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ANALYTICAL MODEL OF APPLICATION LAYER IN NGN OF MINING INDUSTRY ENTERPRISES

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АНАЛІТИЧНА МОДЕЛЬ РІВНЯ ДОДАТКІВ У NGN ПІДПРИЄМСТВ ГІРНИЧОЇ ПРОМИСЛОВОСТІ

Purpose. Creation of an analytical model of the application layer with a centralized control principle to estimate the quality of control over providing new services, taking into account the self-similarity of the flow of applications for new services in the Next Generation Network (NGN) of mining enterprises.

Methodology. Methods of scientific generalization, statistical analysis, and mathematical modelling are used.

Findings. An analytical application-layer model with a centralized control principle over the control of the provision of new services has been developed, which makes it possible to determine the value of sub-criteria for the quality of control of new services - the total service time for requests for new services by the application layer, the probability of blocking the request, the number of requests waiting for service (average queue length) taking into account self-similarity of the flow of requests for new services, and also considers the cost of the control system. The architecture of the application layer with centralized control principle (ALCCP) in NGN of mining enterprises is considered. The sub-criteria for the quality of control of the provision of new services have been proposed. A complex quality criterion has been formed. An analytical model of the layer of applications with a centralized control principle as a queuing system is proposed. The ways of calculation of quality control indicators for the provision of new services are given, taking into account the self-similarity of the flow of applications for new services.

Originality. An analytical model of the application layer with a centralized principle of controlling the provision of new services, taking into account the self-similarity of the flow of applications for new services has been proposed for the first time.

Practical value. The proposed analytical model will allow the designers of NGN mining enterprises, even at the early stages of the project, to determine more accurately the necessary network resources to ensure the required quality of control of the provision of new services.

Keywords: *NGN, ALCCP, new services, quality control, quality sub-criteria, analytical model, self-similarity of the flow of applications*

Introduction. In modern conditions, due to the rapid development of information and communication technologies at mining enterprises, special attention is paid to ensuring the provision of new services with a specified layer of quality, which are managed at the layer of applications in the NGN of mining enterprises. New services for this field of activity include transmission of test data, telemetry information, information on the state of equipment, including three-dimensional images, providing the possibility of network interaction and environmental control for immediate decision-making, that is, the provision of multimedia services as special requirements. It is thanks to the high quality of the new services, as the specialists of the Canadian company Dundee Precious Metals underline, that the annual capacity of the mine in Bulgaria has quadrupled, from 500,000 to 2 million tons. At the same time, overall savings due to the increased productivity and improved infocommunications amounted to $ 2.5 million, which indicates the importance of improving the quality of new telecommunication services [1].

To date, in NGN mining enterprises, in addition to basic services, a certain set of the so-called new services (NSs) is offered, which is able to provide the next-generation network application layer – NGN. The variety of NSs is growing day by day and, accordingly, the demand for them is growing as well. In today's networks, application layer with centralized control principle (ALCCP) is used to control the provision of the NSs, as well as at NGN mining enterprises. Proceeding from the need to ensure the required quality of the NSs, the task of determining the quality of control of the supply of NSs in conditions of growing demand for them and, accordingly, the load on the layer of applications is certainly topical. The paper suggests an analytical model of the layer of applications in the NGN of mining enterprises, which allows determining the quality of control of the provision of NSs, taking into account the self-similarity of the flow of applications for new services.

Analysis of recent research and unsolved aspects of the problem. The allocation of key sub-criteria for the quality of control of the provision of the NSs, formation of a comprehensive quality criterion and development of an analytical model for the layer of NGN applications is a fairly important direction for the development of NGN mining enterprises.

Similar questions have been dealt with by a number of scientists. The issue of controlling networks, services and estimating the effectiveness of the functioning of control systems is discussed in the works of V. K. Steklov, I. Yu. Kviatkovska [2], L. N. Berkman, B. Ya. Kostik, etc. The calculation of network indicators, taking into account the self-similarity of traffic, is considered in the works of A. I. Shelukhin, A. V. Lemeshko, T. V. Vavenko, D. V. Ageiev [3], M. N. Petrov [4], and others.

However, the issue of the quality of the control of the provision of NSs, taking into account the self-similarity of the traffic in these works has not been practically considered.

Previous studies on the quality of control of NSs provision were carried out taking into account the fact that the time of receipt of requests for NSs is distributed according to an exponential law. This approach leads to inaccuracies in the construction of the analytical model of the ALCCP and the calculation of the sub-criteria of the quality of control. Recent research proves that when constructing analytical models of NGN and its subsystems, it is necessary to take into account the self-similarity of the flow of requests that is received for provision (Hurst coefficient $H > 0.5$). Table 1 [5] shows the values of the Hurst coefficient in a multiservice network, which, undoubtedly, NGN mining enterprises are, according to each day of the week.

Table 2 [5] shows the values of the Hurst coefficient in a multiservice network per day.

Table 1

The Hurst coefficient for traffic per week in a multiservice network

Day of the week	Hurst coefficient
Monday	0.82
Tuesday	0.78
Wednesday	0.75
Thursday	0.84
Friday	0.79
Saturday	0.85
Sunday	0.76
Total traffic for the week	0.79

Table 2

The Hurst coefficient for traffic per day in a multiservice network

Interval hour	Hurst coefficient
02.00–08.00 Low Intensity	0.71
08.00–14.00 Medium Intensity	0.73
14.00–20.00 High Intensity	0.76
20.00–02.00 Maximum intensity	0.81
Daily traffic	0.75

Based on the analysis of these tables, it can be stated that traffic in a multiservice network is a self-similar process. The self-similarity effect manifests itself in a wide range of time – from several hours to several months.

Objectives of the article. The conducted research studies testify to the fact that the very urgent task is studying the principles of constructing ALCCP in the NGN of mining enterprises, to determine the sub-criteria of the quality of control of the provision of the NSs, the formation of a comprehensive quality criterion, the construction of an analytical model of the ALCCP, taking into account the self-similarity of the flow of request for to the NSs.

The principle of ALCCP construction. In modern NGN mining enterprises, ALCCP is used. Let us consider a fragment of a network with such architecture (Fig. 1).

At the application layer that is responsible for controlling the provision of the NSs, there is a part of the Softswitch, which performs the SSF (Service Switching Function) service switching function, and an application server that primarily performs the function of servicing the SCF (Service Control Function) service. It is assumed that there are several geographically dispersed areas. The control of the fragment of the network of each district is performed by Softswitch. It simultaneously manages the transport part of the network and is the switching point of the NSs. Each district has its own data network and signaling network. In Fig. 1 more attention is paid to the signaling network. A certain area network must be connected to a separate Softswitch. In Fig. 1, for convenience, this connection is shown only for one Softswitch.

The NS is provided as follows. The request for the NSs comes from the user. If the user is on the IP network, the packets are sent directly to the corresponding Softswitch. If the user is not in the IP network, then the packets arrive only after the transformations in the media gateway (MG) and in the signaling gateway (SG). Softswitch accesses the server for service (a request is sent to the NSs via the signaling network). The server can only serve one request at a time. If the server is free, then it starts to service the request. Otherwise, it is checked if there is free space in the queue buffer. If there are no available seats, then the request is lost. If there are no free places, then the request is queued and waiting.

The choice of sub-criteria and the formation of a complex criterion. The quality of the control of the provision of the NSs to the ALCCP is determined on the basis of a complex criterion, the sub-criteria of which must be formed and the method for their calculation must be determined.

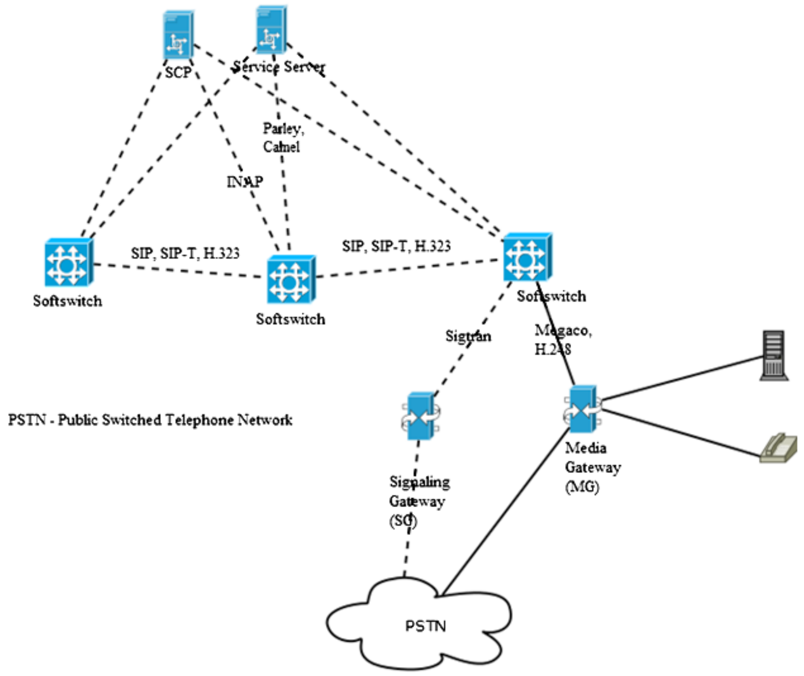

Fig. 1. Architecture NGN with ALCCP

Based on the ITU recommendations [6], as well as the materials in [7], the following sub-criteria for the quality of control of the NSs service are proposed:

1. Total time of request service of the NSs by the layer of applications – $\overline{T}_{tt}$.

2. The probability of blocking a request (the probability of losing a request for NSs when the queue is full) – $\overline{P}_B$.

3. The number of applications waiting to be serviced at the application layer (average queue length) is $\overline{L}$.

4. Cost of the control system ($\overline{C}$). An important indicator that depends on the chosen architecture, the number of installed control devices and their types.

Similar sub-criteria are used for control systems in modern infocommunication networks. However, in this case they have a sense corresponding to the object of application, and corresponding to the calculation method. Note that the first three sub-criteria are technical, the latter is economic. In this paper, a method for calculating technical sub-criteria is shown.

We form the resulting vector criterion from certain sub-criteria K_p.

$$K_p = (\overline{T}_{tt}, \overline{P}_B, \overline{L}, \overline{C}).$$

Working with a vector criterion is rather inconvenient. First of all, inconvenience manifests itself when comparing systems with different organizations. Based on the selected sub-criteria, we aim to achieve the minimum value of K_p. In this case, the control system S' is better or not worse than the system S'' (the systems S' and S'' may differ in the chosen architecture, the number of installed control devices and their type) only if

$$\overline{T_{tt}}' \le \overline{T_{tt}}'' ;$$

$$\overline{P_B}' \le \overline{P_B}'' ;$$

$$\overline{L}' \le \overline{L}'' ; \qquad (1)$$

$$\overline{C}' \le \overline{C}'' .$$

If at least one of the conditions in (1) is not satisfied, then it is impossible to say that one system is certainly worse or better than the other.

To get the quantitative value of the criterion K_p, it is suggested to move on to the complex scalar criterion F_p, for the creation of which we use the additive utility function, which is a weighted sum of sub-criteria, taking into account the weight coefficients of sub-criteria

$$F_p = \sum_{i=1}^{n} K_i \cdot v_i ,$$

where i – is the sub-criterion number; $i = \overline{1,n}$, n is the number of sub-criteria; K_i is the value of the i^{th} sub-criterion; of course, the value of all sub-criteria is provided in a unified system of assessments, for example, in the scoring system; v_i is the weighting coefficient of the i^{th} sub-criterion, $v_i \ge 0$. All weights v_i must match the normalization condition $\sum_{i=1}^{3} v_i = 1$.

To determine the weight coefficients v_i and sub-criteria, it is advisable to use expert estimates of the priority of sub-criteria and determine the priority matrix on the basis of which the system of equations is formed [6]. Solving the system of equations, we find the values of the weight coefficients v_i.

Construction of an analytical model of the ALCCP. For constructing an analytical model of the ALCCP and calculating sub-criteria, it is expedient to use the approaches of the queuing theory. However, the emergence of NGN has led to the fact that the use of classical approaches to the theory of queuing for the calculation of network indicators is problematic enough. First of all, this is due to the identification of the self-similarity of traffic. Using the properties of the simplest flow while constructing analytical models and calculating sub-criteria leads to too "optimistic" results. That is, when forming an analytical model of the ALCCP, it is necessary to take into account the self-similarity of the flow of requests for NSs.

We represent the ALCCP as a queuing system (QS) in the form M/M/1/N.

We shall first assume that a uniform flow of requests arrives at the ALCCP. Then the application layer can be described as the following QS:

1. The system (Fig. 2) contains one serving device (D) and is a single-channel.

2. The flow of requests entering the system is homogeneous. Although there are several classes of requests, but for now we will assume that the λ and μ are identical for them (λ is the intensity of the requests received, μ is intensity of applications service).

3. The length of service of requests in the device is random.

4. The device has places r for requests, pending on service and creating the queue, i.e. within the system there is a storage device with limited capacity $r = N$.

Assumption:

1. The duration of service of requests in the device is exponentially distributed with intensity $\mu = 1/b$, where b is average service durability of applications at the device.

2. Buffering discipline is with losses: a request which come in the system and find storage device filled is lost.

The discipline of service occurs in order of receipt by the rule "first in – first out" (FIFO).

A QS of the form M/M/1/N is classical and quite investigated. However, the results of calculations in the case of determining the quality of control of the provision of new application-layer services without taking into account the self-similarity traffic in the NGN networks of mining enterprises will have a significant error. To account for the self-similarity traffic, we introduce the function $f(H)$, which depends on the self-similarity coefficient H (the Hurst coefficient) and is defined as $f(H) = 2H$ [8]. For $H = 0.5$, the self-similarity property is absent. When H increases from 0.5 to 1, the influence of self-similarity traffic increases.

We calculate the sub-criteria of the ALCCP:

Loading system ρ is

$$\rho = \frac{\alpha \cdot \lambda}{\mu},$$

where α is the share of the serviced traffic.

$$\alpha = \frac{\lambda'}{\lambda}.$$

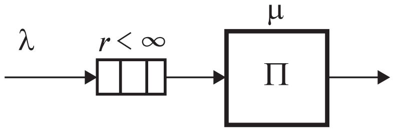

Fig. 2. QS with a storage device of limited capacity

The intensity of the flow of served requests

$$\lambda' = (1 - \overline{P_B}) \cdot \lambda .$$

Average queue length $\overline{L}$

$$\overline{L} = \frac{\frac{\rho}{\pi} f(H)}{1 - \left[\frac{\rho}{\pi} f(H)\right]^{N+2}} \times$$

$$\times \frac{\left\{1 - (N+1)\left[\frac{\rho}{\pi} f(H)\right]^{N} + N\left[\frac{\rho}{\pi} f(H)\right]^{N+1}\right\}}{1 - \frac{\rho}{\pi} f(H)},$$

where π is the probability of no re-request for a new service.

Total service time of request for a new service by application layer is

$$\overline{T_{tt}} = \frac{\overline{L}}{\lambda f(H)} + \frac{1}{\mu} = \frac{\frac{1}{\pi\mu}}{1 - \left[\frac{\rho}{\pi} f(H)\right]^{N+2}} \times$$

$$\times \frac{\left\{1 - (N+1)\left[\frac{\rho}{\pi} f(H)\right]^{N} + N\left[\frac{\rho}{\pi} f(H)\right]^{N+1}\right\}}{1 - \frac{\rho}{\pi} f(H)} + \frac{1}{\mu}.$$

The probability of losing a request for a new service when the queue is full $\overline{P_B}$

$$\overline{P_B} = \frac{1 - \frac{\rho}{\pi} f(H)}{1 - \left[\frac{\rho}{\pi} f(H)\right]^{N+2}} \cdot \left[\frac{\rho}{\pi} f(H)\right]^{N+1}.$$

We will complicate the task and consider the ALCCP, which receives K classes of requests for new services. Then the layer of applications can be described in the form of the following QS (Fig. 3):

1. The system is single-channel.

2. The input flow of requests is not homogeneous: the system receives a limited number of requests of classes K.

3. Storage for requests is with limited capacity $r = N$.

4. Discipline of buffering is without crowding of requests: if a request in any class is received when the storage is full, the request will be lost.

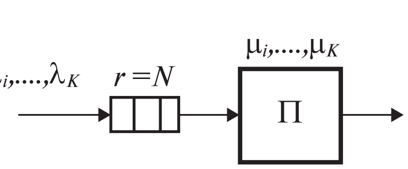

Fig. 3. QS with a storage device of limited capacity and K classes of requests

5. The discipline of service is on the rule "first in – first out" (FIFO) basis.

Assumption:

1. Requests of classes K arriving to the system produce self-similar flows with intensities $\lambda_1,...,\lambda_K$ accordingly.

2. The duration of service for each class of requests is exponentially distributed with intensities $\mu_1 = 1/b_1,...,\mu_K = 1/b_K$, where $b_1,...,b_K$ are the average duration service requests with the relevant class.

There is always a stationary mode in QS, because there cannot be infinite queues.

The analytical model presented by the ALCCP has the following form:

Loading system ρ

$$\rho = \sum_{i=1}^{K} \frac{x_i \cdot \alpha_i \cdot \lambda_i}{\mu_i},$$

where λ_i is the intensity of requests of i-class ($i = \overline{1...K}$); α_i is the part of the served request of the i^{th} class;

$$\alpha_i = \frac{\lambda_i'}{\lambda_i},$$

where λ_i' is the intensity of the flow of the serviced requests of the i^{th} class; x_i is the part of the i^{th} class in the general flow of requests

$$x_i = \frac{\lambda_i}{\lambda},$$

where is $\lambda = \sum_{i=1}^{K} \lambda_i$ the total intensity of all request classes.

Then the average length of the queue $\overline{L}$ is

$$\overline{L} = \frac{\frac{\rho}{\pi} f(H)}{1 - \left[\frac{\rho}{\pi} f(H)\right]^{N+2}} \times \frac{\left\{1 - (N+1)\left[\frac{\rho}{\pi} f(H)\right]^{N} + N\left[\frac{\rho}{\pi} f(H)\right]^{N+1}\right\}}{1 - \frac{\rho}{\pi} f(H)} - \frac{\rho}{\pi} f(H),$$

where π is the probability of no re-request for a new service for all request classes.

Total service time of a request for a new service by application layer T_{tt}

$$\overline{T_{tt}} = \frac{\overline{L} + \frac{\rho}{\pi} f(H)}{f(H) \cdot \sum_{i=1}^{K} x_i \cdot \lambda_i} + \frac{1}{\overline{\mu}} = \frac{\frac{1}{\pi\overline{\mu}}}{1 - \left[\frac{\rho}{\pi} f(H)\right]^{N+2}} \times \frac{\left\{1 - (N+1)\left[\frac{\rho}{\pi} f(H)\right]^{N} + N\left[\frac{\rho}{\pi} f(H)\right]^{N+1}\right\}}{1 - \frac{\rho}{\pi} f(H)} + \frac{1}{\overline{\mu}},$$

where $\overline{\mu}$ is the average value of the intensity of service requests for a new service

$$\overline{\mu} = \sum_{i=1}^{K} \frac{\sigma_i \mu_i}{K},$$

where σ_i is the part of the served requests of the i^{th} class

$$\sigma_i = \frac{\lambda_i'}{\lambda'}.$$

The probability of losing the request for a new service when the queue is full $\overline{P_B}$

$$\overline{P_B} = \frac{1 - \frac{\rho}{\pi} f(H)}{1 - \left[\frac{\rho}{\pi} f(H)\right]^{N+2}} \cdot \left[\frac{\rho}{\pi} f(H)\right]^{N+1}.$$

Conclusions and recommendations for further research. In work the principle of construction of ALCCP, at modern NGN enterprises of the mining industry is considered. Based on the existing ITU standards, subcriteria for the quality of control of providing new services were proposed, as well as a comprehensive quality criterion. The analytical model of ALCCP for calculating the sub-criteria for the quality of control of providing new services, taking into account the self-similarity of the flow of requests, is proposed. Analytical models will allow mining company NGN designers to determine more accurately the necessary network resources at the early stages of the project to ensure the required quality of control. Further development can be the study of the applications layer of NGN with a decentralized control principle and the construction of its analytical model, taking into account the self-similarity of the flow of requests for new services.

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Мета. Створення аналітичної моделі рівня додатків із централізованим принципом управління для оцінки якості управління наданням нових сервісів з урахуванням самоподібності потоку заявок на нові сервіси в мережах наступного покоління (NGN – Next Generatin Network) підприємств гірничої промисловості.

Методика. Використовували методи наукового узагальнення, статистичного аналізу, математичного моделювання.

Результати. Розроблена аналітична модель рівня додатків із централізованим принципом управління наданням нових сервісів, що дає можливість визначити значення підкритеріїв якості управління новими сервісами – загального часу обслуговування заявки на нові сервіси рівнем додатків, ймовірності блокування заявки, кількості заявок, що очікують на обслуговування (середню довжину черги) з урахуванням самоподібності потоку заявок на нові сервіси, а також ураховує вартість системи управління. Розглянута архітектура рівня додатків із централізованим принципом управління (РДЦПУ) у NGN підприємств гірничої промисловості. Запропоновані підкритерії якості управління наданням нових сервісів. Сформовано комплексний критерій якості. Запропонована аналітична модель рівня додатків із централізованим принципом управління як система масового обслуговування. Наведені способи розрахунку показників якості управління наданням нових сервісів з урахуванням самоподібності потоку заявок на нові сервіси.

Наукова новизна. Уперше запропонована аналітична модель рівня додатків із централізованим принципом управління наданням нових сервісів з урахуванням самоподібності потоку заявок на нові сервіси.

Практична значимість. Запропонована аналітична модель дозволить проектувальникам NGN підприємств гірничої промисловості ще на ранніх етапах проекту більш точно визначати потрібні мережні ресурси для забезпечення необхідного значення якості управління наданням нових сервісів.

Ключові слова: *NGN, РДЦПУ, нові сервіси, якість управління, підкритерії якості, аналітична модель, самоподібність потоку заявок*

Цель. Создание аналитической модели уровня приложений с централизованным принципом управления для оценки качества управления предоставлением новых сервисов с учетом самоподобия потока заявок на новые сервисы в сетях следующего поколения (NGN – Next Generatin Network) предприятий горной промышленности.

Методика. Использованы методы научного обобщения, статистического анализа, математического моделирования.

Результаты. Разработана аналитическая модель уровня приложений с централизованным принципом управления предоставлением новых сервисов, которая дает возможность определить значение подкритериев качества управления новыми сервисами – общего времени обслуживания заявки на новые сервисы уровнем приложений, вероятности блокировки заявки, количества заявок, ожидающих обслуживания (среднюю длину очереди) с учетом самоподобия потока заявок на новые сервисы, а также учитывает стоимость системы управления. Рассмотрена архитектура уровня приложений с централизованным принципом управления (УПЦПУ) в NGN предприятий горной промышленности. Предложены подкритерии качества управления предоставлением новых сервисов. Сформирован комплексный критерий качества. Предложена аналитическая модель уровня приложений с централизованным принципом управления как система массового обслуживания. Приведены способы расчета показателей качества управления предоставлением новых сервисов с учетом самоподобия потока заявок на новые сервисы.

Научная новизна. Впервые предложена аналитическая модель уровня приложений с централизованным принципом управления предоставлением новых сервисов с учетом самоподобия потока заявок на новые сервисы.

Практическая значимость. Предложенная аналитическая модель позволит проектировщикам NGN предприятий горной промышленности еще на ранних этапах проекта более точно определить необходимые сетевые ресурсы для обеспечения требуемого значения качества управления предоставлением новых сервисов.

Ключевые слова: *NGN, УПЦПУ, новые сервисы, качество управления, подкритерии качества, аналитическая модель, самоподобие потока заявок*

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