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QUALITY CONTROL OF MULTIMEDIA SERVICES IN MINING ENTERPRISES' CORPORATE NETWORKS

Purpose. Improvement of the multimedia service quality control method for mining enterprises` corporate networks with Multiprotocol Label Switching (MPLS) technology.

Methodology. Improvement of the multimedia service quality control method in MPLS is carried out by applying algorithmic modeling methods and elements of the operational research methods.

Findings. Quality of Services (QoS) control method in MPLS was improved. It is able to configure quality indicators by changing the policy for handling packets of a given type. The method can also change service class by rewriting the Differentiated Services Code Point (DSCP) in the packet header within the acceptable service classes. Multimedia service quality control procedure in MPLS has been developed using an improved method.

Originality. The improved method of multimedia service quality control in MPLS, unlike known ones, allows configuring values of quality indicators within the acceptable service classes depending on QoS requirements for packets of a certain type. It also allows the service providers to predict the necessity of network development.

Practical value. According to the calculation results, application of the improved method of multimedia service quality control in MPLS provides the QoS increase by more than 3 % even in case of changing only two quality indicators out of 22.

Keywords: *corporate networks, mining enterprises, quality of multimedia services, multiprotocol label switching*

Introduction. Because of the rapid development of infocommunication technologies the requirements to the quality of services are increasing. This task is especially important in the industries, where it is necessary to carry out constant monitoring and control of technological processes in real time. Particularly, at mining enterprises it is necessary to ensure the transmission with a given quality level of the test data, telemetric information from autonomous mobile robots, information on the state of equipment, including three-dimensional images, provide the network interaction and environmental control for immediate decision-making [1]. Therefore, during geological exploration and mining, there is an urgent need for the multimedia information transmission, that is, for the provision of multimedia services, which quality meets special requirements.

Analysis of the recent research and publications. At present, there is an active development of infocommunication systems used at mining enterprises. In particular, due to Cisco technologies, Canadian company Dundee Precious Metals (DPM) quadrupled the productivity of the mine in Bulgaria [2]. Thanks to the 50-kilometer-long underground wireless Cisco network, miners and DPM managers can maintain constant communication through instant messages and voice calls. This, in turn, allows for taking the necessary measures immediately. If any problem arises, the use of multimedia services enables to solve it quickly, which is especially important given the remoteness of production facilities, the remoteness of experts-geologists, metallurgists, equipment specialists.

It is thanks to the high quality of multimedia services, as noted by DPM specialists, that the annual production of the mine in Bulgaria increased fourfold, from 500 thousand to 2 million tons. At the same time, overall savings due to increased productivity and telecommunication service improvement amounted to $2.5 million, which indicates the importance of the telecommunication service quality improvement.

Another option for communication provision is satellite communication. For example, the combination of broadband access services and satellite voice communications offered by Inmarsat provides a connection for voice and data transmission, immediately providing the opportunity to quickly organize a construction site, real-time transfer of test data for continuous equipment operation control, solutions for providing protection through hidden video surveillance, environment monitoring and the possibility of a network staff interaction [3].

Unsolved aspects of the problem. Despite extensive research into the issues of providing communication with remote geological exploration sites, the issue of providing multimedia services with the highest quality level in the mining enterprises' corporate networks remains beyond the research scope.

Objectives of the article. The aim of the work is to improve the multimedia service quality control method for mining enterprises` corporate networks, with the ability to determine whether the given segment of the network meets the level required to provide a certain quality of the multimedia service and the ability to generate recommendations on the need of the appropriate changes to ensure the required service quality.

Presentation of the main research. MPLS Virtual Private Network (VPN) technology is widely used in corporate networks, because the application of this technology allows the operator to unite client networks and form a single network isolated from the other customers' networks. For service providers MPLS-VPN technology is the ability to economically support scalable VPN services in IP network. Traffic engineering, service quality, and MPLS connectionless features allow the service providers to grow their VPN infrastructure without sacrificing performance. In MPLS technology the core network devices transmit packets only by labels and do not analyze the headers of IP packets. Fig. 1 shows the structure of MPLS header. It contains one or more labels. This is called a label stack. Each entry in the label stack contains four fields:

- a 20-bit *label value*. A label with the value of 1 represents the router alert label;
- a 3-bit Traffic Class field for QoS (quality of service) priority and ECN (Explicit Congestion Notification). Prior to 2009 this field was called *EXP*;
- a 1-bit bottom of stack flag (*S*). If this is set, it signifies that the current label is the last in the stack;
- an 8-bit *TTL* (life time) field [4, 5].

In order to improve the method of multimedia service quality control in MPLS, it is proposed to use the four market model, recommended by the International Telecommunication Union for assessing the quality of complex multimedia services from the point of view of control of multimedia services, since this model takes into account separation between the transport layer and the service level.

There is a complex chain of actions for multimedia services, from content creation, service provision, service transport and customer equipment. Different parties may be in charge of transport, provision and content and the supply of terminal equipment. Thus, the overall quality of a service (as perceived by the user) is a combination of different elements that are working independently of each other.

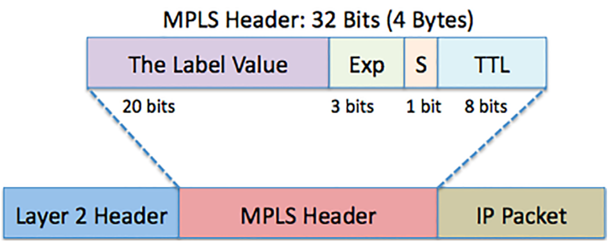

Fig. 1. MPLS header

Four-market model consists of four components that are used to describe the different elements of the services that contribute to the QoS:

1. Customer's equipment: All kinds of equipment that is needed by the user to gain access to the network and, thus, to the service. This equipment consists of personal computers, television sets, set-top boxes, video recorders, modems, multimedia kiosks, etc. Not only the hardware but also the software needed for correct operation of the equipment has to be taken into account.

2. Service transport: All kinds of telecommunication networks that are used for the distribution of telecommunication services like terrestrial (fixed and wireless) and satellite broadcast networks.

3. Service provision: All activities and functions related to the packaging, presentation and management of telecommunication services.

4. Content creation: All activities related to the generation, distribution and packaging of content that is offered via a telecommunication service.

The model enables to identify and categorize more easily the QoS criteria that are pertinent to this type of services [6].

The improved multimedia service quality control method is to perform the following actions:

- correction of quality indicator values within the quality class of this service, if there is such an opportunity;
- change in the quality class for this service.

It is possible to change the header of the packet:

1. At the second level of the OSI model (Open Systems Interconnection – the model of interaction of open systems): the policy of servicing packets in the MPLS network changes – the parameters for servicing packets of a certain class within the MPLS network change. It is checked whether it is possible to increase the value of the indicator within the current service quality class.

2. At the third level of the OSI model: the DSCP class changes.

Previously it is necessary to implement the network settings, which includes several steps.

Criteria for selecting packages by class:

class-map match-all CLASS
match access-group
match input-interface
match protocol
match ip dscp
match ip rtp
match mpls experimental.

Class definition:

class CLASS !—class name;
bandwidth BANDWIDTH !--
bandwidth percent BANDWIDTH_PERCENT
queue-limit QUEUE-LIMIT
random-detect.

Notation:

BANDWIDTH – minimum bandwith in *kbitps*, the value regardless of bandwidth on the interface;

BANDWIDTH_PERCENT – the percentage of bandwidth on the interface;

QUEUE-LIMIT – the maximum number of packets in a queue;

random-detect – use of *WRED*.

Tuning algorithm.

1. Distribution of packages by classes – *class-map*:

access-list 101 permit ip any any precedence critical

class-map match-all Class1

match access-group 101.

2. Description of the rules for each class – p*olicy-map*:

policy-map Policy1

class Class1

bandwidth 100

queue-limit 20

class class-default

bandwidth 50

random-detect.

3. Running the specified policy on the interface – *service-policy*:

interface FastEthernet0/0

bandwidth 256

service-policy output Policy1.

4. View results:

 # sh class Class1

 # sh policy Policy1

 # sh policy interface FastEthernet0/0.

Fig. 2 shows the procedure for implementing the improved quality control method for MPLS.

Let us consider each of the steps in more detail.

Step 1. At the first step of the procedure, the current QoS level is checked. Based on the QoS estimation method, the value of Z – a complex QoS assessment, formed on the basis of the four-market model – is calculated [7]. Further, the obtained QoS value Z is compared with the reference value Z_{ref}. If the condition of step 1 is fulfilled – go to the end of the procedure, otherwise – go to step 2.

Step 2. If $Z < Z_{ref}$ the quality indicators that require correction should be determined. Then system checks whether it is possible to change the quality indicator values within the current service class. In this case, the indicator values limits within the service classes are determined based on the service type (Tables 1, 2) [8].

If it is possible to change the indicator values within the current class – go to step 3, otherwise – go to step 4.

Step 3. In the third step, changing the indicator values within a certain service class is realized by changing the network configuration parameters (*policy-map*).

The total network bandwidth is divided into classes. The bandwidth allocated to each class can be defined as the absolute value (bandwidth in kilobit per second) or in percentage (bandwidth percent) relative to the set value on the interface. As a result of changing the *policy-map*, the policy of servicing packets of this type will change (you can increase the bandwidth, increase the packets priority in the queue, etc.).

The decision is made in accordance with the list of classes shown in Table 3 [8].

Go to step 1.

Step 4. If the limit of the quality indicator value within the current class is reached, in the fourth step it is checked whether it is possible to change the service class (changing the DSCP code) for packets of the current type. The decision is made in accordance with the list of classes defined by the Internet Engineering Task Force (IETF). If a service class change is possible, go to step 5, otherwise go to step 6.

Step 5. At this step the current type packets servicing class changes. During this the recommendations of international telecommunication standardization organizations are taken into account. When you change the DSCP class, the field in the packet header changes. The DS0-DS5 bits define the class selector. On the basis of DSCP IETF a policy of "per Hop Behavior" (PHB) has been developed [8]. This policy defines DSCP codes within classes.

To change the DSCP code network administrator should run on the router the following commands:

Policy-map Policy Map ! – Creates a policy map.

Class Class ! – Indicates the created policy to systemize traffic using class control.

Set ip dscp DSCP ! – Sets the DSCP value in a binary, decimal or alphabetic system (PHB is determined depending on the DSCP value). Go to step 1.

Step 6. Go to this step in case it is not possible to increase the indicator values within the current service class, as well as to change the service class. Thus, in step 6, a message that it is not possible to increase QoS in the existing network is generated. Therefore, there is a need for network development. Go to the end of the procedure.

Let us consider an example of the quality indicator correction in an MPLS network built using Cisco routers. Table 4 shows the initial data.

Here the current and reference absolute values of the indicators are put in line with the ones in scores (in the 5-point system). Absolute values of quality indicators are determined based on ITU-T recommendations on the quality of services provided.

In this example for the considered "video streaming and download service" service the following requirements are defined:

- bandwidth: 5 kbps – 1 Mbps;
- network delay: 1–3 s.

Based on these data, we represent the absolute values of the corresponding scores (Table 5).

Packet classification implies the use of a traffic descriptor to categorize any packets within a certain group and create a packet that is available for processing in the network by the QoS service. Using packet classification, you can divide network traffic into several priority levels or service classes [9].

In the considered example the following service class was defined for the "video streaming and download service":

Policy-map pack-multimedia-video! – Creates a policy scheme called "pack-multimedia-video".

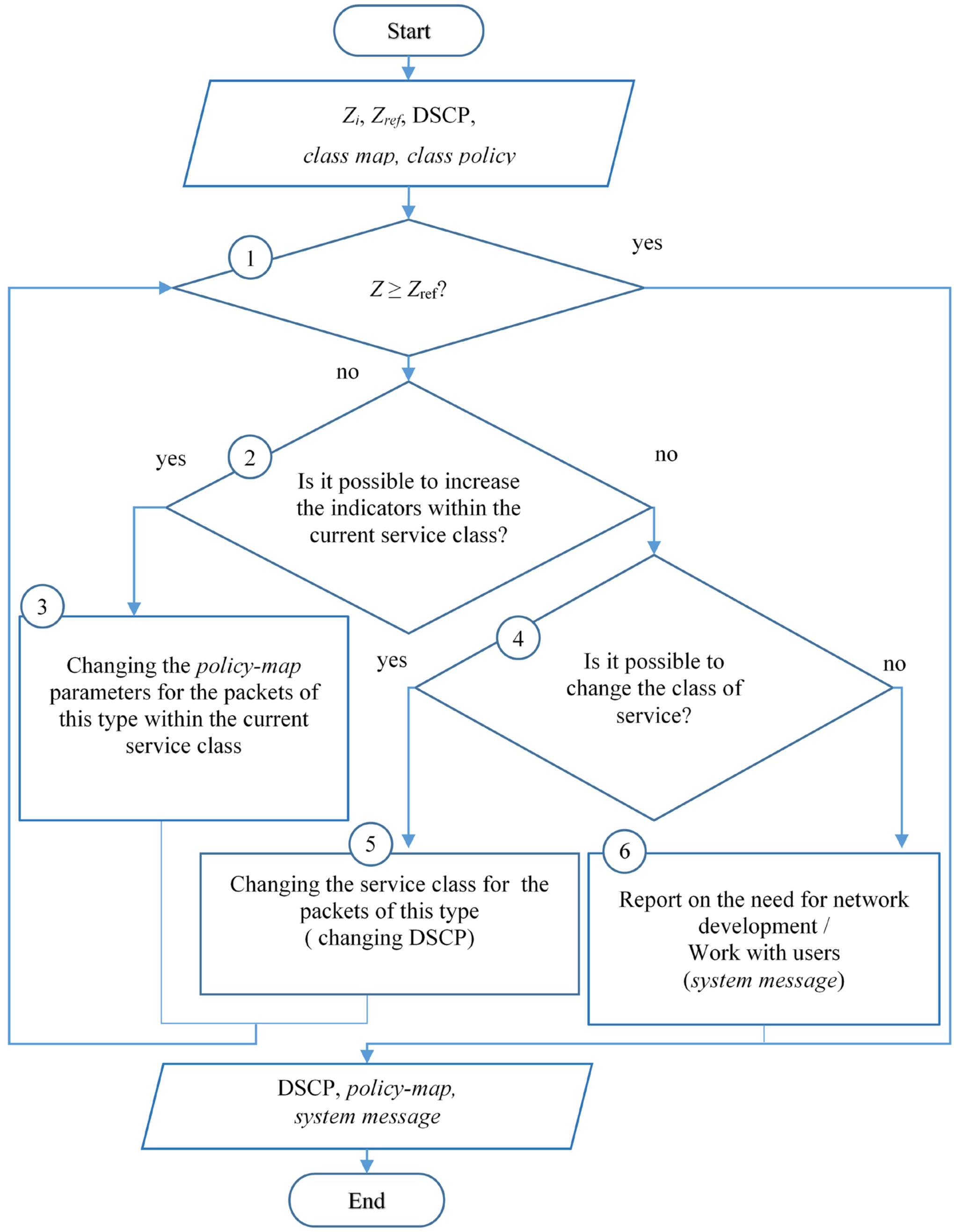

Fig. 2. The procedure of implementing the improved quality control method for MPLS

Table 1

QoS classes and related performance objectives for packet-based networks (ITU-T Rec. Y.1545)

Network performance parameter	QoS Class					
	0	1	2	3	4	5
IP transfer delay (IPTD)	$\leq$ 100 ms	$\leq$ 400 ms	$\leq$ 100 ms	$\leq$ 400 ms	$\leq$ 1 c	*U*
IP delay variation, sometimes referred as jitter (IPDV)	$\leq$ 50 ms	$\leq$ 50 ms	*U*	*U*	*U*	*U*
IP packet loss ratio (IPLR)	$1 * 10^{-3}$					*U*
IP packet error ratio (IPER)	$1 * 10^{-4}$					*U*
NOTE – U means “unspecified” or “unbounded”						

Table 2

The requirements of different applications to the indicators of data loss, bandwidth and delay

Application	Data loss	Bandwidth	Delay Sensitive
File transfer	no loss	elastic	no
E-mail	no loss	elastic	no
Web	no loss	elastic	yes, few secs
Real-time audio/video (VoIP/video telephony)	loss-tolerant	audio: 5kbps-1 Mbps video:10kbps-5Mbps	yes, <150 msec
Stored audio/video	loss-tolerant	same as above	yes, few secs
Online games	loss-tolerant	few kbps up	yes, <100 msec
Instant messaging	no loss	elastic	yes, few secs

Table 3

Relation between DSCP and IP Precedence

DSCP Name	DS Field Value		IP Precedence
	Binary	Decimal	
CS0	000 000	0	0
CS1	001 000	8	1
AF11	001 010	10	1
AF12	001 100	12	1
AF13	001 110	14	1
CS2	010 000	16	2
AF21	010 010	18	2
AF22	010 100	20	2
AF23	010 110	22	2
CS3	011 000	24	3
AF31	011 010	26	3
AF32	011 100	28	3
AF33	011 110	30	3
CS4	100 000	32	4
AF41	100 010	34	4
AF42	100 100	36	4
AF43	100 110	38	4
CS5	101 000	40	5
EF	101 110	46	5
CS6	110 000	48	6
CS7	111 000	56	7

Class control ! – Specifies the policy to be organized for traffic ordering using class control.

Bandwidth 796 ! – sets the bandwidth = 796 kbps.

Set ip dscp 34 ! – Sets the DSCP value for packets equal to 34.

This changes the DSCP field value in the packet header. Instead of the CS4 service class

1	0	0	0	0	0	ECN	ECN

a value relevant to the AF41 service quality class is set (Fig. 3)

1	0	0	0	1	0	ECN	ECN

Fig. 4 shows how the packet header changes.

Table 4

Quality indicators of the "Service transport" component, requiring correction

Quality indicators	Current value		Reference value	
	Points	Absolute value	Points	Absolute value
bandwidth	3.0	597 kbps	4.0	796 kbps
network delay	3.0	1800 msecs	3.9	1260 msecs

Table 5

Correspondence of scores and absolute values of Indicators

Indicator values, points	Bandwidth, kbps	Network delay, msecs
1	5	3000.00
2	398	2400.00
3	597	1800.00
4	796	1200.00
5	1000	1000.00

QoS value changes are calculated using a hierarchical neuro-fuzzy system (Fig. 5), where during the learning process the weight characteristics of quality indicators and components are determined [7].

We introduce the following notations: x_{ij} stands for indicators affecting the quality component Y_i; w_{ij} is significance, "weight" of indicator x_{ij}; w_i is significance, "weight" of the component Y_i; k is the number of quality components; $q(i)$ is the number of indicators that affect the quality component Y_i. The complex QoS assessment is as follows

$$Z = F(Y); \tag{1}$$

$$Y = f\{Y_i, w_i\}, \quad i = \overline{1,k}; \tag{2}$$

$$Y_i = \varphi(x_{ij}, w_{ij}), \quad j = \overline{1,q(i)}. \tag{3}$$

In hierarchical systems the output of one knowledge base is fed to the input of another knowledge base. The first level of the hierarchy determines the value that each

DSCP Name	DS Field Value		IP Precedence
	Binary	Decimal	
CS4	100 000	32	4

DSCP Name	DS Field Value		IP Precedence
	Binary	Decimal	
AF41	100 010	34	4

Fig. 3. DSCP changing

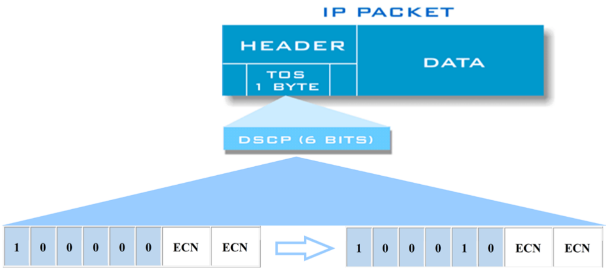

Fig. 4. DSCP changes in the packet header

of the service quality components (Y_1, Y_2,..., Y_k) has reached, depending on the quality indicators (x_{11}, x_{12}, ..., x_{kq}). At the second hierarchy level, the final indicator Z is determined. Results are given in Table 6.

Thus, the application of the improved multimedia service quality control method allowed increasing QoS from $Z = 3.93$ to $Z = 4.06$, or by 3.2 %.

Conclusions. The improved multimedia service quality control method for mining enterprises` corporate networks with MPLS technology corrects the values of quality indicators depending on the requirements for a certain type of transmitted information, and it is possible to correct both the packet service policy within the MPLS network, and the DSCP code in the packet header.

Thus, the proposed method provides the transmission of various information types (voice, video, images, data) through the corporate network of the mining enterprise with a high QoS level, which in turn enhances the quality of information exchange within the corporate networks of mining enterprises. The development of the proposed method is possible by extending the range of the services in question.

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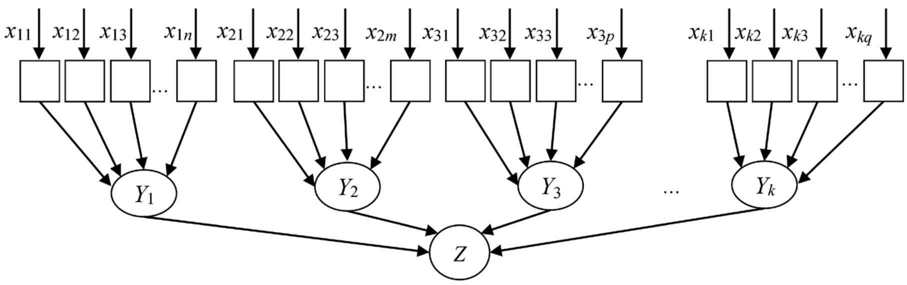

Fig. 5. A hierarchical structure of the neuro fuzzy QoS evaluation system

Table 6

The results of the Y_2 – "Service Transport" – quality component correction

Iteration number	Quality indicators	Quality indicator value before correction, points	Quality indicator value after correction, points	Quality component value before correction, points	Quality component value after correction, points	Complex QoS assessment before correction, points	Complex QoS assessment after correction, points
1	bandwith	3.0 (597 kbps)	4.0 (796 kbps)	3.49	3.67	3.93	3.98
2	network delay	3.0 (1800 msecs)	3.9 (1260 msecs)	3.67	3.97	3.98	4.06

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Управління якістю мультимедійних сервісів у корпоративних мережах підприємств гірничої промисловості

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Мета. Удосконалення методу управління якістю мультимедійних сервісів для корпоративних мереж з технологією мультипротокольної комутації за мітками (multiprotocol label switching, MPLS) підприємств гірничої промисловості.

Методика. Удосконалення методу управління якістю мультимедійних сервісів у MPLS здійснено шляхом застосування методів алгоритмічного моделювання та елементів методів дослідження операцій.

Результати. Удосконалено метод управління якістю мультимедійних сервісів (Quality of service, QoS) у MPLS, що здатний робити настроювання значень показників якості шляхом зміни політики обробки пакетів заданого типу. Також метод може змінювати клас обслуговування сервісу, переписуючи код диференційованих послуг (Differentiated Services Code Point, DSCP) у заголовку пакета в межах допустимих класів обслуговування. Розроблена процедура управління якістю мультимедійних сервісів у MPLS з використанням удосконаленого методу.

Наукова новизна. Удосконалений метод управління якістю мультимедійних сервісів у MPLS, на відміну від відомих, дозволяє налаштовувати значення показників якості в межах допустимих класів обслуговування в залежності від вимог до QoS для пакетів певного типу, а також прогнозувати необхідний розвиток мережі.

Практична значимість. Результати розрахунків показали, що застосування вдосконаленого методу управління якістю мультимедійних сервісів у MPLS навіть при впливі тільки на два показника якості з 22 забезпечує підвищення значення QoS більш ніж на 3 %.

Ключові слова: *корпоративні мережі, підприємства гірничої промисловості, якість мультимедійних сервісів, багатопротокольна комутація за мітками*

Управление качеством мультимедийных сервисов в корпоративных сетях предприятий горной промышленности

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Цель. Усовершенствование метода управления качеством мультимедийных сервисов для корпоративных сетей с технологией мультипротокольной коммутации по меткам (multiprotocol label switching, MPLS) предприятий горной промышленности.

Методика. Усовершенствование метода управления качеством мультимедийных сервисов в MPLS осуществлено путем применения методов алгоритмического моделирования и элементов методов исследования операций.

Результаты. Усовершенствован метод управления качеством мультимедийных сервисов (Quality of service, QoS) в MPLS, который способен производить настройку значений показателей качества путем изменения политики обработки пакетов заданного типа. Также метод может изменять класс обслуживания сервиса, переписывая код дифференцированных услуг (Differentiated Services Code Point, DSCP) в заголовке пакета в пределах допустимых классов обслуживания. Разработана процедура управления качеством мультимедийных сервисов в MPLS с использованием усовершенствованного метода.

Научная новизна. Усовершенствованный метод управления качеством мультимедийных сервисов в MPLS, в отличие от известных, позволяет настраивать значения показателей качества в пределах допустимых классов обслуживания в зависимости от требований к QoS для пакетов определенного типа, а также прогнозировать необходимое развитие сети.

Практическая значимость. Результаты расчетов показали, что применение усовершенствованного метода управления качеством мультимедийных сервисов в MPLS даже при воздействии только на два показателя качества из 22 обеспечивает повышение значения QoS более чем на 3 %.

Ключевые слова: *корпоративные сети, предприятия горной промышленности, качество мультимедийных сервисов, многопротокольная коммутация по меткам*

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