, an important place is occupied by SDN, NFV, LTE, NR and IMS technologies, which provide the provision multimedia services "Triple Play services" (Audio, Video, Data - A, V, D) and "Bandwidth on Demand", which require the provision of a wide bandwidth at the request users.

This paper discusses the problems studying the performance indicators multiservice telecommunication networks based on the NGN and FN architectural concepts, taking into account the QoS (Quality of Service) and QoE (Quality of Experience) parameters in the provision multimedia services and applications.

2 General Statement of the Problem

Based on the study, it was revealed [10, 13–15] that the above innovative technologies open up new opportunities for effective resource management ways to provide a wide range telecommunication services, taking into account the numerous requirements QoS and QoE parameters.

It should be noted that the efficient use of heterogeneous resources of the NGN and FN architectural concepts, a thorough study of the technology for building distributed communication networks such as SDN, NFV and IMS accelerate the launch new multimedia services and applications. As a result, the overall costs for their implementation are thereby reduced and, according to the ITU-T recommendation, Y.3011, they allow the efficient use physical, informational, and network resources [9, 12].

Considering the importance of building multi-service packet-switched telecommunication networks and according to the ITU-T recommendation, Y.3000 ÷ Y.3499, for guaranteed QoS and QoE of useful and service traffic generating multimedia services and applications, special attention should be paid to complex performance indicators.

An analysis of the indicators multiservice telecommunication networks shows that the studied traffic has a special structure [4], i.e. traffic has self-similarity properties. At the same time, a quantitative assessment of the degree of self-similarity of traffic is the Hurst parameter, H.

The Hurst parameter is a measure self-similarity or statistical inertia of the telecommunication process and its values lie within $0 < H < 1$. It is known [3, 14] that a process is exactly self-similar in multiservice networks if.

$$R(\tau) = [(\tau + 1)^{2H} - 2\tau^{2H} + (\tau - 1)^{2H}]/2, 1/2 < H < 1. \quad (1)$$

Thus, the paper considers the performance indicators multiservice telecommunication networks, investigates the problem statements and proposes new approaches to their solutions.

3 Descriptions of the Method for Calculating the Performance Multiservice Telecommunication Networks

Note that at present, only the general architecture system targets and protocols are defined for the FN network, and detailed specifications that determine the interaction system components based on SDN, NFV, IMS, LTE, NR technology and operational protocols are under development by ITU-T. In addition to the lack standards, a significant factor hindering the implementation of the FN network is the difficulty organizing end-to-end QoS and QoE for video and VoIP.

Given the problem statement, a new approach to constructing a method for calculating the performance multiservice telecommunication networks based on SDN, NFV and IMS technologies using switches, SDN controllers with the OpenFlow protocol, and the core of the IMS subsystem is proposed.

As a criterion for the functioning of a system based on SDN, NFV, IMS, LTE and NR technologies, the performance of multiservice telecommunication networks was chosen, taking into account the self-similarity property useful and service traffic in the provision multimedia services, which is determined by the following functional dependence:

$$Q_{KF}(\lambda_i, H) = W\,[\max_i G_{NP}(\lambda_i, H, t), i = \overline{1, n}] \quad (2)$$

under the following restrictions.

$$C_{\max}(\lambda_i, H) \geq C_{\max}^{war.}(\lambda_i, H), R_r(\lambda_i, H, t) \geq R_r^{war.}(\lambda_i, H, t), \quad (3)$$

$$C_a(\lambda_i, t) \leq C_{ank}^{war.}(\lambda_i, t), i = \overline{1, n}, \quad (4)$$

where $R_r(\lambda_i, H, t)-$ coefficient of efficient use heterogeneous resources hardware-software complexes communication networks based on SDN, NFV, IMS, LTE and 5G NR technologies, taking into account the self-similarity H property and the rate incoming flow λ_i during the transmission $i-$ th traffic at a point in time t, $i = \overline{1, n}$, which is functionally described by the following indicators:

$$R_r(\lambda_i, H, t) = F\,[N_k, V_k(\lambda_i, H), \eta_k(\lambda, k)].$$

where $\eta_k(\lambda, k)-$ a function that takes into account channel resource indicators when using technology for building distributed communication networks such as SDN, NFV, IMS, LTE and 5G NR, ITU-T, H.323; $C_{\max}(\lambda_i, H)-$ a function that takes into account the indicators of the maximum value of the throughput of hardware-software systems, taking into account the self-similarity property H and incoming flow rate λ_i when servicing the i-th traffic flow, functionally described by the following indicators:

$$C_{\max}(\lambda_i, H) = [SNR(P_c,\ t),\ \ \Delta F_k,\ \ V_k(\lambda_i,\ H)], i = \overline{1,\ n}, \tag{5}$$

where ΔF_k- frequency bandwidths of the communication channel, taking into account the requirements and conditions for servicing traffic packet flows when providing multimedia services "Triple Play services" and "Bandwidth on Demand"; $V_k(\lambda_i,\ H)-$ operating speed of hardware-software complexes of SDN, NFV, IMS, LTE and 5G NR technologies, taking into account the intensity of the incoming flow λ_i during the transmission of a self-similar H flow packets of the $i-$ th traffic, $i = \overline{1,\ n}$; $SNR(P_c,\ t)-$ signal-to-noise ratio function (SNR-Siqnal Noise to Ratio) taking into account the power of the useful traffic P_c signal at the time t, $i = \overline{1,\ n}$; $C_a(\lambda_i, t)-$ a function that takes into account the criteria for the economic efficiency packet stream transmission systems, taking into account the intensity of the incoming λ_i packet stream when providing i-th multimedia service, described by the following indicators:

$$C_a(\lambda_i, t) = W[C_{ak}(\lambda_i, t),\ K_r(\lambda, t)], i = \overline{1,\ n}, \tag{6}$$

where $K_r(\lambda_i, t)-$ risk function of economic efficiency of hardware and software complexes of the system, taking into account the intensity λ_i packets i-th traffic at a time $t; C_{ak}(\lambda_i, t)-$ a function that takes into account the criteria for the cost communication channels and hardware and software systems, taking into account the intensity packets i-th traffic at a point in time t when providing multimedia services.

Expressions (1)–(6) define the essence of the considered new approach to the creation methods for calculating complex performance indicators multiservice telecommunication networks based on the architectural concepts NGN and FN using technologies such as SDN, NFV, LTE, 5G NR, and and IMS when establishing a connection. In addition, expressions (1)–(6) as a functional dependence, represent the formulation of the general statement problem and describe the behavior methods for calculating the performance of a communication network, taking into account the coefficient self-similarity traffic packet flows.

Considering the above transmission system indicators, technology families and quality issues in NGN and FN networks, we assume that there are three levels: at the user level, the subjective opinion of a person is evaluated, for example, a subjective assessment of the quality of experience of a particular type information, QoE, ITU-T, Y.1541, E.800; quality of service, QoS-ITU-T, Y.1542, E.800 is assessed at the application level; at the network level, the quality of network performance is evaluated, NP (Network Performance), ITU-T, I.350.

At each of the listed levels, with the help (1)-(6), the corresponding indicators for assessing the quality and reliability of communication are determined. At the user level - QoE quality of experience indicators, at the application level - quality of service indicators (QoS - Quality of Service), at the network level - network performance indicators NP - communication network performance.

4 Features Multiservice Telecommunication Networks Based on LTE Technology

Let us consider the features of the functioning multiservice telecommunication networks based on the architectural concepts NGN and FN using LTE technology. The efficiency using this LTE technology strongly depends on the scenario for which it is used and the general conditions in which subscribers are located [7, 9, 10].

Let's consider possible scenarios for using broadcast data transmission technology in LTE networks, taking into account the eMBMS technology (evolved Multimedia Broadcast Multicast Service). Then, based on the considered scenarios, new tasks are formed that need to be solved for the implementation of eMBMS technology. eMBMS is a logical continuation of the MBMS (Multimedia Broadcast/Multicast Service) technology specified in UMTS (Universal Mobile Telecommunications System).

The meaning of this eMBMS technology is to allocate one end-to-end channel to a group of users. For example, if a group 10 subscribers watches the same TV channel, then when using the classical scheme, 10 end-to-end channels will be allocated, and when using eMBMS, only one [9, 11, 13].

One of the important features eMBMS technology is the ability to simultaneously transmit the same data streams in several cells, synchronized in time and using the same carrier frequency. Since the same identical radio resources are used for several simultaneous transmissions, the mobile station perceives it as one transmission. Base stations that transmit data in this way organize a single-frequency multicast network SFN (Single Frequency Network).

The use of broadcast transmission can improve the signal-to-noise ratio $SNR\,(P_c,\ t)$ at the border of cells, which in turn leads to an increase in network throughput $C_{\max}(\lambda_i, H)$. Improved conditions at the edge of the cells allow the use multimedia services and applications that require more bandwidth. For the 4G standard with the introduction of LTE, it is possible to deliver the same content to users of a multi-service network by a broadcast method, which opens up new opportunities for presenting various multimedia services and applications based on wireless data transmission system technology.

The conducted studies have shown [5, 7] that the main disadvantages of the broadcast transmission mechanism in LTE networks include the static allocation radio resources for the needs eMBMS and the lack feedback from users.

One of the criteria for comparing the efficiency dedicated and broadcast transmission is the ratio of the number resource blocks consumed to the amount transmitted unique information:

$$\eta_{LTE}(\lambda_i,\ k_i) = \frac{1}{\sum\limits_{j=t-1}^{T} k_{ij}} \cdot \sum_{j=t-1}^{T} \eta_j(\lambda_i), j = \overline{t-1,\ T}, i = \overline{1\ ,\ n}, \tag{7}$$

where $\eta_j(\lambda_i)-$ the number resource blocks used to transfer to $j-$ th subframe; $T-$ total running time or number subframes transmitted; k_i- number useful bits transferred in j-th subframe [7].

Using some assumptions, expression (7), for the case of a dedicated data transmission, formula (7) can possibly be written as follows:

$$\eta^{u}_{LTE}(\lambda,\ k) = \frac{N_k}{E\,[k_{tj}]} \cdot E\,[\eta_{t,j}(\lambda_i), j = \overline{t-1,\ T}, i = \overline{1\ ,\ n}], \tag{8}$$

where N_k- the number user devices to which data was transmitted via a dedicated channel or the number users; $E\,[\eta_{t,j}(\lambda_i)]-$ average number resource blocks per user in one subframe; $E[k_{t,j}]-$ the average number bits transmitted in one subframe.

From expressions (7) and (8) it can be seen that the choice parameters of the wireless data transmission system and the efficient use channel resources of the LTE technology based on eMBMS contributes to the improvement of the performance characteristics multiservice networks and indicators QoS and QoE traffic.

Based on the proposed calculation method and the described channel resource allocation scheme, the maximum throughput LTE networks was calculated using eMBMS technology: $\Delta F_k = 5,\ ...,\ 20\ MHz$, modulation QAM-16, $N_k = 1$, code speed $R_k \cdot 2^{10} \rightarrow 616$, $C_{\max}(\lambda_i, H) = 3.68,\ ...,\ 14, 7\,Mbps$.

From the numerical calculation result shown above, it follows that up to $N_k \leq 30$ channels through which the maximum throughput LTE networks is significantly increased.

5 Analysis of the Effectiveness Technology Family Mechanism 5G New Radio

Based on the study [1, 2, 5, 9], it was found that the family technologies, united under the general name - new 5G NR radio (5G New Radio), is a standard solution for 5G mobile systems, provides high throughput and low latency on wireless interface in the communication network.

One of the main distinguishing features of the 5G NR radio technology is the addition new radio spectrum ranges ranging from 2,5 to 40 GHz, in the future up to 100 GHz, including the millimeter wavelength range [9, 11, 14].

It is considered that the base station using 5G NR technology has a channel resource volume. Based on the reservation mechanism, it can be assumed that only part of the resource, namely $\eta_k(\lambda_i, k) \cdot F_k$, available for requests to establish a new session. Reserving a share of a resource for accepted sessions, designed to protect them from being dropped, is equal to:

$$R_{sr}(\lambda_i) = 1 - \eta_k(\lambda_i, k), i = \overline{1\ ,\ n}, \tag{9}$$

After the abort signal arrives, the resource occupied with servicing the session is released, and the resource requirement to continue servicing this session is replayed with the same allocation function $F_R(x),\ x > 0$.

Expression (10) determines the share of the public resource 5G NR technology when servicing sessions.

Let us consider a queuing system with signals [10] with a finite number N_k devices and a limited resource F_k. The system serves two types traffic - new and repeated.

To assess the impact of the redundancy mechanism, we introduce two logical pools resources with volumes F_{k0} and F_k. Then the amount of resource available for new and repeated traffic is equal to:

$$F_{k0} = \eta_k(\lambda_i, k) \cdot F_k, F_{k0}, F_k, i = \overline{1,\ n} \tag{10}$$

Taking into account (11), the amount resource available only for repeated traffic with intensity λ_i can be expressed as follows:

$$F_{k0}^{rep} = [1 - \eta_k(\lambda_i, k)] \cdot F_k, i = \overline{1,\ n} \tag{11}$$

It can be seen from expressions (10) and (11) that the system has the amount resources available for new and repeated traffic. In addition, the entire free resource from the total volume of the resource is available to repeated traffic F_k.

It also follows that the traffic received into the system, in addition to the device, occupies a certain random amount of resources in accordance with the distribution function $F_R(x),\ x > 0$. The system receives a Poisson flow of new traffic, which corresponds to the flow requests to establish a new session in the network using 5G NR technology.

It should be noted that the decrease in the resource utilization factor is insignificant for all considered data rates $V_k(\lambda_i,\ H)$. However, it is important to note that at higher speeds, resource utilization increases. The reason for this behavior is as follows: firstly, the improvement is partly due to the higher offered load $\rho(\lambda_i, H)$ secondly, sessions with a higher average speed are characterized by high resource requirements in nLoS (non-Line-of-Sight) conditions.

The latter mechanism means that, due to the reservation, the session for terminal equipment established through the base stations will not be interrupted when the line sight is blocked, but will continue to be serviced through the same base stations.

Considering (1), the critical load factor of a wireless data transmission system using 5G NR technology under nLoS conditions is determined as follows [16]:

$$\rho(\lambda_i, H) = \frac{\lambda_i}{V_k(\lambda_i, H)} \cdot \frac{L_{i.p}}{N_k} \cdot f(H) \leq 1, i = \overline{1,\ n}, \tag{12}$$

where $L_{i.p}-$ packet length $i-$ th traffic; $f(H) = 2H-$ function that takes into account the self-similarity property incoming traffic packets; H – the Hurst coefficient for the traffic flow and is equal to [3]:

$H = 1 - 0,5\beta$ and $0 < \beta < 1$.

Expressions (12) characterize the coefficient of effective use channel and network resources and are an indicator QoS & QoE, as well as a necessary and sufficient condition for the existence stationary mode of the system, taking into account the property self-similar traffic.

6 Conclusions and Recommendation

The important components multiservice telecommunication networks built in accordance with the concept of NGN and FN, taking into account the recommendations ITU-T, Y.1542 and Y.3001, are analyzed and network performance criteria are selected. The paper formulates tasks when choosing performance criteria for communication networks based on common resource management methods.

As a result of the study, a method for calculating the performance indicators multiservice telecommunication networks using promising technologies is proposed. Analytical expressions are obtained to evaluate the indicators channel resources of a communication network in the provision multimedia services.

Based on the study multiservice networks based on the concept of NGN and FN, the results obtained can be used to calculate and analyze the performance both 4G and 5G wireless cellular communication networks using LTE and NR technology.

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