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ANALYTIC MODEL OF THE REAL TIME TRAFFIC TRANSMISSION REQUESTS SERVICE IN A TELECOMMUNICATION NETWORK

Most of the information streams are transmitted through the modern telecommunication networks with packet switching form multimedia traffic. User's requests arrive irregularly and cause ineffective channel utilization. The requests buffering for the real time flows is also proposed, i.e. rejected requests can be served later, when the requested bandwidth is available. This paper deals with a new analytic model of the real time traffic transmission requests service. This model shows how maximum requests queue size influences on the value of the channel utilization coefficient. The results of analytic modeling are verified with imitation modeling experiments.

Key words: *channel efficiency, channel utilization coefficient, requests buffering, analytic model.*

Introduction

Most part of the information streams are transmitted through the modern telecommunication networks with packet switching form multimedia traffic. The information transmission intensity, initiated by the work of appropriate software in real time, is high enough and close to constant value. Therefore such kind of traffic is frequently called streaming traffic or real time traffic.

User's requests arrival for the real time flows transmission varies randomly. The multimedia transmission requests irregularity leads to short-term overloads, on the other hand, it is the reason of the underloaded time periods appearance. The mentioned consequences cause ineffective channel utilization [5]. For the quantitative estimation of the telecommunication network channel utilization, channel utilization coefficient is used. There are several approaches to its computation which are given below.

I. Analysis of the existing approaches to the telecommunication network channel efficiency computation

As it has been mentioned above, channel efficiency is one of the main network performance characteristics which shows its' loading. In most cases utilization coefficient means the current to the maximum bandwidth ratio [4]. Channel utilization coefficient is usually measured in relative units. Foreign sources distinguish two notions: channel utilization and channel efficiency having different meaning.

The channel efficiency, also known as bandwidth utilization efficiency, in percentage is the achieved throughput related to the net bitrate in bit/s of a digital communication channel. For example, if the throughput is 70 Mbit/s in a 100 Mbit/s Ethernet connection, the channel efficiency is 70%. In this example, effective 70Mbits of data are transmitted every second.

Channel utilization is instead a term related to the use of the channel disregarding the throughput. It counts not only with the data bits but also with the overhead that makes use of the channel. The transmission overhead consists of preamble sequences, frame headers and acknowledge packets. The definitions assume a noiseless channel. Otherwise, the throughput would not be only associated to the nature (efficiency) of the protocol but also to retransmissions resultant from quality of the channel. In a simplistic approach, channel efficiency can be equal to channel utilization assuming that acknowledge packets are zero-length and that the communications provider will not see any bandwidth relative to retransmissions or headers. Therefore, certain texts mark a difference between channel utilization and protocol efficiency.

In a point-to-point or point-to-multipoint communication link, where only one terminal is transmitting, the maximum throughput is often equivalent to or very near the physical data rate (the channel capacity), since the channel utilization can be almost 100% in such a network, except for a small inter-frame gap.

For example, in Ethernet the maximum frame size 1526 bytes (maximum 1500 byte payload + 8 byte preamble + 14 byte header + 4 Byte trailer). An additional minimum interframe gap corresponding to 12 byte is inserted after each frame. This corresponds to a maximum channel utilization of 1526/(1526+12)100% = 99.22%, or a maximum channel use of 99.22 Mbit/s inclusive of Ethernet datalink layer protocol overhead in a 100 Mbit/s Ethernet connection.

The maximum throughput or channel efficiency is then 1500/(1526+12) = 97.5 Mbit/s exclusive of Ethernet protocol overhead [4].

Utilization coefficient is an important parameter for the shared medium technologies. If the type of access method is random, so the high value of the utilization coefficient means the low payload throughput, i.e. the low users' data speed. For the network nodes it takes a lot of time for the getting access procedure and retransmissions of the frames after collisions.

If there are no collisions and no waiting for access, network utilization coefficient depends on the size of the frame data field. If the network is loaded up to 50%, Ethernet technology manages the traffic, generated by end nodes, works well on the shared segment. But when the intensity of the generated traffic grows rapidly, the network begins to work ineffectively, retransmitting the frames, which caused collision. As the intensity of the generated traffic grows so that utilization coefficient tends to 1, the collision probability is so high that almost every frame, transmitted by any station, clashes another frame, causing collision. So the network doesn't transmit useful data and works on collision handling.

This effect is well-known in practice and it is researched with the help of imitation modeling. That's why it is recommended to load Ethernet segments so that utilization coefficient is less than 30%. That's exactly why in many controlling systems threshold limit for the Ethernet network load coefficient is set 30% on default [4]. As we can see such technique of utilization coefficient estimation lets us to value the channel efficiency taking into account only the generated traffic intensity. Obviously, the network loading on 30% gives evidence of inefficient channel resources utilization.

In some foreign sources [6] you can find a notion of the protocol efficiency. We define the efficiency of a protocol to be the ratio of communicated information to the channel bandwidth (percentage channel utilization). Protocols are maximally efficient when the node buffer size is less than the bandwidth-delay product (Equation 1.1). The formula is linear in the number of buffers, but inverse in the round trip time, so increases in latency may have severe effects on channel efficiency. There is a point at which the linear lookahead fails (i.e., cannot further anticipate the data stream required by the receiver), and utilization diminishes.

$$K_{util} = \begin{cases} \dfrac{B}{R}, & \text{where } R > B; \\ 1, & \text{where } R \le B, \end{cases} \qquad (1.1)$$

where B – number of buffers in sliding window protocol; R – buffers used in one round trip [6].

However, such method is only suitable for the sliding window protocol efficiency estimation. It is impossible to evaluate channel utilization altogether, especially it is impractical to estimate real time traffic transmission efficiency.

There is an approach to the estimation of the efficient channel utilization, by which we mean the time of:

t_1 – the channel is assigned to user regardless load;

t_2 – the same and paid by user;

t_3 – activity, i.e. the messages are transmitted;

t_4 – useful data is transmitted, excluding address and service and $t_4 < t_3 < t_2 \le t_1 < t_4$, where t_c – correct channel work.

In this case the utilization coefficient is equal to the ratio:

$$\eta = \frac{t_1}{t_{ñ}} \quad \text{or} \quad \eta = \frac{t_1}{T}, \qquad (1.2)$$

where T – the full channel exploitation time [7].

Such an approach to channel utilization estimation doesn't show the value of the real channel load. It only shows the general extent of the channel load. Using this method it is impossible to estimate how efficiently one or another kind of traffic is transmitted.

The analysis that has been carried out, shows that using existing methods of channel utilization coefficient estimation, it is impossible to calculate exactly how efficiently the channel bandwidth is used. On one hand, we can define how the network is loaded or to calculate the time of the channel utilization. It is recommended to load Ethernet channels no more than 30% for the correct data transmission, while the maximum channel utilization coefficient is 97,5%. Also, these techniques cannot define how efficiently the real time traffic is transmitted.

II. The purpose of the article and statement of a problem

This article deals with a new analytic model for the quantitative estimation of the network channel utilization. Besides, rejected requests can be served later, when the requested bandwidth is available, i.e. requests buffering for the real time flows is applied. Implementation of this idea can smooth the requests flow and use the bandwidth more efficiently [5].

The purpose of the article is to receive quantitative information about channel utilization dependence from buffering parameters for the real time traffic flows.

The article presents the scientific problem solution, consisting of developing a new analytic model for the quantitative estimation of the enhancing network channel utilization, received from buffering the requests for the real time flow transmission.

Statement of a problem

We have set:

1) requests stream for the real time (RT) flow transmission through the network channel, which is simple with the parameter λ – requests arrival intensity;

2) random RT flow duration value through the network channel is distributed exponentially with expectancy τ – average RT flow duration;

3) variable r – average RT flow transmission speed;

4) variable C_{max} – bandwidth of the channel, transmitting RT flows;

5) variable m – number, limiting the requests for the RT flow transmission quantity, standing in the channel queue.

It is necessary:

To estimate quantitatively the channel utilization during real time flows transmission.

III. Developing an analytic model of the real time traffic transmission requests service

For the quantitative estimation of the channel utilization let us introduce a new variable U – the rate of channel utilization, which is numerically equal to the ratio of I – amount of information transmitted through the channel during the time interval Δt, to the variable I_{max} – maximum amount of information that channel is able to transmit during the same period of time.

$$U = I/I_{max} . \quad (3.1)$$

Fig. 3.1. presents the realization of the random function $C(t)$ – current channel bandwidth value, used for the RT flow transmission. The channel bandwidth C_{max} =10 Mbit/s. Maximum amount of information which can be transmitted through the channel within Δt =10 s is equal to $I_{max} = C_{max}\Delta t$ =100 Mbits.

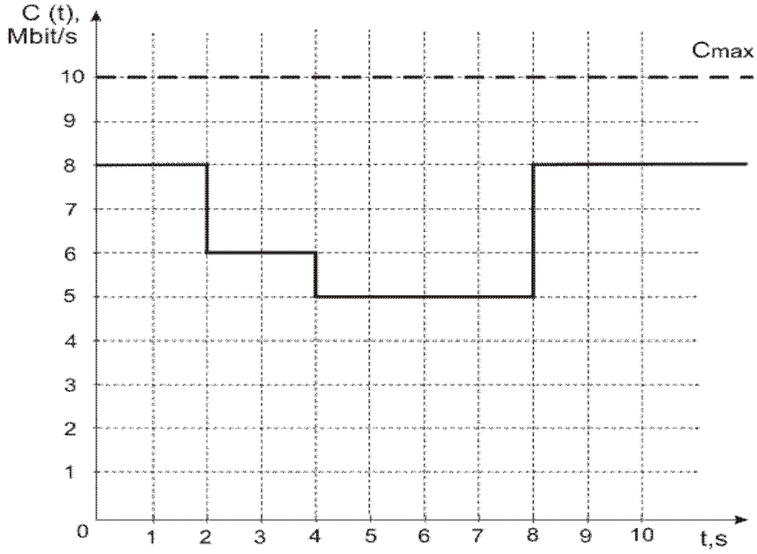

Fig. 3.1. Random function $C(t)$ realization

Actually on the interval $0 \le t < 2$ (s) – 16 Mbits, on the interval $2 \le t < 4$ (s) – 12 Mbits, on the interval $4 \le t < 8$ (s) – 16 Mbits and on the interval $8 \le t \le 10$ (s) – also 16 Mbits. Totally 60 Mbits of the information have been transmitted for 10s. In this case channel utilization coefficient is equal to $U = 0{,}6$, i.e. on the set interval during RT flow transmission 60% of channel bandwidth was used.

For the U estimation we can use the channel bandwidth expectancy – C_{av} – bandwidth mean value, which is defined by

$$C_{av} = AI_1 . \quad (3.2)$$

The variable A can be interpreted as the average number of requests, which can be served by the network channel per unit time. If all the received requests can be served by the channel, then the mentioned variable is equal to $A_{max} = \lambda$. Otherwise, the following equality is true:

$$A = \lambda(1-p) , \quad (3.3)$$

where p – probability of the request rejection for the RT flow transmission.

The average amount of information, containing in one RT flow, can be defined as a product of the average RT flow duration and the average speed of its transmission:

$$I_1 = \tau r . \quad (3.4)$$

Therefore we get:

$$U = \frac{I}{I_{max}} = \frac{C_{cp}\Delta t}{C_{max}\Delta t} = \frac{AI_1}{C_{max}} = \frac{\lambda\tau r}{C_{max}}(1-p) .$$

In the teletraffic theory the $\lambda\tau$ product is called the value of incoming load and defined by ρ. Then the channel utilization parameter while transmitting RT flows can be found as:

$$U = \frac{\rho r}{C_{max}}(1-p). \qquad (3.5)$$

If there's no requests buffering for the RT flows transmission in the system, the probability of the incoming request can be calculated with Erlang formula:

$$p = \frac{\rho^n}{n!} \Big/ \sum_{k=0}^{n} \frac{\rho^k}{k!}, \qquad (3.6)$$

where n – maximum number of the RT flows that can be transmitted at the same time through the network channel.

The number n shows how many times the channel bandwidth exceeds the average RT flow transmission speed:

$$n = \frac{C_{max}}{r}. \qquad (3.7)$$

If requests buffering for the RT flows is available in the network, the rejection probability for the incoming request can be defined by the formula (3.8). This formula is used in the teletraffic theory for the systems with queue restrictions.

$$p = \frac{\frac{\rho^n}{n!}\left(\frac{\rho}{n}\right)^m}{\sum_{k=0}^{n} \frac{\rho^k}{k!} + \frac{\rho^n}{n!}\sum_{s=1}^{m}\left(\frac{\rho}{n}\right)^s}. \qquad (3.8)$$

It is easy to see that as $m = 0$ formula (3.8) transforms into formula (3.6), which is true for the system without requests buffering. Consequently, if there's no request buffering for the RT flow transmission in the network, the value of the channel utilization can be calculated by the formula:

$$U = \frac{\rho r}{C_{max}}\left(1 - \frac{\frac{\rho^n}{n!}}{\sum_{k=0}^{n}\frac{\rho^k}{k!}}\right). \qquad (3.9)$$

If the buffering of such requests is provided the following formula must be applied for the channel utilization calculation:

$$U = \frac{\rho r}{C_{max}}\left(1 - \frac{\frac{\rho^n}{n!}\left(\frac{\rho}{n}\right)^m}{\sum_{k=0}^{n} \frac{\rho^k}{k!} + \frac{\rho^n}{n!}\sum_{s=1}^{m}\left(\frac{\rho}{n}\right)^s}\right). \qquad (3.10)$$

For the adequacy substantiation of the analytic model the imitation models are developed in the software environment MATLAB + Simulink. These models allow receiving the quantitative data, reflecting the dependence of the channel utilization from the buffering requests parameters for the RT flows transmission. The block diagram of the requests service imitation model with requests buffering is given in Fig. 3.2.

The elements of the model imitate:

- Exp Delay – provides the calculation of the time intervals between the starting points of RT flows transmission (they are exponentially distributed);

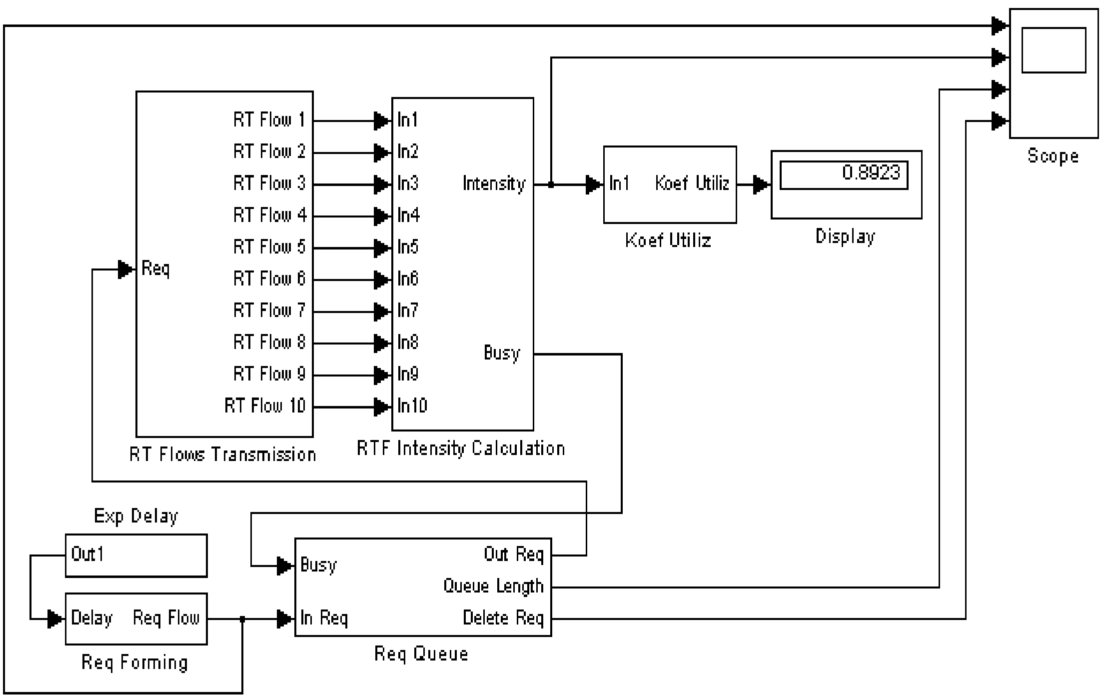

Fig. 3.2. Block diagram of the requests service imitation model with requests buffering

- Req Forming – imitates forming requests for the real time flows transmission;
- RTF Flow Transmission – processes incoming requests and estimates whether transmission is possible at a certain time period;
- RTF Intensity Calculation – is used for the RT flows transmission intensity calculation at a current time period;
- Koef Utiliz – calculates the channel utilization coefficient;
- Scope –virtual registrator for displaying incoming and rejected requests for the real time flows transmission and current intensity values;
- Req Queue – imitates the requests queue for the RT flows transmission.

The series of imitation experiments has been provided, using the developed models. During these experiments the utilization coefficient has been calculated with the different buffer size $m = 0, 2, 4, 6$. Eventually we obtained the diagrams showing the value U received using analytic (2) and imitation (1) modeling (Fig. 3).

The results we have obtained differ by less than 1,5%, therefore we can suppose that analytic and imitation models are adequate.

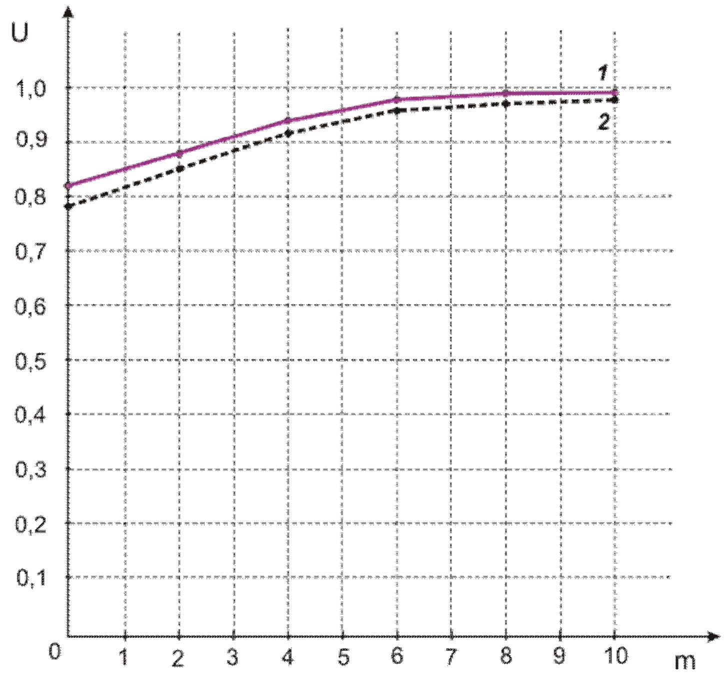

Fig. 3.3. Dependence U from m diagram

The models adequacy is proven by:

1) the calculation results control while running imitation process;

2) the correct models work verification in the situations typical for the investigated process;

3) the comparison of the results obtained while analytic and imitation modeling.

Conclusions

1. Analysis of the existing channel utilization coefficient calculation methods shows that they cannot estimate the real time traffic transmission efficiency.

2. An analytic model has been developed, which enables the channel utilization estimation while transmitting the real time flows.

3. Imitation models of the real time flow transmission requests service have been elaborated.

4. Results of the experiments show that analytic and imitation modeling differ by less than 1,5%, therefore they can be considered adequate.

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АНАЛІТИЧНА МОДЕЛЬ ОБСЛУГОВУВАННЯ ЗАПИТІВ НА ПЕРЕДАЧУ ПОТОКІВ РЕАЛЬНОГО ЧАСУ У ТЕЛЕКОМУНІКАЦІЙНІЙ МЕРЕЖІ

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Більшість інформаційних потоків передаються сучасними телекомунікаційними мережами зі зміною пакета від мультимедійного трафіку. Користувальницькі запити є причиною неефективного використання каналу. Пропонується буферизація запитів для потоків реального часу, тобто відхилені запити будуть обслужені пізніше, коли буде доступна пропускна здатність каналу. Стаття розглядає нову аналітичну модель обслуговування запитів на передачу потоків реального часу. Представлена модель може бути використана для дослідження впливу максимальної довжини черги запитів на коефіцієнт утилізації каналу. Результати аналітичного моделювання верифікуються експериментами імітаційного моделювання.

Ключові слова: використання каналу, коефіцієнт утилізації каналу, буферизація запитів, аналітична модель.

АНАЛИТИЧЕСКАЯ МОДЕЛЬ ОБСЛУЖИВАНИЯ ЗАПРОСОВ НА ПЕРЕДАЧУ ПОТОКОВ РЕАЛЬНОГО ВРЕМЕНИ В ТЕЛЕКОММУНИКАЦИОННОЙ СЕТИ

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Большинство информационных потоков передаются современными телекоммуникационными сетями со сменой пакета от мультимедийного трафика. Пользовательские запросы являются причиной неэффективного использования канала. Предлагается буферизация запросов для потоков реального времени, т.е. отклоненные запросы будут обслужены позже, когда будет доступна пропускная способность канала. Статья рассматривает новую аналитическую модель обслуживания запросов на передачу потоков реального времени. Представленная модель может быть использована для исследования влияния максимальной длины очереди запросов на коэффициент утилизации канала. Результаты аналитического моделирования верифицируются экспериментами имитационного моделирования.

Ключевые слова: используемость канала, коэффициент утилизации канала, буферизация запросов, аналитическая модель.

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