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DEVELOPMENT OF A METHOD FOR THE EXPERIMENTAL ESTIMATION OF MULTIMEDIA DATA FLOW RATE IN A COMPUTER NETWORK

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Запропоновано метод експериментального оцінювання швидкості мультимедійного потоку даних на основі методів математичної статистики. Метод дозволяє отримати значення математичного очікування та середньоквадратичного відхилення швидкості потоку даних. Метод також дозволяє оцінити узгодженість гіпотези про нормальний характер закону розподілу швидкості мультимедійного потоку даних. Наведені експериментальні оцінки величини швидкості мультимедійного потоку даних при різних параметрах відео

Ключові слова: аналіз мережевого трафіка, статистична обробка результатів експерименту, швидкість потоку даних

Предложен метод экспериментального оценивания скорости мультимедийного потока данных на основе методов математической статистики. С помощью метода могут быть получены значения математического ожидания и среднеквадратичного отклонения скорости потока данных. Метод позволяет оценить согласованность гипотезы о нормальном характере закона распределения скорости мультимедийного потока данных. Приведены экспериментальные оценки величины скорости мультимедийного потока данных при различных параметрах видео

Ключевые слова: анализ сетевого трафика, статистическая обработка результатов эксперимента, скорость потока данных

1. Introduction

Multimedia information is widespread in the modern world. The multimedia information is understood as digital video information, graphics, and audio information.

Compared with other types of information, multimedia information is generally characterized by large amounts of data. Therefore, when multimedia is transmitted, a computer network often experiences delays, distortions, and other difficulties. Internet users are often not satisfied with the quality of online video playback, video conferences, or IP telephony. One possible problem is the insufficient throughput of a computer network or its individual segments. In addition, there are a number of other applications that require a substantial amount of transmitted data, which are appropriately named Big Data [1].

When designing a new, or analyzing existing, computer network, there emerges a task to evaluate data flow rate, and, in this case, the volume of multimedia traffic often turns out to be the largest and even decisive. When designing computer networks, in order to estimate the characteristics of data flow, a variety of mathematical models of traffic are typically applied [2 5]. However, such an approach is justified only if the constraints in the mathematical models themselves are met, such as, for example, stationarity, ordinarity, and the absence of aftereffect for the Poisson stream of packets, etc. A real pattern of the performance of a network traffic can only be obtained by experimental observations with compulsory subsequent statistical processing. This will not only make it possible to obtain the desired characteristics, but also to assess the reliability of the results derived. Accordingly, the development of a method for experimental estimation of the multimedia data flow rate in a computer network seems to be a very relevant task.

2. Literature review and problem statement

The model of PTFK control protocol over TCP transmission, proposed in paper [2], enables the estimation of the effect of TCP parameters on the rate of data transfer among nodes in a computer network. A given model was further developed in papers [3, 4] where it is shown that the data transfer rate depends on the frequency of errors in a data transmission channel, applied algorithms for retransmissions, and timeouts. The model, described in [5], makes it possible to estimate parameters of the improved version of the mechanism TCP NewReno. However, the above models do not take into account features of the inner nature of traffic, transported by a flow of TCP segments.

Study [6] illustrates a contribution from each of the levels of a TCP/IP protocol stack to the redundancy, introduced to transmitted data, and defines an effective data transmission rate as the percentage of useful information in the overall flow of data.

The issue of efficiency of data transmission is addressed in paper [7] where it is proposed an integrated indicator of multi-factor efficiency, taking into consideration both technical and economic characteristics of several existing technologies of computer networks. However, the proposed indicator does not account for the requirements to parameters of quality of service (QoS) in the traffic of various nature.

This shortcoming was eliminated in paper [8], which also considered a comprehensive indicator of multifactor data transfer efficiency, taking into account the QoS settings. In an earlier work [9], a similar performance indicator was used to generate requirements put forward to modern computer networks. However, this indicator includes data transmission rate as only one of the constraints, while in most cases the transmission rate must be the main component of the performance indicator in data transmission.

Article [10] described a comprehensive indicator of the effectiveness of data transmission, which reflects a rate of data transmission as a function of BER bit error frequency and a method, applied in a network, for retransmissions ARQ. However, the proposed indicator is more applicable to describe processes that occur at the channel level of the model of interaction between open systems OSI; it does not account for patterns in the nature of transmitted data.

It should be noted that the forms of a data transfer efficiency indicator, described in [7–10], are continuation of the indicator proposed in an earlier work [11].

A slightly different approach was proposed in paper [12]. The authors suggested a performance indicator for data transmission, the basis of which is the duration of processing a packet by the network; while a data transfer rate, similar to [7–9], is included in the system of constraints. A mathematical model, described in [13], takes into consideration a delivery time of data package and the likelihood of its errors, the rate of data transmission is not addressed in this case.

Authors of study [14] proposed a conceptual approach to the synthesis of an information-telecommunication network structure. This approach takes into consideration the principles of synthesis and is based on mathematical models of the information and technical structure of the network. One of the input parameters in the proposed model is, in particular, the amount of data transmitted. The proposed method for the experimental estimation of multimedia data flow rate in a computer network makes it possible to obtain a value for the volume of transferred data for subsequent application of the conceptual approach, suggested in [14].

Network traffic analysis methods are described in detail in several papers. Thus, [15] describes a prototype of the infrastructure for measurement, storage, and comparison of network data of different type and character in the commercial IP network of the firm AT&T, which employs the principle of a network traffic analysis. Article [16] shows a circuit and reports results of traffic analysis in the Fast Ethernet network using the network analyzer Wireshark. Comparison of different network traffic analysis tools is described in paper [17]. Summing up the results of studies [15–17] makes it possible to draw a conclusion on the feasibility of the approach to assessing rate of a multimedia data stream based on the use of experimental statistical data, which in this case should be properly processed and interpreted. Article [18] reports results of research into traffic at the Internet TV and IPTV access level; authors obtained distribution of packet durations and intervals between the moments the packets arrive.

The generalization of results given in the above studies allows us to suggest that existing approaches to solving the task on estimation of multimedia data flow rate in a computer network rely on mathematical models based on the provisions from the theory of information and the probability theory. It is clear that the processes taking place in a computer network are stochastic in nature, and the use of methods of mathematical statistics to analyze network traffic seems to be sufficiently justified.

Thus, the task on estimating the rate of multimedia data flow in a computer network has remained unresolved in full up to now. We propose using an approach to the estimation of a multimedia data flow rate based on the application of experimental statistical data; the method for acquisition, processing, and interpreting them is described in this paper.

3. The aim and objectives of the study

The aim of present study is the acquisition, processing, and interpretation of reliable experimental estimates of the magnitude of a multimedia data flow rate in a computer network. This would make it possible to correctly identify the required throughput for the segments of the designed computer network, and to ensure a proper level of service quality.

To accomplish the aim, the following tasks have been set:

– to capture a traffic of multimedia data flow between the client and the media server and to obtain a set of observed values for a random variable of the multimedia data flow rate in a computer network at various parameters of video;

– to develop a method for the experimental estimation of a multimedia data flow rate in a computer network based on the methods of mathematical statistics;

– to run an analysis of the results obtained using the developed method for the experimental estimation of a multimedia data flow rate in a computer network.

4. Materials and methods to study the multimedia data flow rate in a computer network

The multimedia data flow rate can be estimated both theoretically and experimentally. Theoretically, the amount of transmitted data of online video is composed of two parts: a video stream and an audio stream.

The volume of a video stream depends on the resolution of the video, color depth, frame frequency rate, and a degree of data compression enabled by the chosen codec.

The audio stream volume depends on the sampling frequency of the sound, the bitness of the analog-to-digital conversion, the number of audio channels, as well as on a degree of data compression by the audio codec.

Experimentally, a data flow rate (the amount of data transmitted per unit of time) can be estimated using a network analyzer. In this work we used the software network analyzer Wireshark, version 2.4.3. Schematic of the experiment is shown in Fig. 1.

A server of multimedia contains a video file with a resolution of 320×240 pixels, a refresh rate of 15 frames per second, a video flow rate of 144 Kbps, an audio stream rate of 99 kbps, a total flow rate of 243 Kbps.

At the client side, the video file is displayed in the browser; in this case, all traffic between the server and the client was captured by the buffer of the network analyzer.

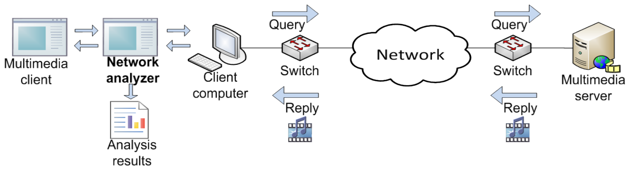

Fig. 1. Schematic of experiment on the analysis of a multimedia stream traffic

The volume of data that we measured, sent from the server to the client over a time interval T=30 s, was divided by the duration of this interval T. Thus, we experimentally obtained the observed values for the multimedia data stream rate C_i, $i=\overline{1,n}$, where i is the number of experiment, n is the number of experiments. The total number of experiments in this paper is n=50. A block diagram of the method for the experimental estimation of multimedia data flow rate in a computer network is shown in Fig. 2.

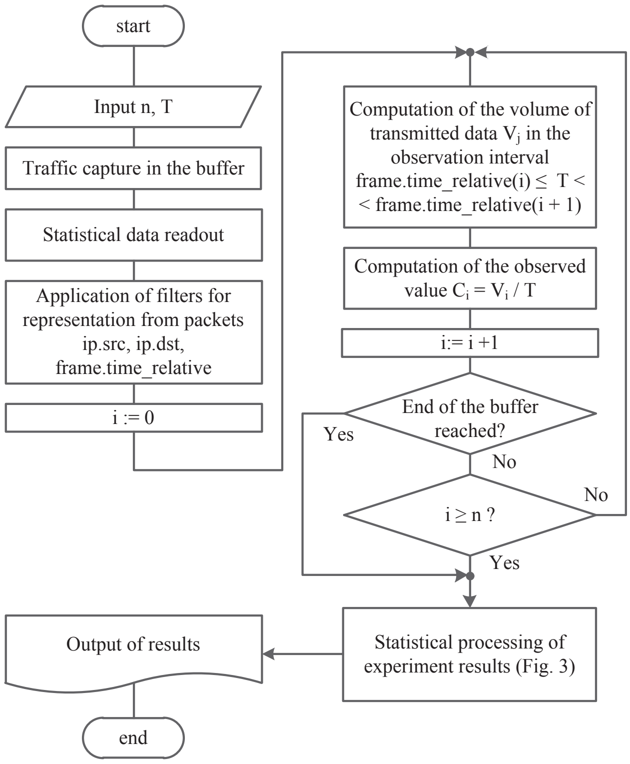

Fig. 2. Block diagram of method for the experimental estimation of a multimedia data flow rate in a computer network

The obtained set of observed values for a random variable of the multimedia data stream rate $\{C_i\}$ (Table 1) was statistically processed in accordance with the method shown in Fig. 3, based on the methods of mathematical statistics [19].

Table 1

Rate of multimedia data stream with a video resolution of 320×240 and a frame rate of 15 frames/s, measured experimentally in the interval of 30 s

No. of experiment	*C* value, bps
1	304 682
2	291 286
3	266 304
4	298 214
5	282 938
6	290 186
7	291 526
8	301 041
9	291 707
10	271 824
11	318 396
12	302 515
13	309 254
14	290 548
15	294 600
16	294 607
17	297 436
18	297 461
19	303 862
20	294 056
21	293 319
22	289 996
23	305 730
24	299 295
25	300 335
26	281 088
27	291 584
28	300 474
29	295 331
30	293 133
31	286 363
32	279 721
33	282 793
34	287 527
35	301 595
36	290 244
37	295 595
38	294 607
39	291 075
40	293 508
41	302 768
42	301 811
43	286 100
44	278 613
45	299 197
46	294 951
47	283 472
48	305 631
49	293 440
50	303 486

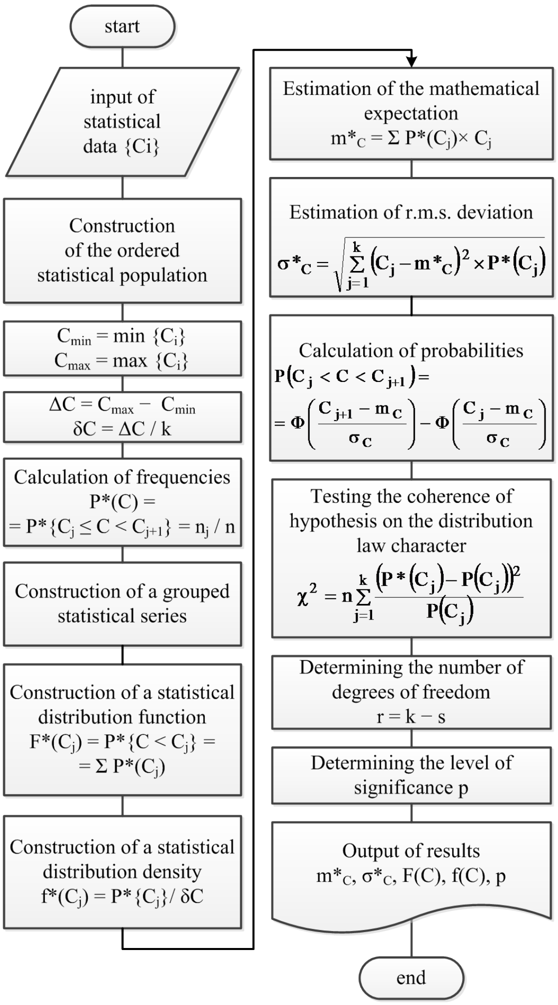

Fig. 3. Block diagram of the algorithm for statistical processing of results of the experiment

First, based on the results of experiment, given in Table 1, we construct an ordered statistical population of the observed values for a random variable of the rate of multimedia data stream C_i (Table 2). For this purpose, the observed values of a random variable C_i are arranged in ascending order. Next, we determine a minimum $C_{\min}$ and a maximum $C_{\max}$ of the observed values for the multimedia data stream rate C_i. Then we define the limits of range ΔC of the observed values C_i by using expression

$$\Delta C = C_{\max} - C_{\min}. \tag{1}$$

In this case,

$C_{\min}$=266 304 bps;

$C_{\max}$=318 396 bps;

ΔC=52 092 bps.

Nest, range ΔC is divided into k intervals of equal length

$$\delta C = \left\lceil \frac{\Delta C}{k} \right\rceil,$$

where sign $\lceil \; \rceil$ denotes rounding to a larger integer (Fig. 4). In this case, k=10, δC=5 210 bps.

Table 2

Ordered statistical population based on the results of experiments given in Table 1

i	*C* value, bps
1	266 304
2	271 824
3	278 613
4	279 721
5	281 088
6	282 793
7	282 938
8	283 472
9	286 100
10	286 363
11	287 527
12	289 996
13	290 186
14	290 244
15	290 548
16	291 075
17	291 286
18	291 526
19	291 584
20	291 707
21	293 133
22	293 319
23	293 440
24	293 508
25	294 056
26	294 600
27	294 607
28	294 607
29	294 951
30	295 331
31	295 595
32	297 436
33	297 461
34	298 214
35	299 197
36	299 295
37	300 335
38	300 474
39	301 041
40	301 595
41	301 811
42	302 515
43	302 768
44	303 486
45	303 862
46	304 682
47	305 631
48	305 730
49	309 254
50	318 396

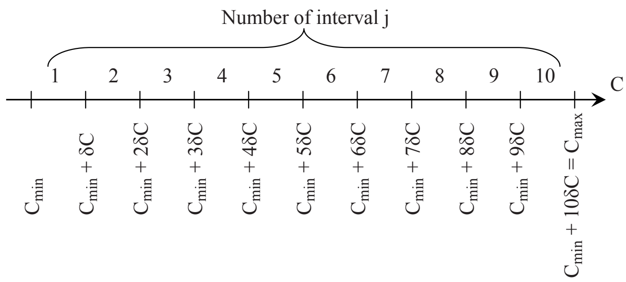

Fig. 4. Division of the range of the observed values for a random variable C into intervals

Then we count the number of cases a random variable C hits the j-th interval (Table 3) (Fig. 5).

Each interval can be assigned with a single value for a random variable C, equal, for example, to the midpoint of interval $\bar{C}_j$. The hit rate of random variable C in the j-th interval can be derived from formula

$$P^*(\bar{C}_j)=P^*\{C_j\le C\le C_{j+1}\}=\frac{n_j}{n}, \tag{2}$$

where n_j is the number of hits in the j-th interval; n is the total number of experiments.

Table 3

Quantity and frequency of cases when a random variable C hits the j-th interval

Number of interval j	Left bound of the interval	Interval midpoint $\bar{C}_j$	Right bound of the interval	Number of cases when C hits the j-th interval n_j	Frequency of cases when C hits interval $P^*(\bar{C}_j)$
1	266 304	268 909	271 514	1	0.02
2	271 514	274 119	276 724	1	0.02
3	276 724	279 329	281 934	3	0.06
4	281 934	284 539	287 144	5	0.10
5	287 144	289 749	292 354	10	0.20
6	292 354	294 959	297 564	13	0.26
7	297 564	300 169	302 774	10	0.20
8	302 774	305 379	307 984	5	0.10
9	307 984	310 589	313 194	1	0.02
10	313 194	315 799	318 405	1	0.02

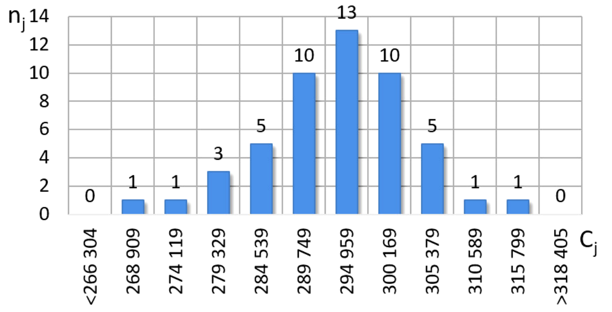

Fig. 5. Histogram of the number of cases a random variable C hits the j-th interval

Next, based on the data obtained, we construct a grouped statistical distribution series for random variable C (Table 4). Once a grouped statistical series is built, we construct a statistical distribution function of a random variable C (Table 4) using formula

$$F^*(C_j)=P^*\{C<C_j\}=\sum_{i=1}^{j}P^*(C_i). \tag{3}$$

Table 4

Grouped statistical series, a statistical distribution function $F^*(C_j)$ and the density of frequency $f^*(C_j)$ for a random variable C

$C_j\div C_{j+1}$	j											
	0	1	2	3	4	5	6	7	8	9	10	11
$P^*\{C_j\le C<C_{j+1}\}$	0	0.02	0.02	0.06	0.1	0.2	0.26	0.2	0.1	0.02	0.02	0
$F^*(C_j)=$ $=P^*\{C\le C_j\}$	0	0.02	0.04	0.1	0.2	0.4	0.66	0.86	0.96	0.98	1	1
$f^*(C_j)$, $\times10^{-5}$	0	0	0.38	0.38	1.15	1.92	3.84	4.99	3.84	1.92	0.38	0

Thus,

$F^*(266\ 304)=P^*\{C<266\ 304\}=0;$

$F^*(271\ 514)=P^*\{C<271\ 514\}=$
$=P^*\{C<266\ 304\}+P^*\{266\ 304\le C<271\ 514\}=$
$=0+0.02=0.02;$

and so on.

A statistical distribution density (frequency density) for a random variable C can be derived by dividing the frequency of hits of a C_j value in each of the intervals by the length of this interval δC_j (Table 4)

$$f^*(C_j)=\frac{P^*(C_j)}{\delta C_j}. \tag{4}$$

Charts of statistical distribution function $F^*(C)$ and a hypothetical distribution function $F(C)$ are shown in Fig. 6. Fig. 7 shows charts of frequency density $f^*(C)$ and the probability density $f(C)$.

If we assume that a random variable C of the multimedia data stream rate is continuous, that is it can take fractional values (which, in practice, can be rounded), the character of the distribution curve suggests that a continuous random variable C of the multimedia data stream rate is distributed by the normal law (Gaussian law).

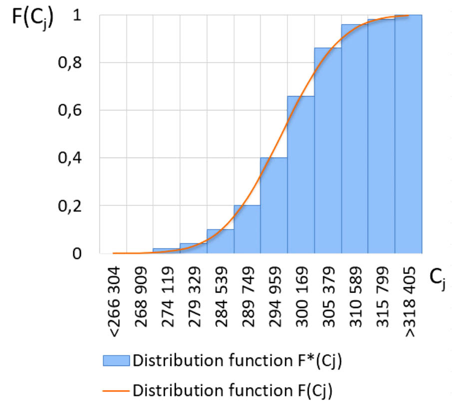

Fig. 6. Charts of the statistical distribution function $F^*(C)$ and the hypothetical distribution function $F(C)$ for the video with a resolution of 320×240

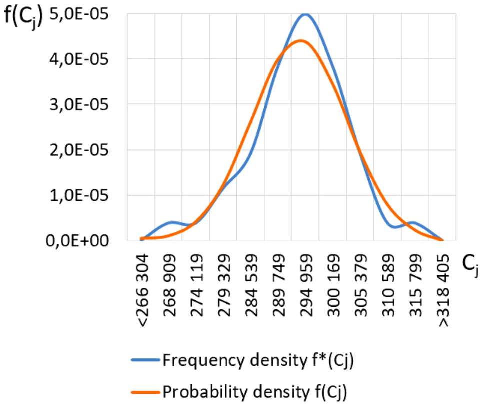

Fig. 7. Charts of the frequency density $f^*(C)$ and the probability density $f(C)$ for the video with a resolution of 320×240

Next, we estimate statistical characteristics of the random variable C distribution law, that is, mathematical expectation m^*_C and mean deviation σ^*_C. Mathematical expectation m^*_C takes the form

$$m^*_C=\sum_{j=1}^{n}\bar{C}_j P^*\left(\bar{C}_j\right)=293\,813. \tag{5}$$

Root-mean-square deviation σ^*_C takes the form

$$\sigma^*_C=\sqrt{\sum_{j=1}^{n}\left(\bar{C}_j-m^*_C\right)^2\cdot P^*\left(\bar{C}_j\right)}=9\,041. \tag{6}$$

To determine the expected probability $P(C_j)$ (Table 5), we apply formula

$$P\left(C_j<C<C_{j+1}\right)=\Phi\left(\frac{C_{j+1}-m_C}{\sigma_C}\right)-\Phi\left(\frac{C_j-m_C}{\sigma_C}\right), \tag{7}$$

where $\Phi(x)$ is a Laplace function, calculated from known formula

$$\Phi(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x}e^{-\frac{t^2}{2}}\mathrm{d}t. \tag{8}$$

Table 5

The expected probability of cases when a random variable C hits the j-th interval

Number of interval j	Left bound of interval C_j	Right bound of interval C_{j+1}	Frequency of C hitting interval $P^*(C_{j+1})$	Expected probability of C hitting interval $P(C_{j+1})$
1	266 304	271 514	0.02	0.00683
2	271 514	276 724	0.02	0.02255
3	276 724	281 934	0.06	0.06507
4	281 934	287 144	0.10	0.13593
5	287 144	292 354	0.20	0.20552
6	292 354	297 564	0.26	0.22498
7	297 564	302 774	0.20	0.17830
8	302 774	307 984	0.10	0.10230
9	307 984	313 194	0.02	0.04249
10	313 194	318 405	0.02	0.01277

To test the proposed hypothesis H_0 that assumes that a random variable for the multimedia data stream rate C is distributed by the normal law, we can use the Pearson χ^2 consensus criterion

$$\chi^2=n\sum_{j=1}^{k}\frac{\left(P^*\left(C_j\right)-P\left(C_j\right)\right)^2}{P\left(C_j\right)}=2.99483. \tag{9}$$

The significance level in this case is set at α=0,01.

The number of degrees of freedom r in this case is equal to the number of intervals k=10 minus the number of independent conditions imposed on frequencies.

Such conditions are as follows:

– the experiment covers a complete group of events

$$\sum_{j=1}^{k}P^*\left(C_j\right)=1; \tag{10}$$

– statistical mean m^*_C and hypothetical mathematical expectation m_C coincide

$$m_C=m^*_C=\sum_{j=1}^{k}C_j P^*\left(C_j\right); \tag{11}$$

– statistical and hypothetical root-mean-square deviation σ^*_C coincide

$$\sigma_C=\sigma^*_C=\sqrt{\sum_{j=1}^{k}\left(\bar{C}_j-m^*_C\right)^2\cdot P^*\left(\bar{C}_j\right)}. \tag{12}$$

Hence, r=10–3=7.

Based on values r=7 and χ^2=2.99483, we find the probability that a random variable, distributed according to the χ^2 law, exceeds a given value. This probability can be found using the tables, given in literature [19], or using specialized mathematical programs. A value for the significance level, p=0.88548, derived in a given experiment, significantly exceeds the assigned α=0.01. This means that the probability that the proposed hypothesis H_0 on that the character of a random variable C distribution is contrary to experimental data, is very low. Thus, one could argue that the hypothesis on that the random variable C of multimedia data stream rate is in line with the normal law of distribution is consistent with the experimental data.

5. Results of the experimental estimation of multimedia data flow rate in a computer network

By analogy with the above calculations, we obtained values for numerical characteristics of the random variable C and tested hypotheses about the normal character of its distribution for other experiments. The results are given in Table 6. The total bit rate of video and audio data is taken from the video file attributes and is the original data.

Fig. 8–15 show charts of statistical distribution function $F^*(C)$, a hypothetical distribution function $F(C)$, the density of frequency $f^*(C)$ and the probability density $f(C)$ for experiments with multimedia data streams with the parameters of video given in Table 6.

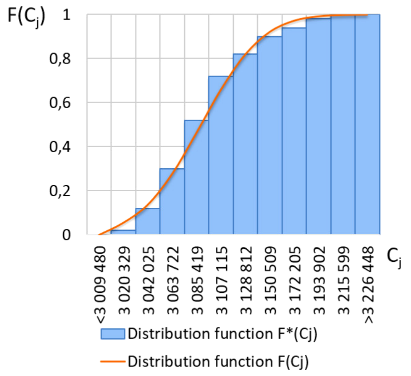

Fig. 8. Charts of the statistical distribution function $F^*(C)$ and the hypothetical distribution function $F(C)$ for the video with a resolution of 382×288

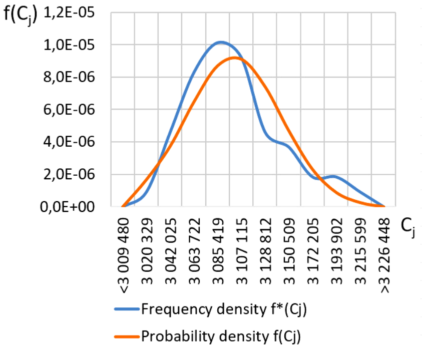

Fig. 9. Charts of the frequency density $f^*(C)$ and the probability density $f(C)$ for the video with a resolution of 382×288

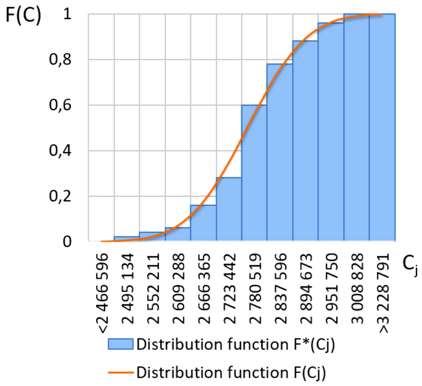

Fig. 10. Charts of the statistical distribution function $F^*(C)$ and the hypothetical distribution function $F(C)$ for the video with a resolution of 640×480

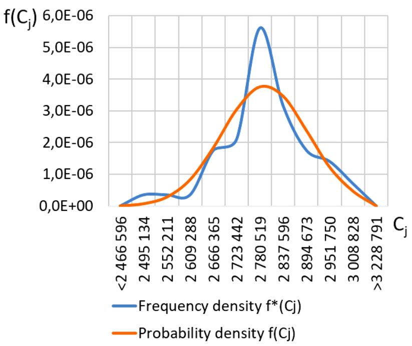

Fig. 11. Charts of the frequency density $f^*(C)$ and the probability density $f(C)$ for the video with a resolution of 640×480

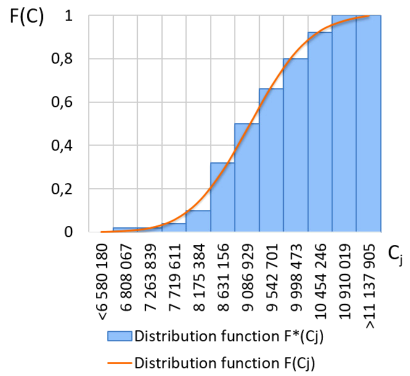

Fig. 12. Charts of the statistical distribution function $F^*(C)$ and the hypothetical distribution function $F(C)$ for the video with a resolution of 1280×720

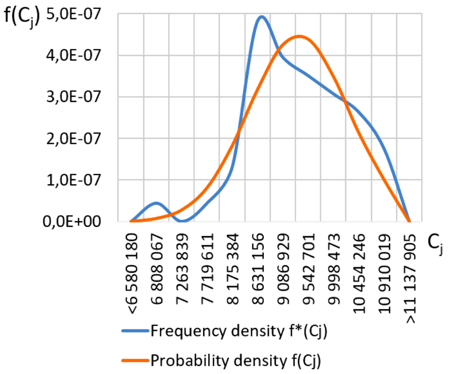

Fig. 13. Charts of the frequency density $f^*(C)$ and the probability density $f(C)$ for the video with a resolution of 1280×720

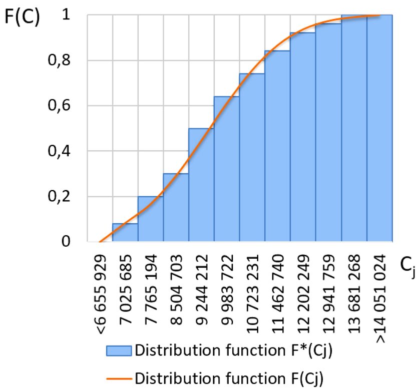

Fig. 14. Charts of the statistical distribution function $F^*(C)$ and the hypothetical distribution function $F(C)$ for the video with a resolution of 1920×1080

Table 6

Results of the experimental estimation of multimedia data flow rate

Video parameters		Total rate of video and audio data flow, bps	Experimental estimation C, bps		Significance level p
Resolution	Frame rate/s		m^*_C	σ^*_C	
320×240	15	243 000	293 813	9 041	0.89
384×288	25	2 983 000	3 100 172	43 272	0.50
640×480	25	2 689 000	2 793 076	105 424	0.39
1,280×720	30	9 097 000	9 369 508	892 616	0.33
1,920×1,080	25	9 160 000	9 850 610	1 779 069	0.74

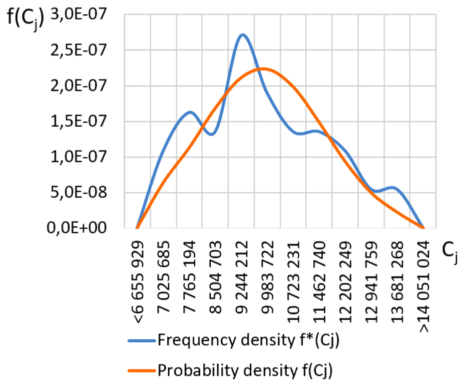

Fig. 15. Charts of the frequency density $f^*(C)$ and the probability density $f(C)$ for the video with a resolution of 1,920×1,080

In all the cases considered, the value of multimedia data stream rate estimates exceeded values, given in test files, by 3...20 %. Significance level p in all experiments is significantly larger than the preset value α=0.01. This means that the proposed hypothesis H_0 about the character of distribution of the random variable C for the multimedia data stream rate is consistent with experimental data with a probability of 99 %.

6. Discussion of results of the experimental estimation of multimedia data flow rate in a computer network

The character of statistical distribution functions $F^*(C)$ (Fig. 6, 8, 10, 12, 14) and the frequency density $f^*(C)$ (Fig. 7, 9, 11, 13, 15) for a random variable of the multimedia data stream rate in a computer network, derived from the experiment, allows us to assume that the random variable is governed by the normal distribution law.

In our work, we obtained results of the experimental estimation of multimedia data flow rate in a computer network in the form of numerical characteristics of a random variable, distributed by the normal distribution law, specifically mathematical expectation m^*_C and root-mean-square deviation σ^*_C for the data flow rate. Based on these characteristics, we derived analytical expressions for the distribution function $F(C)$ and probability density $f(C)$. The hypothesis on that the random variable obeys a normal distribution law was tested based on the Pearson χ^2 consensus criterion, and, with a probability of 99 %, is consistent with experimental data.

The developed method for the experimental estimation of multimedia data flow rate in a computer network differs from methods based on queueing theory or the theory of self-similar processes by using, as the law of distribution of a random variable of data flow rate, the normal law as a superposition to disparate laws of distribution.

Using the proposed method makes it possible to obtain scientifically sound values of the range of values of multimedia data stream rate with a high confidence probability. According to the rule of “three σ” [19], a value of the random variable for multimedia data flow rate deviates from its mathematical expectation by the magnitude not exceeding 3σ, with a probability of 0.0027. Thus, with probability P=1–0.0027=0.9973, one can argue that the transmission of video with a resolution of 320×240 and a refresh rate of 15 frames per second would require a throughput from 266 689 to 320 937 bps. These calculations suggest that the transmission of video with a theoretically required rate of 243 Kbps in practice would require a rate of 321 Kbps, which is 20 % higher. This may be due to the redundancy of protocols at the transportation, network, and channel levels, which, depending on the TCP segment useful load, may range from 4 % to 30 % [6]. At a large number of user connections, the divergence may increase. Therefore, in the process of designing new, and upgrading existing, network segments, values for the required throughput should be increased by 20 %.

7. Conclusions

1. We have designed an experiment that includes a client computer, which captures traffic from a multimedia data stream, a media server, and the communication equipment Gigabit Ethernet in a local computer network. The software WireShark, version 2.4.3, was used as a network analyzer. We conducted an experiment to capture traffic at five different sets of parameters for multimedia, which resulted in the sets of observed values for a random variable of multimedia data stream rate in a computer network at different video settings.

2. A method for the experimental estimation of multimedia data stream rate in a computer network was developed, based on the methods of mathematical statistics. The devised method, in contrast to the existing ones, is based on considering the rate of multimedia data stream as a random variable that obeys the normal distribution law. The method makes it possible to obtain a reliable estimate of rate C in the form of numerical characteristics of a random variable   its expected value and a standard deviation. One can also calculate the probability of any value for the rate of multimedia data stream $P(C)$; we built its probability distribution function $F(C)$ and a probability density function $f(C)$.

3. By using the developed method, we analyzed the derived results of multimedia data stream rate in a computer network at different values of resolution and video frame rate (Table 6). The results of analysis clearly showed that the actual rate of data flow exceeds the theoretical one by 3...20 %, which could exert a significant impact on the performance of a computer network. This fact should be taken into consideration by the designers of computer networks and network integrators when developing projects of networks.

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