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METHOD FOR EVALUATION QUALITY PARAMETERS OF TELECOMMUNICATIONS SERVICES

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***Abstract.** Currently, cellular networks have become widespread, the operators of which simultaneously use the infrastructure of the second generation GSM networks, DCS to build third generation W-CDMA networks that provide broadband multiple access with code division. At the same time, the problem of providing high-speed Internet connections is exacerbated due to the growing volume of data of diverse types transmitted over the Internet. When testing the entire network coverage area, the total number of voice calls increases, so a method of long-term measurement of bit rate of information transmission via wireless communication channels is proposed, which does not increase the service information in the network. Mathematical modeling of Internet traffic consumption using the proposed measurement method is performed and entropy estimates of information channel bandwidth are given.*

Keywords: communication channel, mobile network, subscriber, internet connection, bit rate

SPOSÓB OCENY PARAMETRÓW JAKOŚCI USŁUG TELEKOMUNIKACYJNYCH

***Streszczenie.** Obecnie upowszechniły się sieci komórkowe, których operatorzy jednocześnie wykorzystują infrastrukturę sieci drugiej generacji GSM, DCS do budowy sieci W-CDMA trzeciej generacji, które zapewniają szerokopasmowy wielokrotny dostęp z podziałem kodowym. Jednocześnie problem zapewniania szybkich łączy internetowych jest nasilany przez rosnącą ilość danych różnego typu przesyłanych przez Internet. Przy testowaniu całego obszaru pokrycia sieci wzrasta sumaryczna liczba połączeń głosowych, dlatego proponuje się metodę długoterminowego pomiaru przepływności transmisji informacji kanałami komunikacji bezprzewodowej, która nie zwiększa informacji o usłudze w sieci. Przeprowadzane jest matematyczne modelowanie zużycia ruchu internetowego przy użyciu proponowanej metody pomiaru i podane są entropijne estymacje przepustowości kanału informacyjnego.*

Słowa kluczowe: kanał komunikacji, sieć komórkowa, abonent, połączenie internetowe, przepływność

Introduction

Currently, cellular networks have become widespread, the operators of which use the infrastructure of the second generation network GSM, DCS to build third generation networks W-CDMA, providing broadband multiple access with code division. At the same time, both types of networks work simultaneously, complementing each other. The second-generation networks are mostly voice calls, and the third-generation networks are mostly traffic. To ensure a high level of communication networks service quality, operators have to constantly test existing systems. Hardware and software systems from manufacturers such as Ericsson, ASCOM, Rohde & Schwartz are used to test the networks. These complexes are able to perform measurements in both 2G and 3G networks [2].

A significant disadvantage of such complexes is the mandatory presence of qualified operators at the control panel of the measuring complex. The exception is the TEMS Automatic complex, which collects data from the subscriber terminal without the user's knowledge, and there are restrictions. For example, when testing an active connection, funds from the subscriber's account will be spent. Also, for testing a certain sector, it is necessary that the subscriber is in this sector.

1. Literature review

One of the important parameters that affect the quality of communication is the bit rate of the Internet connection. The problem of providing high-speed Internet connections is exacerbated by the growing amount of data transmitted over the Internet. Wireless networks are now very actively used for watching movies in streaming mode, as well as for visiting social networks, where information pages are heavily overloaded with graphic information. For comfortable work on the Internet at the moment speeds of 1.5...2 Mbit/s are necessary. In light of the above, the requirements for the quality of the data channel, as well as the stability of technical and operational characteristics of cellular networks are increasing [7].

An important task is to monitor the speed of the Internet connection, which is currently used to ensure various Internet resources, such as the speed test provided by nPerf or SpeedTest.net. These services allow you to quickly determine the speed of the Internet connection but have a number of significant limitations, such as a limited number of requests per day, the inability to test the speed of the Internet connection without user participation (Automated testing), the inability to arbitrarily change the test size package. In this regard, there is a need to develop a test system that is independent of any external services [10].

Currently, telecommunications are developing rapidly. One of the most important areas of development is cellular communication. In recent decades, there has been a sharp jump in increasing the capacity of the designed communication networks. For example, the second generation GSM system – Global System for Mobile Communications with add-on packet data GPRS (General Packet Radio Services), and then Enhanced Data rates for GSM Evolution) has a maximum bandwidth of 474 kbps in packet switching mode (8 slots × 59.2 kbit on the coding scheme MCS-9). Further development of cellular communication has led to the emergence of third-generation communication systems UMTS (Universal Mobile Telecommunications System – Universal Mobile Telecommunications System). UMTS, using the development of WCDMA (English Wideband Code Division Multiple Access – broadband multiple access with code division), allows you to maintain the data rate at a theoretical level up to 21 Mbps. when using HSPA + (High-Speed Packet Access – high-speed packet data) in multi-channel mode [1, 5].

Currently, the highest speeds are considered to be 384 kbps for mobile stations of R99 technology and 7.2 Mbps for HSDPA stations (High-Speed Downlink Packet Access) in data mode. from the base station to the mobile terminal. Data transfer speeds in third-generation networks are hundreds of times faster than data rates in second-generation networks. As a result, you can comfortably browse the Web, stream movies, and listen to multimedia resources.

However, the second-generation GSM network currently has a much larger coverage area than the third-generation W-CDMA network. In addition, second-generation subscriber terminals are characterized by the low cost of manufacture and ease of maintenance. In this regard, there is a double situation where two generations of cellular communication coexist and operate simultaneously: the existing GSM network is used for voice information, and the third generation W-CDMA network is used mainly for data transmission (Internet traffic). The third generation of cellular communication systems has much higher bandwidth then the radio channel and therefore has a much higher data rate. Therefore, the third generation of WCDMA communication is used mainly for broadband Internet access, as well as for video calls and streaming movies. These systems can operate simultaneously without interfering with each other, as they have different frequency ranges [3, 11].

2. Researches methodology

To assess the quality of services to the end-user, a large number of parameters of data transmission are studied, but the level of consumer satisfaction with the received service, regardless of the data transmission technology used, is based on the following parameters:

- criterion "availability of communication", which meets such a quality indicator as to the share of successful calls from the total number of calls when establishing a connection with a subscriber of both mobile and fixed networks. The share of successful calls is estimated from measurements of the number of successful and unsuccessful calls created by network subscribers in the direction of network subscribers and fixed-line subscribers.

$$P_y = \frac{Q}{N} \quad (1)$$

N – the total number of control calls for all measurement sessions,

Q – the total number of successful control calls for all measurement sessions.

- the criterion of "continuity of communication", which meets such a quality indicator as to the proportion of calls that ended in disconnection at the initiative of the subscriber. The share of calls with scheduled disconnection is estimated from measurements of the number of successful calls and calls with premature disconnection.

$$P_n = \frac{R}{N} \quad (2)$$

R – the total number of control calls that ended in disconnection of the established connection at the initiative of the subscriber.

- the criterion "quality of broadcasting", which meets such an indicator of quality as the share of calls that meet the standards for the quality of broadcasting. The share of calls that meet the standards for the quality of speech transmission is estimated from measurements of the number of calls with satisfactory and unsatisfactory quality of speech transmission.

$$R_y = \frac{N_{np}}{N} \quad (3)$$

N_{np} – the total number of control calls that meet the standards for the quality of broadcast transmission, for all measurement sessions.

Thus, to determine these quality indicators in any part of the network it is necessary to make a large number of voice calls. When testing the entire network coverage area, the total number of voice calls will be very large, which increases the load on the network [1, 4].

Another parameter to which high requirements are placed is the speed of data transfer when a subscriber uses the Internet. For comfortable work on the Internet at the moment speeds of 1.5...2 Mbit/s are enough. The inability of the cellular operator to provide such speeds leads to the fact that subscribers move to competitors who provide higher quality services. In light of the above, the requirements for the quality of the data transmission channel of cellular networks, as well as the stability of the characteristics of the claimed services.

To ensure high-quality services, it is necessary to conduct regular testing and monitoring. Monitoring requires highly qualified specialists as well as specialized measuring systems.

To measure the bit rate, a measurement technique is proposed, which determines the actions of the operator in the measurement process, as well as during the primary processing of the results.

Method of long-term measurement of the bit rate of information transmission via wireless communication channels [5, 12].

The method contains the following items:

1) Select the measurement location.
2) Install the test (testing) tool in the selected location.
3) Carry out daily monitoring of the speed of the Internet connection in an active way, by exchanging data between the server and the test (testing) tool. When performing daily monitoring, it is necessary to register the signal power level and the signal-to-noise ratio brought to the input.
4) Calculate the value of the daily change in bit-rate based on the data obtained about the signal power level and the signal-to-noise ratio brought to the input.
5) Find the maximum value of the bit rate measured by the active method.
6) Find the maximum value of the bit rate.
7) Carry out daily monitoring of the bit rate of the Internet connection in a passive way, by recording the data obtained on the signal power levels and the signal-to-noise ratio brought to the input, at the required time.
8) Calculate the value of the bit rate of the Internet connection.
9) Output information for analysis in text or graphical form.

3. Results

When using the described method according to the above method, there is a significant saving of radio network resources. Consider the cost of traffic for round-the-clock monitoring of bit rate during the week, using the active and passive methods. In Fig. 1 presents the results of mathematical modeling of Internet traffic consumption in MathCAD.

From the graphs presented in fig. 1, it is seen that the total cost of Internet traffic increases when using the standard method, and when using the proposed method remains constant. This is due to the fact that when using the method described above, the flow of traffic occurs only when determining the correction factor on the first day of measurements. Further measurement of the bit rate of the Internet connection takes place without active data exchange, so traffic costs do not increase.

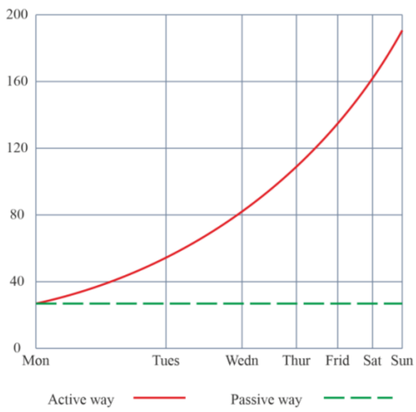

Fig. 1. The results of mathematical modeling of Internet traffic consumption using the known and proposed measurement method

However, during the monitoring, it is necessary to take into account that recently the volumes of traffic transmission (speech, video, data) are starting to significantly exceed the volumes of transmitted voice messages. The statistical characteristics of such heterogeneous traffic can no longer be described using standard distributions. Non-parametric methods should be used to assess the quality parameters of such networks, for example, using information-entropy measures of these distributions.

To quantify the information used logarithmic measure (Hartley measure):

$$I = loga \cdot N \quad (4)$$

I – the amount of information obtained from one count;
N – the number of possible different measurement results by this measuring instrument;
a – a number that determines the unit of information; when $a = 2$ unit of information is called a bit.

1 bit of information is contained in one bit of the binary number. Indeed, one digit can take one of two values: 0 and 1, ie $N = 2$. Then $I = \log 2 + 2 = 1$ bit.

Hartley's formula is valid only when each of the N messages appears with equal probability. The fact is that the information is only a message, not previously known to the recipient of this message. The amount of information in a reliable (in a pre-known message) is zero.

In the general case, the amount of information contained in one message depends on the probability of this message:

$$I_i = log_2\left(\frac{1}{p_i}\right) \tag{5}$$

p_i – the probability of the i-th message.

From the above formula it is clear that the less likely the message is received, the more information it carries. If the law of distribution of values of the measured parameter (in the range of change of this parameter) is NOT equally possible, the results obtained in the process of measurements will carry a different amount of information.

For information estimation of the system "researched object-measuring instrument" the concept of entropy is introduced in the information theory. Entropy is the average amount of information per message [9].

To obtain a formula for determining entropy, consider a source of information that can issue N independent discrete messages with probability $p_1, p_2, \ldots, p_i, \ldots, p_N$. Consider a long sequence of m messages ($m >> N$). According to probability theory, each i-th message will appear in this order $m \cdot pi$.

Given that each i-th message carries information:

$$I_{1i} = \log_2 \frac{1}{p_i} = -\log_{p_i} \tag{6}$$

all received messages will give information:

$$I_{mi} = -m \cdot p_i \cdot \log_2 p_i \tag{7}$$

General information from all m messages will be:

$$I_m = -m \cdot \sum p_i \cdot \log_2 p_i \tag{8}$$

The average amount of information per message, ie the entropy of the source, will be:

$$H = \frac{I_m}{m} = -\sum p_i \cdot \log_2 p_i \tag{9}$$

This formula is called Shannon's formula.

It is easy to see that for all equally possible messages ($p_1 = p_2 = \ldots = p_N$) this formula will turn into a Hartley formula:

$$H = log_2 \cdot N \tag{10}$$

The physical quantity controlled in the process of measurement is, as a rule, a continuous random process characterized by the law of probability distribution $F(X)$ or probability density $\varphi(X)$.

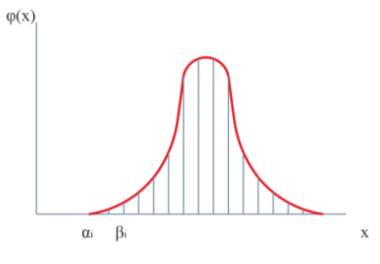

Fig. 2. Distribution of the measured value

To estimate the entropy of the system "signal source – controlled parameter – measuring instrument" it is necessary to take into account the resolution of the device Δx. In this case, the system can be considered as discrete with the interval of a division of the measuring range $X_{max} - X_{min}$ into discrete segments equal to Δx. Denoting by αi and βi the boundaries of the i-th partition section (Fig. 2), we can determine the probability of the value of the controlled parameter in this interval:

$$p(a_i < x < \beta_i) = \int_{a_i}^{\beta_i} \varphi(X)dx \tag{11}$$

Determining the probabilities of the values of the parameter in all intervals of the partition, according to Shannon's formula (9), we can obtain an estimate of the entropy in this case.

1. The entropy of the source of information is maximum if all outgoing messages (outputs of the source) are different.
2. Entropy decreases if there is a relationship between outputs.

The entropy of the system $H\ (X, Y, \ldots)$, consisting of several subsystems having entropies $H\ (X), H\ (Y), \ldots$, is equal to the sum of entropies, if the messages of the subsystems do not depend on each other. If there is a dependence, the total entropy is less than the sum of the entropies of the subsystems:

$$H(X, Y, \ldots) \le H(X) + H(Y) + \cdots \tag{12}$$

1. Information redundancy is manifested in the fact that the information content of messages is less than the resources that allow the transmission of these messages.
2. Information redundancy may be due to the following factors.
3. An excessive number of elements of discrete signals compared to those required for the presentation of data messages. For example, 8-bit binary code is used to transmit text. The number of different characters used in the text – 53: 33 letters, 10 decimal numbers, and 10 auxiliary characters (punctuation marks, parentheses, quotation marks). 6 bits of code ($2^6 = 64$) are enough to encode all characters, 2 bits are superfluous. They form redundancy.
4. The inequality of the appearance of individual messages. According to the first property of entropy, it decreases. If the source gives 4 different messages and they are different, the entropy according to the Hartley formula will be 2 bits. With different probabilities of messages, for example, 1/2, 1/4, 1/8, 1/8, entropy will be 1¾ bit.
5. The presence of interrelationship between messages. This statement, according to the second property of entropy, also reduces the entropy of messages.

Information redundancy is assessed by the expression:

$$R = \frac{(I_{max} - I)}{I_{max}} = 1 - \frac{I}{I_{max}} \tag{13}$$

I_{max} – the maximum possible entropy value for the selected messaging technology;

I – the true value of entropy.

Information flow is the average amount of information issued by a source per unit of time:

$$\Phi = \frac{I}{T} = \frac{H}{t_1} \tag{14}$$

H – source entropy;

t_1 – time of issuance by the source of one message.

Then the bandwidth of the information channel (communication line, measuring device, including sensor and information display means) is the maximum speed at which the channel can transmit information:

$$C = \left(\frac{I}{T}\right)_{max} = \frac{I_{max}}{T} \tag{15}$$

If at time T the channel can transmit m messages, and the transmission of each message occurs at time t_1, the formula (15) can be represented as:

$$C = m\frac{H_{max}}{m \cdot t_1} = \frac{H_{max}}{t_1} \tag{16}$$

H_{max} – maximum entropy that messaging resources can have (determined by Hartley's formula).

When sending messages in binary code, you can write:

$$C = \frac{H_{max}}{\alpha \cdot \tau} = \frac{n}{n \cdot \tau} = \frac{1}{\tau} \tag{17}$$

n – the number of bits of the code combination; τ – the time of transmission of one bit of code; H_{max}– code entropy (equal to the number of bits in the code combination).

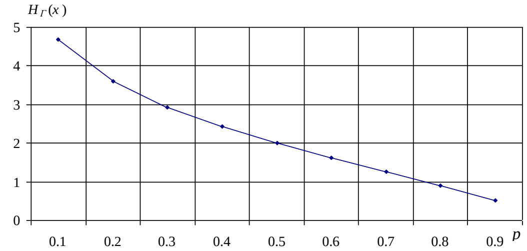

Fig. 3. Dependence of entropy of geometric distribution on probability of success of transfer p

The dependence of the entropy of the geometric separation on the probability of successful data transmission of one of the network nodes was calculated (Fig. 3). It has been seen that with a higher probability of success, the entropy of the distribution decreases, therefore, the required resource for data exchange decreases.

However, this has been achieved only by reducing the likelihood of network congestion. This can be achieved, for example, by limiting such a key performance indicator as to the maximum duration of packets transmitted [6, 8].

For comparison, the dependence of the differential entropy on the standard deviation of the transmission interval from the maximum allowable is calculated (Fig. 4). There is a monotonic increase in entropy, hence the growth of the required resource of data exchange.

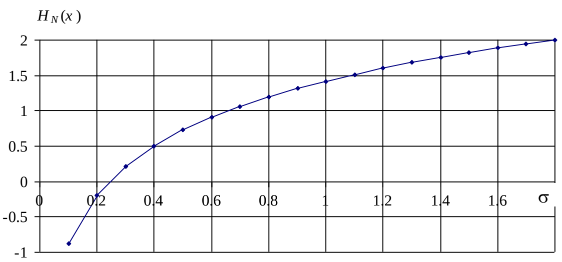

Fig. 4. Dependence of entropy of Gaussian (normal) distribution on standard deviation σ

Note that when calculating entropy measures, you can use different parameters of model distributions. At the same time, comparative estimates based on entropy will be quite universal and clear.

4. Conclusions

The optimal parameters for assessing the quality of service provision in the joint use of second and third-generation networks are selected.

The method of long-term measurement of the bit rate of information transmission through wireless communication channels is offered.

Mathematical modeling of Internet traffic consumption using the proposed measurement method is performed, and it is shown that the proposed method does not lead to excessive creation of service traffic.

Entropy estimates of the bandwidth of the information channel are given.

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