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Monitoring the Quality of Heterogeneous MAN Performance

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Introduction

Networks of different operators are spread geographically over the whole city or over several administrative districts of a larger city very often. These networks are classified as Metropolitan Area Networks (MAN). It has to be noted that MAN operators provide various services, e.g. cable TV, Internet, fixed line and mobile link.

The service quality depends on networks performance. Standardization organizations such as ITU-T have defined the performance management functions to evaluate and report upon the behaviour of network equipment and the performance of the network or network element. Its role is to gather and analyse statistical data for the purpose of monitoring and correcting the behaviour and performance of the network, network element (NE) or other equipment and to aid in planning, provisioning, maintenance and the measurement of quality.

In order to accommodate as many customer requests as possible, and at the same time satisfying their quality of service (QoS) requirements it is necessary to observe the state of the network through a monitoring system (to evaluate the status of the network, analyze the network behavior during a certain time period, and provide feedback reports to a management system.

Acute fault conditions will be detected by alarm surveillance methods. Very low rate or intermittent error conditions in multiple equipment units may interact resulting in poor service quality and may not be detected by alarm system. Performance monitoring is designed to measure the overall quality, using monitored parameters in order to detect such degradation. It may also be designed to detect characteristic patterns of impairment before signal quality has dropped below an acceptable level.

Talking about the physical MAN operator's network aspects, it has to be noted that they mostly can be of heterogeneous nature - implemented in different transmission media: optical, twisted pair, coaxial, or wireless and different data transmission technologies are employed on the same network, e.g. Ethernet, Docsis, etc (Fig. 1). Heterogeneous of cable TV MANs' is considerably greater, than traditional heterogeneous networks usually. They are heterogeneously regarding services, technologies and transmission media used.

All these factors define the different quality of the services provided. Obviously, the currently functioning MAN networks', are being heterogeneous, makes it impossible to guarantee the same QoS.

The aim of the service provider is to offer the best quality service for the acceptable price to the service customer. Unfortunately, a better quality means an increase in service cost. The heterogeneous network of the service provider allows the customer to receive the different QoS and the ability to choose between different services. The choice of a particular provider will be determined by the best QoS and price ratio. All the above aspects can be formalized by having a Service Level Agreement (SLA) signed between service provider and customer. If providers do not deliver the agreed QoS, they can be penalized.

Monitoring idea, aims and objectives

Monitoring systems are becoming increasingly important for providing quantified QoS based services and these services assurance. We have come up with an idea to create heterogeneous MANs performance quality monitoring system, the aim of which would be to monitor the service quality states (SLA levels).

The developed monitoring system should assure the following:

- MAN operator will be able to trace the "weakest" links in their networks as well as to react in real time to the degradation on the network. It is necessary to assist of traffic engineering in taking provisioning decisions for optimizing the usage of network resources according to short term changes, to assist the efficient and effective allocation of resources and in providing analyzed traffic and performance information for long term planning in order to optimize the network, and to avoid undesirable network conditions;
- user will be guaranteed to receive services on a different range of quality and price, i.e. to verify, whether the QoS performance guarantees (SLA levels) are in fact being met.

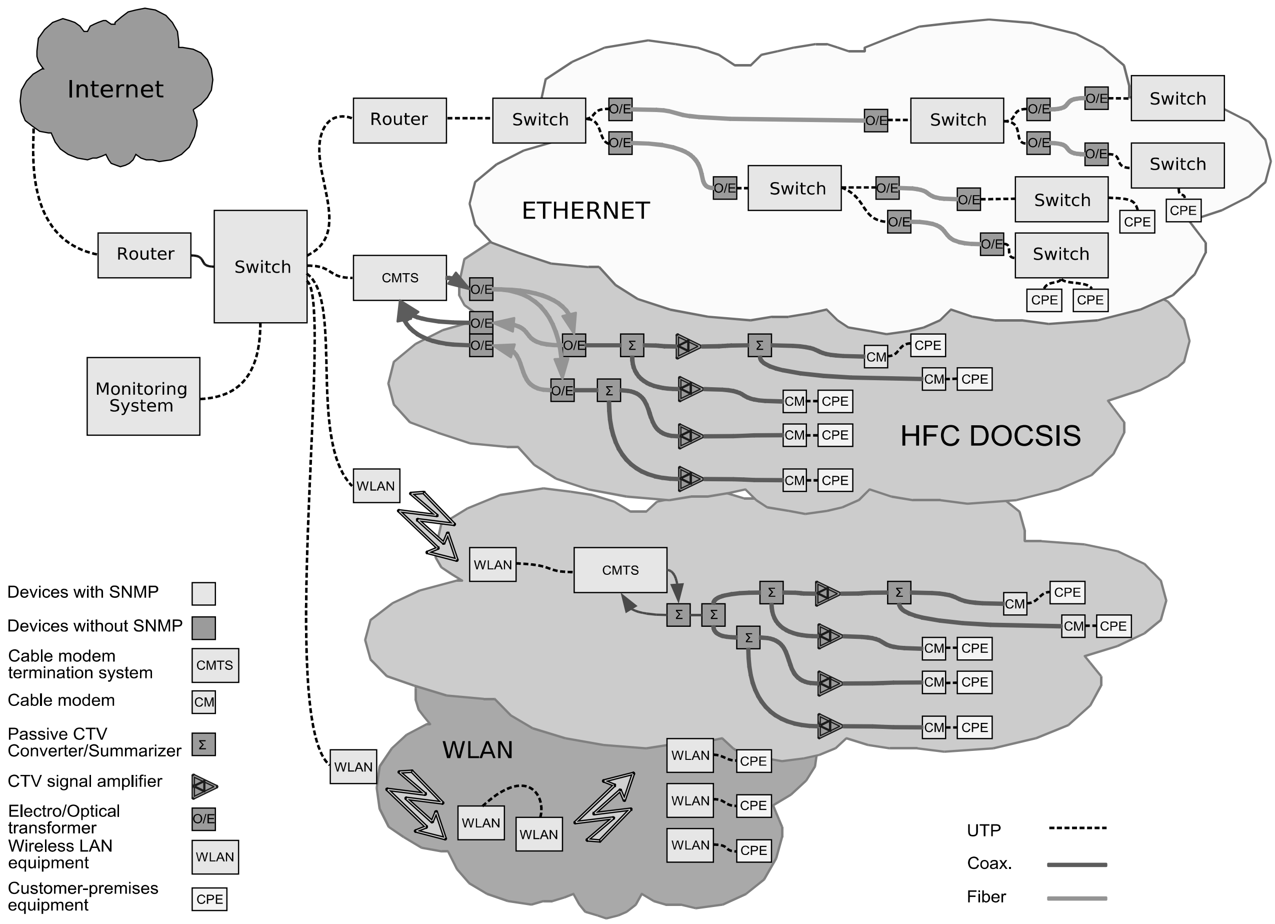

Fig. 1. Heterogeneousness of MAN operator's *X* network

Monitoring can be performed at different levels of abstraction. Measurements can be used to derive packet level, application level, user/customer level, traffic aggregate level, node level, and network wide level characteristics. Traffic engineering, networks monitoring occurs at the network layer for deriving all these characteristics.

There are typically used two types of methods for performing of measurements: active (or intrusive - inject synthetic traffic in to networks) and passive (or non-intrusive) quality monitoring (are used to simply observe data traffic transmitted through the network and require continuous collection of data and monitoring the link at full load, which can be problematic for high - speed links [1, 2]). In both cases, the quality of analyzed information depends on the granularity and integrity of collected data.

Besides that, the system should be scalable with three aspects: size of network topology, granularity of the supported service classes and number of subscribed customers [3]. Network topologies are characterized by a number of parameters, such as number of nodes, number of links, speeds links, degree of physical and logical connectivity, network diameter, etc. The number of supported MAN service classes is characterized by services customer's categories (defined by SLA). We suggest those principles for building of scalable monitoring system architecture for MAN (Table I).

Table I. Principles for Building of MAN Scalable Monitoring System Architecture

Principle	Optimal Scope and Required Action
Defining the monitoring process granularity	At the path level
Distributing the data collection system	At node level for processing and aggregating data at source
Minimizing the measurement transmission overhead	By employing event notification and summarization of statistics
Using aggregate performance measurements in combination with per-SLA traffic measurements	By carrying out performance measurements at the path level and traffic measurements at the SLA level
Controlling the amount of synthetic traffic	By having a trade-off between the synthetic traffic load and sampling frequency

The first principle is to define the monitoring process granularity at the path level for data gathering. Collecting packet level micro-flow statistics is expensive and not scaleable. The second principle is to distribute the data collection system at node level for processing and aggregating data at the source. The third principle is to minimize the measurement transmission overhead by employing event notification and summarization of statistics. In the fourth principle it is identified the need for carrying out *performance* measurements at the route and *traffic* measurements at the SLA levels. This principle aims to reduce the amount of synthetic traffic injection for carrying out the SLA monitoring as several SLAs may use a single route. Finally, the last principle states the need to control the amount of synthetic traffic: smaller time intervals mean injecting more synthetic traffic into the network, but injecting more synthetic traffic mean introducing higher load in the network that affect the network performance.

To achieve the discussed above objectives in developing of performance monitoring system for MAN services, authors suggest these set of problems must be solved.

1. *Examination and systematization of the operational quality parameters* for heterogeneous MAN networks, as recommended by international organizations of standards (ITU-T M.3200, M.3400). The number of characteristics in the sample depends on what specific technology is being employed.

2. *Proposition of quality monitoring model.* One of the major developed at present telecommunications management network (TMN) functions should be the critical status prediction of any telecommunications network element (links, routers) by using network quality parameters. Consider the structure of the model, the estimation process of network operability states can be divided into two stages. First stage specifies the networks operability classes standards formation according to measured networks quality parameters in busy hour of maximum traffic load and the second stage specifies the classification of measured parameters at every time moment. So, this means the following:

- formation of network states standards;
- classification of network states.

As the probability distribution function $p(\vec{x}/k)$ of measured network quality parameters is unknown then for the formation of networks operability classes standards was applied methods of cluster analysis, which are designed to classify the similar states (vectors) [4, 5]. In order to estimate standards of the network states it was suggested the method of the nearest *k* neighbours. If the number *k* of network operability classes is set before, then the primary network's parameters $X = \{X_1, X_2, ..., X_m\}$ can be grouped consider this criterion:

$$d = \sum_{i=1}^{k} q_i \sum_{j=1}^{k} q_j \frac{1}{N_i N_j} \sum_{n=1}^{N_i} \sum_{l=1}^{N_j} d_N \left(x_{in}, x_{jl}\right), \quad (1)$$

where q_i, q_j – appearance probability of clusters; N_i, N_j – number of *i* and *j* clusters quality parameters; d_N – Euclidean distance between two meanings of cluster quality parameters.

It was suggested a model [6] for telecommunications network status recognition, which is formed by the network elements status standards determination according to the network quality parameters, using training algorithms and the evaluation of the network elements status at every moment, using classification algorithms.

In general case here should be resolved a recognition problem of multidimensional vectors $\mathbf{X}_1^{(l)}, \mathbf{X}_2^{(l)}, \ldots, \mathbf{X}_{n_l}^{(l)};\ l = 1,2,\ldots,L$, where L is the number of network states.

The quality of heterogenous network and its elements at a certain moment of time is being estimated by a multidimensional quality vector $X\,(x_1$- number of packets, x_2 - throughput, x_3 - packet loss and x_4 - loss metrics (maximum loss burst, maximum loss distance, number of loss periods), x_5 - delay (mean, maximum and minimum delay), and x_6 - delay variation) [1]. During the day, when are operating both random and determinate factors, there varying network traffic, quality parameters and the state of network. Conventionally, the state of network might be called good, satisfactory or bad [6].

Classifier makes decision the vector $\vec{X}$ of network parameters belongs to this state l, if the distance of standard to this state is the shortest.

One of the main problems is development of quality level reference classes, which are built from informative quality parameters, choosing the state qualifier, as well as modelling of the conditions in heterogeneous network and their monitoring. It would be helpful to optimize network performance evaluation process, by highlighting important factors, i.e. informative, universal parameters, that can best reflect the change in QoS, and on the basis of which we can differentiate the SLA levels. However, given a big range in instruction implementations, this task becomes quite difficult. When different network performance classes that are built from separate network quality parameters' norm values overlap, the quality level assessment process becomes more complex. It is advisable to pay attention to parameters' statistical dependency and their correlation when developing optimal multidimensional states standard vectors – factors for monitoring systems [4].

The issues of performance state classification of telecommunication networks and of situation recognition in them are discussed in [5-7]. Referring to empirical Voice over IP service data, having calculated factor charges, the equation of main factor was written [7]:

$$F = 0.933 \cdot D + 0.905 \cdot J + 0.950 \cdot A + 0.737 \cdot L, \quad (2)$$

where F – main factor, *D* – delay, *J* – delay fluctuation, *A* – channel workload, *L* – packets loss.

Using the analogy of informative parameters assessment for the data transfer quality evaluation [7], it would be possible objectively to evaluate the QoS (SLA level) of heterogeneous MAN services also.

3. Specification of methodology for quality monitoring.

4. Implementation of proposed quality assessment model for cable TV services as a flexible software package.

5. *Developing of telecommunication service monitoring system that consists of these stages:*

- developing of accounting module for users and network devices;
- developing of agent for network scanning and events registration (collecting data, data sampling);

- developing of SQL database. It is necessary to develop the methodology for creation of relational databases, containing information about users, network devices and network topology, based on data mining (DM), semantic web (SW), and concept modelling (CM) for more efficient data analysis. Data mining enables the researchers to notice valuable patterns in existing data, and semantic web prepares the future data for easier analysis, while concept modelling enables later on the retrieval of relevant knowledge based on concepts;
- developing of user graphic interface, i.e. visualization module (it is necessary to present data and analysis in a convenient form to the customer);
- developing of signalling module.

6. *Carrying out measurements on the service provider networks by utilizing the proposed system* (testing of: SNMP data collecting module, graphic interface, the system utilization).

7. *Implementation of proposed technology in the cable TV services industry*.

Technical aspects of monitoring system

When discussing the monitoring issues and the technical aspects of the future system with the service providers, the heterogeneous nature of the currently existing MAN becomes apparent.

For example, in one of the MAN, the data transmission network is comprised of wireless communication equipment which transmits on two frequencies, i.e. 2.4 and 5 GHz. In the main network station there are several transmission equipment Access Point modules. The wireless communication equipment of the client is working in Access Point "Client" mode.

When organizing the monitoring of service for this sort of network, it necessary to collect technical information from the network equipment regarding the work efficiency and radio link quality.

The collection of data can be organized in several stages, depending on their importance and dynamic characteristics. For example, in order to find the efficiency of the network it is necessary to examine as often as possible (no less than 1 to 3 times per minute). The radio link signal amplitude registers can be examined every 5 to 10 minutes, MAC address table can be examined every 20 to 30 minutes.

For the issues related to data transmission speed it is advisable to check whether each of the network devices is reachable. For this purpose ICMP packet loss should be measured.

The MAC tables of wireless network devices collectively can describe the given network topology: which device is connected to which. Additionally, the data about the work load for each of the devices, the number of errors and the strength of the radio signal can give the idea to the supporting personnel regarding to which network node requires to be updated or fixed.

It is helpful to present the resulting network topology in a visual form, marking the different states of the devices in different colors. It is advisable to chart the workload of the given network for the last 24 hours, giving the number of errors and the variation in the signal level.

The other MAN data transmission network is build from two components, each of which uses different technologies for data transmission.

DOCSIS standard cable transmission network - the first component – which uses cable TV HFC network as transmission medium [8]. The main station houses are the terminal CMTS (Cable Modem Termination System) modems. One of these modems is capable to serve from several hundred up to fifteen hundred customers. The cable modems are set up in customers' homes and offices. These modems can provide service for up to 8 customers. The data and parameters from cable modems (CM) and from CMTS can be read through SNMP.

The problem is with cable TV network devices: electro – optical converters, direct and return channel amplifiers, reductors, dampers, which are non - IP devices and there is no way how to collect working information from them remotely.

The second component of this MAN is an Ethernet network. Single mode optical cable is used as transmission media in the main lines; whereas the 5th category twisted pair cable is used for the networks at users' premises.

The working information from the distributing equipment – the monitored Ethernet switches – can be read through SNMP. Since the devices on this network carry working information some of which is superfluous, so, when monitoring them, only the relevant data for the analysis should be read. Part of the information will be the same for all the devices (e.g. *uptime*); the rest will be specific for each device type (e.g. MAC address table for Ethernet switch, RF signal characteristics for CM).

Experiments

Some experiments were made and statistics of network device availability is shown in the Fig. 2 and Fig. 3.

Statistics is gathered with open source measurement tool *SmokePing,* which can be used to measure, store and display latency, latency distribution and packet loss. Every 5 minutes, *SmokePing* bounces 20 pings off the target device and measures the time it takes for a response to return. The pings build the gray area behind the graph. The grayer the area is, the higher the fluctuation in ping times. Fig. 2 shows that average RTT delay time to target network device is about 6.1 ms. Average packet loss is about 9.93 % during this period of time (approximately 30 hours), which indicates a probable problem with network device availability from 14:30 until 16:30. Fig. 3 shows the results of another experiment. The average RTT delay time to target network device is about 35.1 ms in this case. Average packet loss is about 6.65 % during the observable period. The data from Fig. 3 shows, that there is a probable problem with the link bandwidth from 07:50 until 01:50. To verify this assumption we made additional experiment.

Statistics is gathered with *mgstats* and RRD tool. There was monitored the same network device (Fig. 3). The router via monitored Ethernet interface *eth0* was connected to 1024 kbps download and 512 kbps upload speed link.

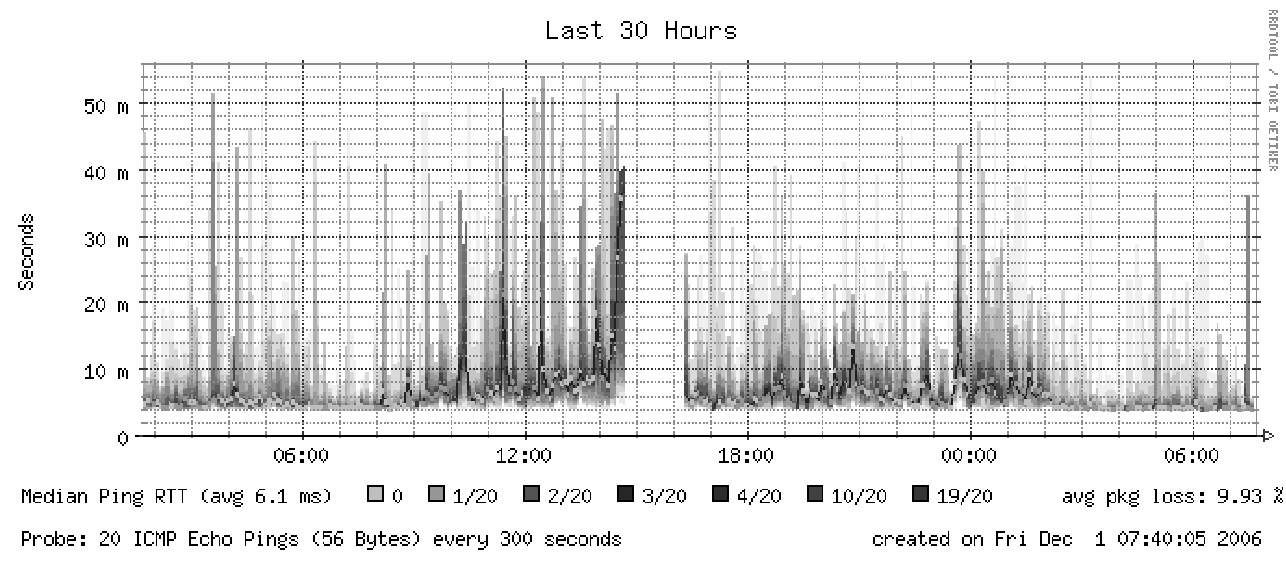

Fig. 2. Availability, delay and loss statistics from 2006-11-30 02:00 to 2006-12-01 08:00

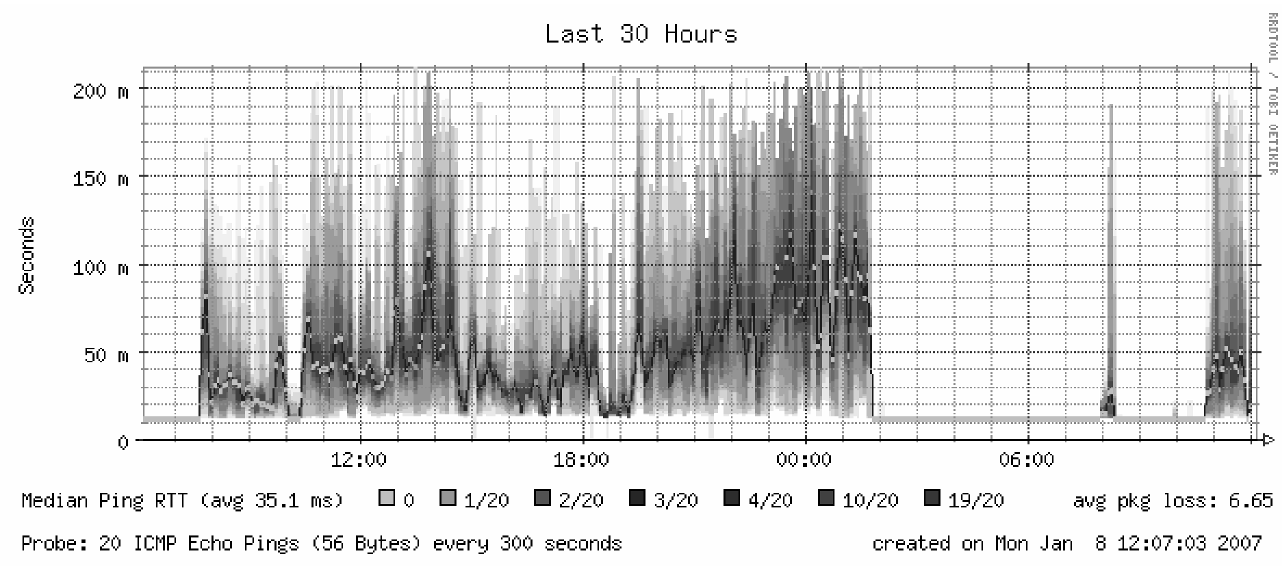

Fig. 3. Availability, delay and loss statistics from 2007-01-07 06:00 to 2007-01-08 12:00

From experiment data (Fig. 4) it's obvious, that our assumption was proved right - the bandwidth problem exists and optimization of network resources usage must be done.

This kind of network's functionality problems can be minimized applying the proposed QoS monitoring approach.

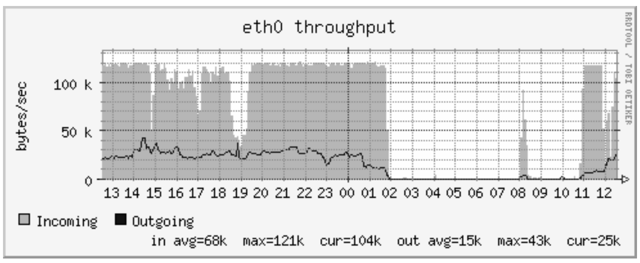

Fig. 4. Link bandwidth statistics from 2007-01-07 12:30 to 2007-01-08 12:00

Conclusions

As for now the visualization of heterogeneous MAN topology is done at irregular time intervals, so we may not have the real time view of situation in network performance. The suggested approach for QoS monitoring system will be a new product for assessing a quality of heterogonous MAN's services. The service providers will be able to trace the "weakest" links in their networks and, by means of SNMP, to observe networks and react in real time, so, this will reduce the waste of resources due to ineffective network utilization and will guarantee the agreed QoS to the user.

It must be noted, that users of MAN services will gain the opportunity to choose the QoS level for an affordable price, offering them service packages of different range of quality and price.

This will guarantee the competitiveness for operators in the medium size enterprise market.

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Actual questions for evaluation and management quality of service (QoS) and issues about organizing and developing the QoS monitoring system of heterogeneous MAN networks are analyzed. The Monitoring System will facilitate the following: the service providers will be able to determine the "weakest" links in their network, whereas the SNMP protocol will permit them to react to the current state of the network in real time; the user will be guaranteed a range of choice in QoS and price; the service providers will have a good means allowing them to compete in the telecommunication service market. Ill. 4, bibl. 8 (in English; abstracts in English, Russian and Lithuanian).

Р. Янкунене, Ю. Гвергждис, А. Будникас. Мониторинг качества функционирования гетерогенных MAN сетей // Электроника и электротехника. – Каунас: Технология, 2007. – № 2(74). – С. 69–74.

Анализируются науковые проблемы, связанные с оцениванием и управлением функционирования гетерогенных MAN сетей, организацией мониторинга качества предлагаемых услуг в этих сетях. Внедрение предлагаямых решений в систему мониторинга операторам услуг создаст возможность обнаруживать «слабые» места своей сети и с помощью протокола управления сетями SNMP в реальном времени реагировать на существующую ситуацию сети. Потребителям будут гарантированы различные уровни качества услуг и их цена. Операторы услуг будут иметь возможность успешно конкурировать в рынке телекоммуникационных услуг. Ил. 4, библ. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

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Analizuojamos mokslinės problemos, susijusios su MAN tinklų funkcionavimo kokybės įvertinimo ir valdymo klausimais, paslaugų kokybės stebėsenos organizavimu ir stebėsenos sistemos kūrimu. Siūlomų sprendimų panaudojimas stebėsenos sistemose paslaugų teikėjams suteiks galimybę nustatyti „silpnąsias“ savo tinklo vietas ir SNMP tinklo valdymo protokolo priemonėms realiu laiku reaguoti į esamą tinklo darbingumo situaciją; vartotojui bus užtikrinami skirtingi paslaugų kokybės lygiai ir kaina; paslaugų operatoriai turės galimybę sėkmingai konkuruoti telekomunikacinių paslaugų rinkoje. Il. 4, bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).