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INVESTIGATION OF THE EFFICIENCY OF NEXT-GENERATION MULTISERVICE TELECOMMUNICATIONS NETWORKS BASED ON THE SDN ARCHITECTURAL CONCEPT

KH.KH. HASHIMOV¹, E.C. MURSHUDOV¹¹Azerbaijan State Oil and Industry University, Baku, Azerbaijan

ARTICLE INFO	ABSTRACT
Article history: Received:2025-08-19 Received in revised form:2025-08-30 Accepted:2025-09-29 Available online:2026-06-30	Abstract: This paper discusses the application of the Software-Defined Networking (SDN) architectural concept in the investigation of the efficiency of Next-Generation Multiservice Telecommunications Networks. The main objective is to analyze approaches that enhance the efficiency of SDN-based multiservice networks. The paper highlights the development of modern telecommunications technologies, network management issues, and the advantages of the SDN concept in addressing these challenges. It is noted that SDN networks, with software-based control and centralized management, ensure more flexible management of network resources. This approach optimizes multiservice network services, improves service quality based on traffic flow, and ensures the efficient use of network resources. The research presents sustainable analytical expressions based on models of SDN networks and their characteristics. The authors emphasize the virtualization of network resources and the provision of various services (such as voice, video, and data transmission) over a single network. These methods aim to improve service quality (QoS), automate network management, and increase productivity. In conclusion, the role of SDN network architecture in modern telecommunications networks enables the implementation of flexible and efficient approaches in providing various services. These approaches also assist network managers in controlling network traffic and optimizing resource utilization more effectively.
Keywords: multiservice; telecommunications; network; virtualization.	
JEL Classification: L96, O33, C63	

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1. INTRODUCTION

The development of modern telecommunications technologies and the increasing volume of information and service traffic transmitted over virtual communication channels require the efficient construction of multiservice communication networks that improve Quality of Service (QoS) and simplify the management of multimedia services through software-configurable network architectural concepts. It should be noted that, with the increasing load on the elements of multiservice networks, the management of telecommunications networks and information resources has become more complex [Roslyakov, A. V., (2015) Ibragimov, B. G., (2018)]. Therefore, the elements of multiservice communication networks are built on the architectural concept of next-generation networks, utilizing packet-switched systems, subscriber, network,

channel, and switching equipment, and using various signaling systems and protocols based on the new International Telecommunication Union (ITU-T) recommendations Y.3000-3499 [Loginov, S. S., (2017) Pshenichnikov, A. P. (2017)] for providing communication services.

The research results show that the architecture of commonly used multiservice communication networks is becoming increasingly complex, as telecommunication service providers are forced to support the standards of next-generation networks and protocols to offer "Triple Play services" [Stepanov, S. N. (2015)]. To address the above-mentioned challenges, a new concept is required for the architecture and operational organization of the elements of multiservice communication networks, which is recognized as the Software-Defined Network (SDN) architectural concept. An SDN network is a network architectural concept for the creation of multiservice communication networks deployed for general use with predefined parameters and program configurations [Islamov, I. J., (2021)].

Thus, the SDN network becomes programmable, using existing resources for specific applications, transforming into a more open network that ensures automatic configuration of multiservice networks according to a specific set of business applications [Islamov, I. J., (2020)]. The SDN-based programmable network allows applications to query and manipulate network services, while also providing them with the network's topology and status. One of the essential aspects of SDN is the efficient use of Network Function Virtualization (NFV), which becomes particularly important in the construction of multiservice communication networks based on next-generation network concepts.

A key feature of the SDN architecture is the separation of the data plane from the control plane through standard protocols for packet transmission. The use of the SDN architectural concept enables the establishment of modern multiservice communication networks, which is essential for creating information-communication environments and multi-operator ecosystems. This, in turn, will meet the communication service demands of public telecommunications networks, corporate and government networks, and public and private users [Islamov, I. J., (2022)].

Considering the above, this paper discusses the issue of investigating and analyzing the efficiency of the elements of multiservice communication networks based on the new SDN architecture. In general, we will review the problem formulation and the mathematical models of SDN network performance efficiency. Research shows that building multiservice communication networks based on the SDN concept is crucial for service providers to offer a wide range of multimedia services. It ensures the efficient use of information and network resources and optimizes their usage in a multi-operator environment. Considering the management of resources in multiservice communication networks based on the SDN architectural concept, the issue of resource productivity distribution and effective utilization will be formulated based on.

In this case, minimizing the average delay time during the transmission of information and service traffic and determining the effective productivity set of Software-Defined Networks (SDNs) is required. Furthermore, under the constraint of limited total productivity, OpenFlow protocols will be used. These constraints refer to the limitations associated with determining the total cost of SDN network equipment.

2. OPERATIONAL SCHEDULING OF ELEMENTS OF MULTISERVICE COMMUNICATION NETWORKS USING SDN SWITCH AND CONTROLLER BASED ON OPENFLOW PROTOCOL

Considering the importance of the interaction between software and hardware tools, terminal, network, and channel equipment, simplified mathematical models are proposed for the study of the elements of multiservice communication networks based on the concept of next-generation networks to address the above-mentioned issue.

The proposed new approach, based on the SDN network architectural concept, is described through mathematical formulas for evaluating the productivity of software and hardware tools in multiservice communication networks. This is represented by the following objective functions:

$$kf = \text{Argmax} \left\{ \prod_{k=1}^n k \right\} \quad (1)$$

Under the following constraints:

$$\eta_k \leq \eta_{k,\text{dop.}}, T_k.\text{cz} \leq T_{k,\text{cz.dop.}} \quad (2)$$

$$C_{k.\text{ap}} \leq C_{k.\text{ap.dop.}}, k = 1, \bar{n} \quad (3)$$

Here, $P_{k.\text{max}}$ represents the productivity of software and hardware tools in multiservice communication networks based on the SDN network architecture, during the transmission of the k -th packet flow, $k = 1, \bar{n}$; $C_{k.\text{ap}}$ is the cost of the equipment and software tools in SDN networks, $k = 1, \bar{n}$; $T_k.\text{cz}$ is the average dwell time of packets of the k -th traffic flow, $k = 1, \bar{n}$; $\eta_k.\text{dop.}$ is the coefficient of effective use of information, network, and channel resources in SDN networks during the transmission of the k -th packet flow.

$C_{k.\text{ap.dop.}}, T_{k.\text{cz.dop.}}, \eta_{k.\text{dop.}}$ are the accepted values for the cost of the equipment and software tools, the average delay time, and the coefficient of effective use of information and network resources in SDN networks, respectively, for the k -th packet flow, during the transmission of user and service traffic, $k = 1, \bar{n}$.

Equations (1) and (2) define the essence of the problem being considered, and based on this, a mathematical model (MM) is proposed to evaluate the performance characteristics of multiservice communication networks using the new network architectural concept (SDN) in the delivery of multimedia services.

Additionally, equations (1) and (2) describe the characteristics that allow for more accurate consideration of telecommunications processes occurring within the elements of next-generation networks using OpenFlow protocols in software and hardware tools (SDN networks).

The operational scheduling of elements in multiservice communication networks is analyzed within the framework of a model based on the SDN (Software-Defined Networks) switch and controllers using the OpenFlow protocol. Based on this model, the SDN network architecture can be used to organize the operations and interactions of network elements to ensure the provision of various services.

SDN network architecture is an approach that ensures the centralization of network management and the software-based control of network elements. This approach enables network operators to manage network resources more flexibly and regulate network services. SDN networks also provide a high level of transparency and flexibility because network elements are managed and programmed through a central controller. This allows for the network structure to be reconfigured and modified at any time.

Another advantage of the SDN model is that it enables the creation of multiple networks that are logically independent of each other and adaptable to different business applications. This supports multiservice network architectures and facilitates the delivery of various services (voice, video, data transmission, etc.) over a single network. Each service has its own packet flow and operates independently without interacting with other services on the network.

Such logical networks also improve the efficiency of business applications, as each application can use network resources according to its specific needs. Providing different services over a single network optimizes the use of network resources and increases the overall efficiency of the system. The SDN architecture not only allows network managers to control the traffic on the network but also enables them to properly assess its impact on network resources.

This approach also simplifies network operations and ensures the centralization of management operations. The SDN controller communicates with network elements to monitor their status and, when necessary, makes adjustments to the network. This helps in the more efficient management of network resources and improves the overall performance of the network.

The core idea of SDN is to separate the network management level (Control plane) from the data transmission level (Forwarding plane). All control logic and functions are moved to a separate device – the controller, which ensures centralized management based on the most optimal decisions for the network. Key benefits of SDN include rapid deployment, the flexible integration of network functions on a single server platform, and the simplicity and systematization of the management process.

According to statistical data, the application of the SDN concept significantly reduces material costs in areas such as service modernization, management, administration, and technical support.

In modern multiservice communication networks, a variety of heterogeneous traffic types are transmitted, and service-specific requirements are defined for each traffic type. Different priority heterogeneous traffic can be conditionally divided into two types:

- Useful traffic – voice, data, and video traffic;
- Service traffic – traffic used for the management and transmission of connections in multimedia services such as "Triple Play Services."

With the expansion of the spectrum of multimedia services and the increasing volume of transmitted useful and service traffic, multiservice communication networks are rapidly developing, new services are being added, and the existing service quality assurance methods often fail to meet their required tasks. Therefore, many incoming packet flows are processed with different priorities without considering network design.

The dynamic routing protocols available in network elements choose routes based solely on the efficient use of channel transmission capacity and the number of packets received. However, telecommunications operators do not take into account the actual load on the multiservice network.

Moreover, when providing multimedia services such as "Triple Play Services," most of the methods and models used for calculating multiservice networks are based on classical approaches, which do not consider the structure and self-similarity characteristics of packet-switched heterogeneous traffic, leading to improper load assessment.

To address this issue, many large operators, providers, and IT organizations are utilizing solutions based on the next-generation network concept to ensure the required Quality of Service (QoS) for useful and service traffic and to reduce the costs of providing multimedia services. A key role in this concept is the creation of a joint info communication infrastructure and multi-operator environment based on the Software-Defined Network (SDN) architectural concept for the establishment of multiservice communication networks for general use.

SDN – the Software-Defined Networking concept – is a set of methods and models that allows each subscriber to directly program, organize, manage, and control network and information resources.

The system-technical analysis of international SDN network standardization shows that these resources and capabilities help ensure the availability of "Triple Play Services" type multimedia services, increase the requirements for network management and transmission mechanisms, and escalate the need for continuous improvement of these networks.

Considering the above, SDN, which enables the dynamic and efficient distribution and management of information and network resources, will set a new standard in the creation of next-generation network systems due to the advantages of the network architectural concept.

Research has shown that the key advantages of SDN networks in creating effective elements for multiservice communication networks for general use are as follows:

1. **Centralized Management:** SDN networks ensure centralized management of information and network resources, facilitating easier and more efficient network operations in multiservice communication networks and multi-operator environments.
2. **Automation and Reduced Complexity:** Automation of service and management processes reduces the complexity of multiservice networks, simplifying the work of network managers and providing more flexible management capabilities.
3. **Increased Transmission and Service Speed:** Increasing the speed of services and data transmission in a multiservice environment ensures higher quality service for users and improves the overall performance of the network.
4. **Reliability and Security:** The reliability and security of networks for general use are enhanced through centralized management and the optimization of network resources offered by the SDN architecture. This minimizes network failures and security threats.
5. **Policy Compliance:** Ensuring compliance with management policies regarding subscriber and network access improves the quality of network services and provides more stable and reliable connectivity for users.

6. Quality of "Triple Play Services": SDN ensures the improvement of quality parameters for various multimedia services (Triple Play Services: voice, video, and internet), thereby delivering higher service quality to users.
7. Guaranteed Quality of Service (QoS): SDN networks enhance the guaranteed Quality of Service (QoS) for both useful and service traffic, as well as engineering traffic, ensuring more efficient use of network resources and high-quality service delivery.
8. Increased Speed of Innovation Implementation: The flexibility and programmability of SDN enable faster implementation of new technologies and innovations, helping network operators remain competitive in the market.
9. Narrow-Scope Network Connection Management: The narrow-scope management of SDN network elements enables more efficient use of network resources and more precise control over services.
10. Improved Quality of Experience (QoE): The services offered by SDN networks enhance the users' Quality of Experience (QoE), increasing their positive experiences and thereby improving customer satisfaction.

In light of the above, it is necessary to explore new solutions for analyzing the indicators of SDN networks—models and research methods for massive service systems reflecting the infrastructure of next-generation multiservice communication networks and describing telecommunication processes.

Now, let us examine an example of a typical segment of SDN networks using a switch and controller operating based on the OpenFlow protocol. Figure 1 presents the operational diagram of an element of multiservice communication networks using an SDN switch and controller operating based on the OpenFlow protocol.

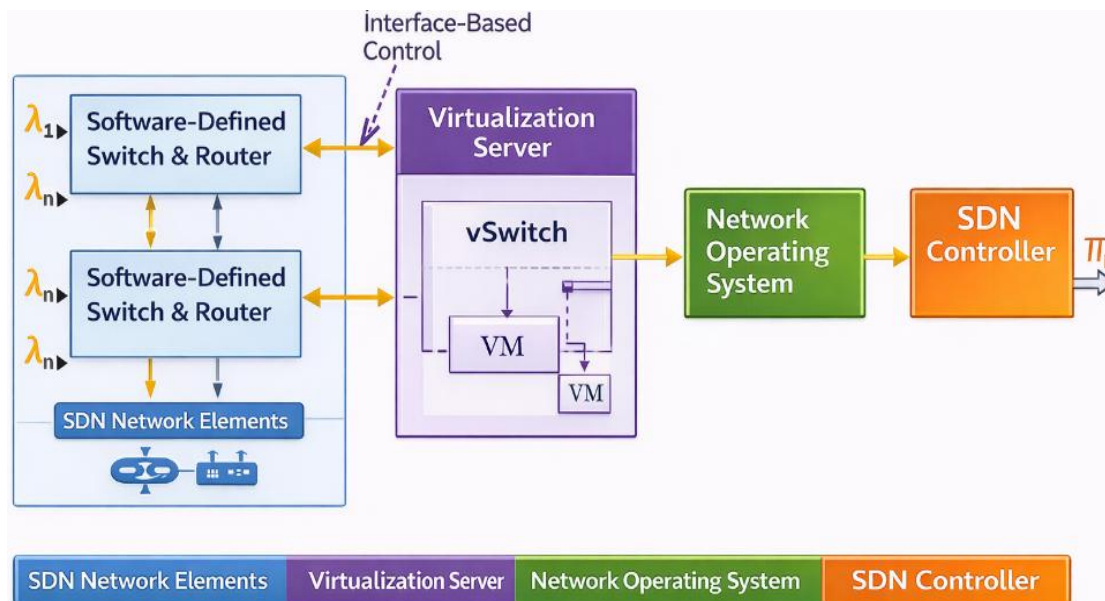


Figure 1. Operational Diagram of Multiservice Communication Networks Using SDN Switch and Controller Based on OpenFlow Protocol

As shown in the figure, the network elements primarily consist of SDN network elements, network function virtualization servers, network operating systems, and the SDN controller.

3. INVESTIGATION AND ANALYSIS OF THE INDICATORS OF MULTISERVICE NETWORK ELEMENTS FOR GENERAL USE BASED ON THE SDN NETWORK CONCEPT

In this section, it is assumed that the traffic flow entering each SDN network switch consists of useful and service data packets with specific headers. The network controller determines the set of forwarding rules corresponding to the incoming header and sends these rules back to the switch. As a result, the packets are queued, and the switch processes the traffic packets with different priorities in sequence.

This approach is designed to optimize the management and transmission of data over the network. In SDN networks, the traffic packets received by switches are routed according to predefined rules, and each packet is processed based on a specific priority. This process allows for the more accurate and efficient management of traffic flows and enables more efficient use of network resources. The quality management of the analyzed indicators and the provision of service quality (QoS) play a significant role in multiservice methods and teletraffic theory models. These methods ensure the optimal distribution of traffic flows for different types of services over the network. For instance, optimal distribution between services with different priorities and useful data helps efficiently manage the network load.

The analytical methods and models are also designed to improve network performance and user experience. These approaches enhance the management of network traffic and the interaction between services, ensuring that SDN networks operate faster and more reliably. As a result, the application of these approaches leads to an increase in network service quality and positive outcomes for service providers.

Research in this field shows that the SDN network architecture increases the flexibility and efficiency of multiservice communication network management, which leads to a more optimized use of network resources, improved service quality, and enhanced overall system performance.

For the communication channel, we accept the speed as C_k in the SDN network element. Therefore, the greatest common divisor (GCD) of these speeds is referred to as the unit of the channel resource, and it is expressed as follows:

$$E = \text{GCD}(v_k, C_k) = \text{GCD}(w(v_1, v_2, \dots, v_n), C_k) \quad (4)$$

From the analysis, it is evident that the communication channel speed of the network element, v_k , defines the channel units, and consequently, the service speed requirement for the k -th packet flow is determined as follows:

$$v_k = \frac{C_k}{\text{GCD}(v_1, v_2, \dots, v_n)}, b_k = \frac{v_k}{E}, k = 1, n \quad (5)$$

Here, b_k is the number of channel resource units required to serve a packet for the k -th traffic flow.

Based on equations (3) and (4), the quality indicators of joint service for useful and service traffic can be determined:

- Considering the probability $p(i)$ that the service system is in the i -th state, the fraction of lost k -th packet flows can be determined as follows:

$$p_{k,n} = \sum_{i=m}^{C_k} p(i), m = C_k - b_k + 1 \quad (6)$$

Where C_k is the operational speed of the SDN network element, expressed in units of channel resources.

It should be noted that the set of states in the SDN network element is finite, and it consists of vectors $i_k = i_1, i_2, \dots, i_n$, where $k = 1, \bar{n}$, and agrees with the following inequality:

$$\sum_{k=1}^n i_k \cdot b_k \leq C_k, k = 1, \bar{n} \quad (7)$$

Expression (7) defines the coefficient of effective use of resources in the SDN network element during the transmission of the k -th packet flow, and it represents the total number of channel resources required to serve all traffic flow packets in the network element.

For the normal operation of the SDN network element, when there is no bounded increase in the queue, expression (7) will be as follows:

$$\eta_{r.} = k = 1n [Ld(Nk \cdot Ck) - 1 \cdot ik] \leq \eta_{r.dop.}, k = 1, \bar{n} \quad (8)$$

Where L_d is the length of the transmitted packet of the traffic flow; N_k is the number of communication channels used for packet transmission in the SDN network element.

The fulfillment of the last condition allows for the determination of the channel resource reserve of the SDN network element:

$$R(N_k) = 1 - \eta_{r.}(N_k), k = 1, \bar{n} \quad (9)$$

Equations (4), ..., (8) determine the productivity indicators of the PKS network element and the quality (QoS) indicators of the joint service of traffic flows using software-controlled switches and controllers.

Additionally, the relationships obtained based on the mathematical model (RM) from equations (5), (6), (7), and (9) allow for a more accurate assessment of the effectiveness of resource use and management in SDN network elements.

- In the system, when the values of $p(i)$ are known, we will determine the average value of the channel resources used to serve the k -th packet flow, which is one of the important indicators of QoS service quality, and it is given by:

$$M[\eta_k] = \rho_k \cdot (1 - p_{k,n}) \cdot b_k, k = 1, \bar{n} \quad (10)$$

Where ρ_k is the intensity of the useful and service traffic load for the k -th packet flow.

For the evaluation and management of channel resources, in equations (2.10) and (2.10), the probability $p(i)$, which plays a special role, is the normalized probability, and its determination is related to the following recurrent relations:

$$p(i) = \frac{1}{i} \cdot k = 1, n \cdot p \cdot b_k(i - b_k) \cdot \rho_k \cdot I[(i - b_k) \geq 0], k = 1, \bar{n} \quad (11)$$

Expression (2.11) characterizes the probability of the service system being in the i -th state. Furthermore, the condition in (10) is also satisfied for non-normalized values.

Thus, based on the derived analytical expressions, the probabilistic-time characteristics of the elements of next-generation multiservice communication networks can be determined.

The productivity indicators of the SDN network element and next-generation network elements, as well as the effective dynamic distribution and management of information and network resources, have been analyzed.

4. CONCLUSION

1. The SDN (Software-Defined Networking) architecture centralizes network management, ensuring more flexible and efficient use of resources. This approach simplifies the operations of telecommunications networks and improves service quality (QoS), thereby providing users with more stable and reliable connections.
2. SDN networks enhance the quality of various multimedia services, such as "Triple Play Services," in multiservice communication networks. The centralized management provided by SDN ensures the optimal use of network resources, leading to improved network performance and service quality.
3. The flexibility and programmability of SDN enable the faster implementation of new technologies. This allows network operators to remain competitive in the market and achieve positive results in their services through the rapid application of innovations.

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