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Analysis of the model hierarchical state management telecommunications systems using the logistic approach

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Abstract. The effectiveness using the architectural concept of the next NGN (Next Generation Network) and future FN (Future Networks) networks for building multiservice telecommunication networks that support a wide range multimedia services and applications is analyzed. In order to analyze the quality of indicators of the functioning multiservice telecommunication networks with the introduction hardware and software systems, a new approach is proposed, on the basis which optimization tasks can be formulated for further research their quality of functioning, taking into account the concept building a communication network for the period up to 2030. The issues application of a new approach to the construction of an analytical model hierarchical control of the states hardware-software complexes multiservice telecommunication networks based on digital technologies are considered. For a qualitative analysis indicators model hierarchical control of the states hardware-software complexes, it becomes necessary to solve the problem of structural-parametric synthesis of the network, the output which is the optimal structure of the network and the optimal vector parameter values and its operation efficiency. Based on the model of the network efficiency management system, analytical expressions are obtained for estimating the throughput and probabilistic and temporal characteristics multiservice communication networks in the provision various services. Statements problems analysis and synthesis multiservice telecommunication networks using the logistic approach also are formulated. The composition components and the structure of the analytical model are discussed.

Keywords: *logistic system; network bandwidth; SDN; performance indicators; IMS; quality of service; NFV; multimedia services; efficiency*

1. INTRODUCTION

Currently, modern multiservice communication networks, as objects scientific research and their models for managing the states hardware and software complexes SDN (Software Defined Networking), NFV (Network Functions Virtualization), and IMS (IP Multimedia Subsystem) technologies, belong to the class complexly organized telecommunication systems [1]. Research and analysis systems of this class is a rather laborious task [1, 2]. At the same time, it should be taken into account that, unlike other types multiservice communication networks, when studying telecommunication systems, the main criterion is not the best quality of service QoS (Quality of Service) and QoE (Quality of Experience), as well as the maximum throughput, which expressed in the requirement to transmit over the network the maximum number messages with a given communication quality [2, 3, 4].

It should be noted that ensuring the high-quality operation all types of multimedia services provided by the modern architectural concepts NGN and FN is no longer possible without the effective use digital technology and the integrated management of the state of its hardware and software systems. In this case, it is necessary to take into account the nature and behavior useful and service flows traffic packets [1, 5, 6]. In this regard, the International Telecommunication Union ITU-T has developed and proposed the concept of hierarchical management of a multiservice communication network, which is based on the ideology TMN (Telecommunications Management Network) and the concept "Network-2030" (Network 2030), carried out by the focus group ITU- T, FG NET-2030 to study the possibilities and principles building fixed communication networks for the period up to 2030 and beyond [7, 8].

Given the above, to study the quality of functioning of a multiservice communication network, developers or designers telecommunication systems, as a rule, need to solve the problem structural-parametric analysis and synthesis of the network, the output of which is the optimal structure of the network and the optimal vector values of the parameters its functioning.

However, when solving such a problem, network developers often rely on their experience and intuition, which, as a rule, does not lead to the best results [1, 6]. More accurate solutions can be obtained if the network developers in the arsenal research tools have tools and innovative technologies that implement such analytical models that allow, by setting the values of the bandwidth requirements for multiservice telecommunication networks and probabilistic-time characteristics, to obtain the best structure at the output communication networks [7, 9, 10, 11, 12].

The proposed new approach can be attributed to such tools as hierarchical network element state management models, SDN, NFV and IMS technologies. Its consideration in relation to solving problems analysis and synthesis multiservice telecommunication networks based on logistics systems is the purpose this article.

2. STATEMENT OF THE PROBLEM AND CREATION OF A NEW APPROACH TO BUILDING A MODEL

When solving problems analysis and synthesis multiservice telecommunication networks, the following model of a multiservice telecommunication network is considered:

$$S(t,\lambda_i) = W[X(\lambda_{i.in},t), G(\lambda_i), Y(t,\lambda_{i.out})] \quad , \quad i=\overline{1,n} \quad , \tag{1}$$

where $Y(t,\lambda_{i.out})] -$ a function that takes into account the external load on the network coming from message sources, taking into account the intensity of the outgoing flows packets $i-$th traffic at a point in time t.

And it is determined by the following indicator as the requirements for the process transmitting and processing streams traffic packets and the probabilistic and temporal characteristics $T_{bbx}(t,\lambda_i)$ of the communication network, restrictions on the available resource $D_R(t,\lambda_i)$, using which the communication system will be synthesized when providing multimedia services, and destructive effects on the hardware and software systems of the network and the impact interference sources $N_m(t)$ on the communication channel by the functional dependence [12]:

$$Y(t,\lambda_{i.out})] = F_{\acute{o}}[\mathrm{T_{bbx}}(t,\lambda_i),\ D_R(t,\lambda_i), N_m(t)] \quad , \ i=\overline{1,n} \quad , \tag{2}$$

In expression (2), network indicators $\mathrm{T_{bbx}}(t,\lambda_i),\ D_R(t,\lambda_i)\ \grave{e}\ N_m(t)$ are important components of the system $Y(t,\lambda_{i.out})$ and represent a set external network parameters that reflect the most significant, from the point view of the management system, aspects of its quality of operation.

The model $X(\lambda_{i.in},t) -$ includes a function that takes into account the internal load on the network coming from the message sources, taking into account the intensity λ_i of the incoming traffic packet $i-$th flows at the moment time t and is determined by the following functional dependence:

$$X(\lambda_{i.in},t) = F_x[\,\mathrm{C}(\mathrm{t},\lambda_\mathrm{i}), G(\lambda_i)] \quad , \ i=\overline{1,n} \quad , \tag{3}$$

where $G(\lambda_i)-$ the physical structure of the multiservice network, taking into account the intensity of the traffic packet $i-$th flows;

$\mathrm{C}(\mathrm{t},\lambda_{\mathrm{i}})-$ throughput (bandwidth) structural elements of the hardware and software complexes of the communication network, taking into account the intensity λ_i of the incoming flows $i-$th traffic packets at the moment time t.

In (3), indicators $\mathrm{C}(\mathrm{t},\lambda_{\mathrm{i}}), G(\lambda_i)$ and $D_R(t,\lambda_i)$ are internal parameters telecommunication systems that are used in the construction highly efficient communication networks using SDN, NFV and IMS technologies.

3. DESCRIPTION AND EVALUATION OF THE NETWORK PERFORMANCE MANAGEMENT SYSTEM MODEL

According to the ITU-T recommendations, the TMN network management system model is built hierarchically and has the following levels [1, 8]:

- network elements; element management and network management;
- service management; administrative management.

Here, in the communication network, all functions related to management are divided into two parts: general and applied.

The description of the network management system model and the formal side building flow control models are as follows. When constructing models of queuing networks that make it possible to investigate the criteria for the effectiveness of global control, the throughput of the data transmission network and the average time of packet delivery to the addressee are considered.

Assume that there are subscribers N in the network exchanging messages with each other in the form packet streams. Message addressing is organized by means of the IMS multimedia platform in switching systems. The switching system receives packet flows with intensity λ_i at random intervals from subscribers N with average time intervals $t_1,t_2,...,\mathrm{t}_\mathrm{N}$.

In IMS switching systems, messages belong to one of the categories k with the probabilities of their occurrence $p(k_1),\mathrm{p}(\mathrm{k}_2),...,\mathrm{p}(\mathrm{k}_\mathrm{N})$ and the computational complexity of processing packet streams of the SDN controller of telecommunication processes and $S_1,\mathrm{S}_2,...,S(N)$ operations, respectively. In the network with the help of NFV, the main, backup and virtual communication channels are organized to transmit streams packets of useful and service traffic at a rate $V_i^N(\lambda_i)$, $i=\overline{1,n}$.

In the IMS platform, switching systems have inputs k and outputs k. In this case, the input buffer $L_{1.bn}(\lambda_{\mathrm{i}})$ has a capacity $L_{1.bn}$ bytes to store messages waiting to be processed. In the switching system, messages are processed by computing hardware-software complexes with the performance of operations $G_{PS}(t,\lambda_i)$ per second.

If the buffer is full $L_{1.bn}(\lambda_{\mathrm{i}})$, incoming messages to the switching system are lost. And it is assumed that one operation computational complexity corresponds to one byte when placing a message in the buffer [5, 6].

Thus, the considered communication system, the operation execution scheme and its algorithms based on the Kendalle-Basharin coding, corresponds to the QS model of the form $G/\mathrm{G}/1$ [8].

Based on the algorithms of operation switching systems, the capacity of the buffer drive, taking into account the data compression $K_{i.c}$ ratio, is expressed as follows:

$$L_{bn}(\lambda_i)=V_i^N(\lambda_i)\cdot T_{i.cd}(\lambda_i)\cdot K_{i.c}\le L_{bn}^{all.}(\lambda_i),\quad K_{i.c}>1,\quad i=\overline{1,n}, \tag{4}$$

where $T_{i.cd}(\lambda_i) -$ the average delay time in the transmission of streams of traffic packets and in general in the form in the path on the "End-to-end" algorithm, the following expression will be valid:

$$T_{i.cd}(\lambda) = \frac{1}{N} \cdot \sum_{i=1}^{N} T_{i.cd}(\lambda_i) \cdot K_{i.c}^{-1} \leq T_{cd}^{all.}(\lambda) \quad , \quad i = \overline{1,n} \tag{5}$$

Based on the model, the obtained analytical expressions (4) and (5) is an indicator QoS and QoE useful and service traffic and determines the probabilistic-temporal characteristics of the studied communication network.

Therefore, the quality of service QoS and QoE traffic is one of the main indicators of the functioning telecommunication network, reflecting the ability of the network to perform its functions.

An analysis of the efficiency problem shows that the model of network aggregation and quality of operation during joint traffic virtualization using NFV is associated with providing the highest throughput value for a given minimum value of the average delay time in the transmission traffic packet streams.

The implementation this task on the basis an analytical model is an integral assessment of the characteristics of the efficiency of a communication network for a continuous process at a given time interval [t_1; t_2], which is written as:

$$H(\lambda) = \int_{t_1}^{t_2} W[C(\lambda, t)]dt, \qquad \lambda = \sum_{i=1}^{n} \lambda_i \quad , \tag{6}$$

where λ - the average rate of the incoming flow of a packet useful and service traffic, $\lambda = f(\lambda_{nm}, \lambda_{sm})$.

Expression (6) is determined by the largest number transmitted streams traffic packets with the minimum average message delay time at a given time interval [t_1; t_2] and is a QoS and QoE quality of indicator for multimedia services and applications.

4. ANALYSIS OF THE QUALITY OF MULTISERVICE NETWORKS

The task of analyzing a multiservice network is to determine its properties, quantitatively expressed using external parameters, based on known internal parameters:

1. For external network load coming from message sources:

$$Y(t, \lambda_{i.out})] = F_Y[\mathrm{C}(\mathrm{t}, \lambda_{\mathrm{i}}), \mathrm{G}(\lambda_{\mathrm{i}}), \mathrm{X}(\mathrm{t}, \lambda_{\mathrm{i.in}})] \quad , \quad i = \overline{1,n} \; . \tag{4}$$

2. For the requirement probabilistic-temporal characteristics to the process packet transmission:

$$T_{BBX}(t, \lambda_i)] = F_T[\mathrm{C}(\mathrm{t}, \lambda_{\mathrm{i}}), \mathrm{G}(\lambda_{\mathrm{i}}), \mathrm{X}(\mathrm{t}, \lambda_{\mathrm{i.in}})] \quad , \quad i = \overline{1,n} \; . \tag{5}$$

3. For destructive effects on the hardware and software systems of the network and the effects interference sources $N_m(t)$ on the communication channel

$$N_m(\lambda_i)] = F_N[\mathrm{C}(\mathrm{t}, \lambda_{\mathrm{i}}), \mathrm{G}(\lambda_{\mathrm{i}}), \mathrm{X}(\mathrm{t}, \lambda_{\mathrm{i.in}})] \quad , \quad i = \overline{1,n} \; . \tag{6}$$

4. To limit the available resource (channel, information and network) using digital technology:

$$D_R(t, \lambda_i)] = F_Y[\mathrm{C}(\mathrm{t}, \lambda_{\mathrm{i}}), \mathrm{G}(\lambda_{\mathrm{i}}), \mathrm{X}(\mathrm{t}, \lambda_{\mathrm{i.in}})] \quad , \quad i = \overline{1,n} \tag{7}$$

Expression (4), (5), (6) and (7) are functional dependencies for analyzing the quality of functioning hardware-software complexes multiservice communication networks, taking into account the intensity of the incoming flows $i-$th traffic packets at time t. In addition, these expressions define the λ_i tasks analyzing a communication network using quantitatively expressed external and internal parameters.

Thus, based on the obtained analytical expressions, it can be judged that multiservice telecommunication networks using SDN, NFV and IMS technologies are characterized by a significant complexity of the processes occurring in them.

5. ANALYSIS PROBABILISTIC-TIME CHARACTERISTICS OF A COMMUNICATION NETWORK

After solving the problem analyzing a communication network, one of the important indicators of the quality of functioning telecommunication systems can be determined - an indicator efficiency. The indicator efficiency $Q_{KF}(t,\lambda)$ of the information direction for routing depends on the external and internal characteristics (i,j) of the communication network. Based on the considered approach, the quality of functioning multiservice telecommunication networks can be determined by the following expression:

$$Q_{KF}(t,\lambda) = \frac{1}{M}\sum_{i,j=1}^{M} Q_{i,j}(t,\lambda), \qquad i \neq j, \; i,j = 1,2,...,M, \tag{8}$$

where $M-$ the number telecommunication processes performed, taking into account the external and internal characteristics of the network in the information direction;

$Q_{i,j}(t,\lambda)-$ indicator of the quality of functioning of the information direction and depends on all parameters of the communication network, taking into account the total intensity of the incoming flow packets of service and useful traffic, which is expressed as follows:

$$\lambda = \sum_{i=1}^{n} \lambda_i(\lambda_{\text{nm}}, \lambda_{cm}), \qquad i = \overline{1,n}, \tag{9}$$

where λ_{nm} и $\lambda_{cm}-$ intensity of the incoming flow packets of service and useful traffic, respectively.

Taking into account expressions (8) and (9), it is possible to use the principle load-weighted additive convolution particular indicators of information directions as the basis for the formation of a network-wide performance indicator.

In this case, based on the proposed approach for describing and determining the quality of network operation, we take into account two important indicators [1, 8, 10, 11, 12]:

●load in the information direction,

$Ó_{i,j}(t,\lambda)$, $i,j = 1,2,...,M$;

● system performance indicator when performing various telecommunication operations,

$$E_{i,j}^{EF}[S(t,\lambda)], \quad i,j = 1,2,...,M,$$

here, $S(t,\lambda)-$ is both generalized and particular indicators of the multiservice network model and can be represented in the following form:

$$S(t,\lambda) = W[\,\mathrm{Y}(\mathrm{t},\lambda_{out}), \mathrm{T}_{\mathrm{bbx}}(t,\lambda), C(t,\lambda), X(t,\lambda_{in.}), N_m(t)], \tag{10}$$

Expressions (10) describe a generalized model of a communication network, taking into account the external and internal parameters of the communication network when performing various telecommunication processes at the time t. In addition, this functional dependence (10) describes the behavior multiservice communication networks and characterizes the dignity this representation of the system.

In addition to the models discussed above, here the TMN mathematical model is presented as a system hierarchical models based on queuing theories. The system of hierarchical models takes into account the criteria for the effectiveness global management of a communication network with the following characteristics:

$$E_{EF}(\lambda_i) = U[\mathrm{C}_{\max}(\lambda_i, N_k), T_{cd}(\lambda_i, N)], \qquad i = \overline{1,n}, \tag{11}$$

where $E_{EF}(\lambda_i)-$ a function that takes into account the criteria for the effectiveness global management of the communication network;

$C_{max}(\lambda_i, N_k) -$ maximum throughput of a multiservice network, taking into account the number communication channels used N_k and λ_i, $i=\overline{1,n}$;

$T_{cd}(\lambda_i, N)$ - the average delivery time packet streams to the N addressee and is found as follows:

$$T_{cd}(\lambda_i, N) = \frac{1}{n}\sum_{i=1}^{n}[T_i^R(\lambda_i) - T_i^S(\lambda_i)], \qquad i=\overline{1,n}, \tag{12}$$

where $T_i^S(\lambda_i) -$ sending time of packet i; $T_i^R(\lambda_i) -$ reception time of packet *i*.

Expressions (11) and (12) characterize the efficiency global communication network management and evaluate the network bandwidth and average packet transmission delay time between two network nodes, as well as QoS and QoE parameters.

As a result, the study proposed a new approach to the construction of an analytical model hierarchical control of the states hardware and software complexes of a communication network, allowing to operate with the structure of the network and the conditions for the quality of functioning of the system, and also provides the construction both generalized and partial indicators on a set external and internal parameters.

On the basis of the model, the analysis and synthesis performance indicators multiservice telecommunication networks were carried out using a logistic approach. Analytical expressions are obtained to determine the throughput and the average time packet delivery to the addressee, taking into account the external and internal parameters of the system.

References

1. Bayram, Ibrahimov &Ali ,Tagiyev & Almaz, Aliyev. *Research and Analysis of the Functioning Quality of Hardware and Software Complexes Automotive Service Systems with Using Logistic Approach. Proceedings International Conference on Problems of Logıstıcs, Management and Operatıon in the East-West Transport Corrıdor (PLMO)*. (27-28 October), 2021. Baku, Azerbaijan. 2021. pp.64- 69.
2. Liu, Y. & Zhang, J. & Ren, A. & Wang, H. & Sim C. TCM-based heptaband antenna with small clearance for metal-rimmed mobile phone applications. *IEEE Antennas and Wireless Propag. Letter*. 2019. Vol.18, No 4. P. 717 - 721.
3. Volkov, D.V. Simulation multiagent modeling of a special purpose communication system. *International Journal of Advanced Studies*. 2017. Vol. 7, No 1–2. P. 31–37.
4. Ibrahimov, B.G. & Hashimov, E.Q. Analysis and selection performance indicators multiservice communication networks based on the concept NGN and FN. *Computer and Information Systems and Technologies, Kharkiv*, 2021. P. 96-98.
5. Wei, L. & Huosheng, H. A hybrid human-machine interface for hands-free control of an intelligent Wheelchair. *International Journal of Mechatronics and Automation*. 2011. Vol.1, No.2. P. 97–111.
6. Ibrahimov, B. G. & İsayev, Y.S. & Aydemir, M.E. Performance of MultiService Telecommunication Systems Using the Architectural Concept of Future Networks. *Journal of Aeronautics and Space Technologies*. 2023. Vol. 16. No.1. pp. 41- 49.
7. Doherty, D.H. & et al. Next generation networks multiservice network design. *Proceedings of the 13-th International Telecommunications Network Strategy and Planning Symposium*. 2008. P. 1–8.
8. Ibrahimov, B.G. & Tagiyev, A.D. *Research of the Performance Multiservice Telecommunication Networks Based on the Architectural Concept NGN and FN. Lecture Notes in Mechanical Engineering*. Editors Numan M. Durakbasa Institute of Production Engineering and Photonic Technologies TU Wien Vienna, Austria. Springer Nature Switzerland AG. 2023. P. 333–341
9. Goransson, P. Ch.Black. *Software Defined Networks: A Comprehensive Approach*. Morgan Kaufmann Pub-lishers, 2014. 352 p.
10. Rodger, E. Ziemer. **&** William H, Tranter. *Communication Systems*. Wiley. 2015. 726 p.

11. Ibrahimov, B.G. & Namazov, M.B. & Quliev, M.N. *Analysis performance indicators network multiservice infrastructure using innovative technologies*. Proceedings of the 7-th International Conference on Control and Optimization with Industrial Applications. 2020. Vol.II. P.176-178.
12. Ibrahimov B.G., Talibov A.M. (2019). *Researches efficiency functioning systems processing's information flows automobile services*. T- Comm, Vol. 13. No 5. P. 56 - 60.