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COMPARATIVE EVALUATION OF PUASSON'S AND SELF-SIMILAR TRAFFIC OF TELECOMMUNICATIONS NETWORKS

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Abstract: The question of estimation and choice of a way of management of a telecommunication network in the conditions of considerable loading for various structures of traffic is considered. The requirements to the characteristics of the software switch for the simplest and self-similar input streams are analyzed and formulated. The expediency of increasing the number of independent parallel channels of the software switch with the organization of the general queue to several input ports is caused.

The concept of the network management system is proposed, which consists in the use of a two-level model of the autonomous segment with a four-level model of the network as a whole. It is shown that the transition from centralized management to management of autonomous segments allows to increase the reliability of management systems and reduce the amount of service traffic.

Keywords: self-similar traffic, control protocol, telecommunication network, Hearst parameter, queuing system, overload, congestion, quality management

ПОРІВНЯЛЬНІ ОЦІНКИ ПУАССОНІВСЬКОГО І САМОПОДІБНОГО ТРАФІКІВ ТЕЛЕКОМУНІКАЦІЙНИХ МЕРЕЖ

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Анотація. Розглянуто питання оцінки і вибору способу управління телекомунікаційною мережею в умовах значного завантаження для різних структур трафіку. Показана необхідність роздільної обробки трафіку не тільки з різними статистичними характеристиками, але і з принциповими відмінностями в структурі трафіку. Виконані асимптотичні порівняльні оцінки для класичного пуассонівського і самоподібного потоків одноканальної системи масового обслуговування з очікуванням. Отримані аналітичні вирази для рекурентного

обчислення розподілів тривалості очікування обслуговування для будь-якої заявки (пакета). Проаналізовані і сформульовані вимоги до характеристик програмного комутатора для найпростішого і самоподібного вхідного потоків. Показано, що швидкість зростання необхідного обсягу пам'яті зростає при збільшенні параметра Херста, який обумовлений ступенем групування однорідних пакетів і сплесками навантаження на мережу. Тому просте нарощування буферної пам'яті (апаратним або програмним способом) є малоефективним. Обумовлена доцільність збільшення числа незалежних паралельних каналів програмного комутатора з організацією загальної черги до кількох вхідним портам. Виконано порівняння основних протоколів управління мережею (SNMP і CMIP), розглянуті їх переваги і недоліки.

Запропонована концепція системи управління мережею, яка полягає в використанні дворівневої моделі автономного сегмента при чотирьохрівневій моделі мережі в цілому. Показано, що перехід від централізованого управління до управління автономних сегментів дозволяє підвищити надійність систем управління і скоротити обсяг службового трафіку. Основну частину функцій з управління слід покласти саме на рівень автономних сегментів.

Ключові слова: самоподібний трафік, протокол управління, телекомунікаційна мережа, параметр Херста, система масового обслуговування, перевантаження, якість управління

Introduction

The construction of modern telecommunications is based on the principle of integration of networks of different purposes with different principles of construction (fixed and mobile networks) and methods of switching, harmonization of computer and telecommunications technologies. Due to the constant change in the ratio between the volume of speech traffic and traffic of other information (in favor of the second), the organization of telecommunications services will be less associated with the transport of information [1-3]. It is known, this approach is the basis for building intelligent networks. Therefore, we can assume that these trends are interrelated components of the overall process of modernization of existing networks and the introduction of promising computer networks.

Statement of the research problem

The objective complexity of computer networks is primarily due to the use of the principles of dynamic routing. In addition, even in the simplest NGN models we encounter a multiparameter system, the behavior of which can be predicted only at short intervals, which are usually an order of magnitude less than the duration of the transmitted message, divided into individual packets [4]. The latter is due to changes in statistical characteristics of traffic.

A very important issue is the choice of methods for controlling the congestion of switching nodes of computer networks. The efficiency of network use is largely determined by the quality of management in overload conditions. While the network is slightly loaded, the number of processed packets is equal to the number received. However, when the network receives too much data, congestion can occur and performance may deteriorate. At excessive loadings the bandwidth of the channel

or network can become zero [1, 2, 4]. This situation can cause the network to collapse.

This may be due in part to a lack of memory for the input buffers, but even if the router has infinite memory, the congestion effect can be even more severe. This is due to the processing waiting time. If it exceeds the timeout duration, retransmitted packets appear, which reduces the useful network bandwidth. The cause of congestion can be a slow processor or a "bottleneck" – low bandwidth of a particular section of the network. Simply increasing the performance of the processor or interface does not always solve the problem – the bottleneck is usually transferred to another segment of the network.

Congestion creates avalanche processes: buffer overflow leads to the loss of packets that have to be retransmitted or even several times. The sending party's processor receives an additional spurious boot. All this suggests that congestion control is an extremely important process. A distinction should be made between flow control and congestion control. Flow control means balancing the flow of the sender and the ability to receive and process the recipient. This type of control assumes the presence of feedback between the recipient and the sender. As a rule, only two partners take part in the process. Congestion is a more general phenomenon related to the network as a whole or to its segment.

During the development and implementation of networks there was an objective need for separate processing of traffic not only with different statistical characteristics, but also with fundamental differences in structure: traffic "Triple Play" (language + video + data), and then "Quadruple Play" (language + video + data + mobile subscribers). In [5, 6] it is shown that the data traffic circulating in digital networks, and in particular in packet-switched networks, has self-similar, or fractal, properties. "Self-similarity" is the property of the process to preserve its behavior and external signs when considered at different scales. For time sequences, the magnitude of the scale is time. Based on the definition of self-similarity, it can be argued that the temporal and spectral characteristics of a random process (in our case – traffic) when changing the averaging scale will be described by the same equations, functions, but with appropriate scale factors. In other words, the self-similarity of any process (phenomenon) can be interpreted as invariance to changes in scale or size.

The peculiarity of self-similar processes is that it contains bursts of data observed at different time intervals and the correlation between packets. In contrast to Poisson processes, they are characterized by the presence of an aftereffect: the probability of the next event depends not only on time but also on previous events.

In [7, 8] it is shown that for self-similar traffic the results of the classical queuing theory should be applied with some reservations. The specific characteristics of network traffic are explained by the high degree of grouping of packets on client sites, in routers and switching nodes of infocommunication networks. Even if the source generates a regular flow of packets, the data is delivered to the consumer in series, interspersed with downtime. The reasons for this are the limited speed of network devices, insufficient buffers, etc.

The purpose of this work is a comparative analysis of different models of management of a large corporate computer network and the selection of optimal options for their implementation.

Analysis of information exchange in telecommunication networks

To obtain asymptotic comparative estimates for the classical Poisson and self-similar flows, consider a single-channel queuing system (QS) with the expectation of class G1/G/1 [9]. Since the correlation function of self-similar traffic is not exponential, the incoming flow of applications should be considered a stream with limited aftereffects [7, 10].

Applications are received in successive discrete moments $t_i, t_{i+1}, \dots, t_n, \dots, t_j \leq t_{j+1}$ for any j . The intervals between them $\tau_n = t_n - t_{n-1}$ are independent and distributed according to the same law:

$$F_n(\tau) = P\{\tau_n < \tau\}, \quad n \geq 2.$$

Duration of service applications – independent values with the law of distribution:

$$\Psi_n(\zeta) = P\{\zeta_n < \zeta\}, \quad n \geq 1.$$

Let's mark $\xi_n = \zeta_{n-1} - \tau_n$.

Then, provided that the sequences $\{\tau_n\}$ and $\{\zeta_n\}$ are mutually independent, we can determine the probability:

$$\theta(\tau) = P\{\xi_n < \tau\} = \int_0^\infty \overline{F}_n(\eta - \tau) d\Psi_n(\eta), \quad (1)$$

where $\overline{F}_n(\eta - \tau) = 1 - F_n(\eta - \tau)$.

Let us denote the waiting time of the n -th application by ω_n . If the n -th application arrives immediately after the $(n-1)$ -th, n -th application, taking into account the size of the interval τ_n , you will have to wait for service for $\omega_{n-1} + \zeta_{n-1} - \tau_n = \omega_{n-1} + \xi_n$ units of time. When large enough τ_n , the value $\omega_{n-1} + \xi_n$ can formally become negative. It is clear that in this case the actual waiting time of the n -th application will be zero – there is no queue, and the application is received for service immediately after appearance. Therefore, the recurrent relation is satisfied:

$$\omega_n = \max_n\{\omega_{n-1} + \xi_n, 0\}. \quad (2)$$

Let's mark $G_n(x) = P\{\omega_n < x\}$. Then relation (2) can be expressed in terms of distribution functions as follows:

$$G_{n+1}(x) = \begin{cases} \int_{-\infty}^x G_n(x-y) d\theta(y), & x > 0, \quad n \geq 2; \\ 0, & x \leq 0, \quad n \geq 1. \end{cases} \quad (3)$$

Supplement expression (3) with an obvious relation for the timeout function of the first application:

$$G_{n+1}(x) = \begin{cases} 1, & x > 0; \\ 0, & x \leq 0. \end{cases} \quad (4)$$

Expressions (1) and (3) are Stieltjes integrals, which in the case of continuous distribution+s almost everywhere and turn into ordinary integrals. Thus, using

expressions (3) and (4), you can recurrently calculate the waiting time distributions for the application with any number. In addition, as noted in [9, 11], it turns out that they can be applied to the interdependence of sequences of random variables $\{\tau_n\}$ and $\{\zeta_n\}$. Only the independence of quantities ξ_n matters.

It is logical to assume that the service time of the application, for example, the processing time of the packet in the software switch, is associated with a functional relationship with the length of the packet. Then, knowing the characteristics of the duration of packets at the input of the switch as a queuing system (QS), it is possible in the areas of local stationary inbound traffic to specify the parameters of the distribution of service time. For example, when grouping homogeneous packets (which is typical for self-similar traffic), it is possible to make assumptions about the determined service time (model GI/D/1).

Taking into account the results obtained above, we analyze the requirements for the characteristics of the software switch for the simplest and self-similar input streams. With the self-similar nature of traffic, the dependence of the average queue duration (respectively, the required buffer size) q on the average utilization factor is as follows [11]:

$$q = \frac{\rho^{\frac{1}{2(1-H)}}}{(1-\rho)^{\frac{H}{1-H}}}. \quad (5)$$

When the value of the Hirst parameter $H = 0.5$, this formula is simplified:

$$q = \frac{\rho}{(1-\rho)}, \quad (6)$$

which is a classic QS result with the simplest input stream and exponentially distributed service time

(M/M/1). For a system with a determined service time (M/D/1), the classic result is as follows:

$$q = \frac{\rho}{1-\rho} - \frac{\rho^2}{2(1-\rho)}. \quad (7)$$

The growth rate of the required amount of memory increases with increasing Hirst parameter, which is mainly due to the degree of grouping of homogeneous packets and bursts of load on the network.

It can also be concluded that a simple increase in buffer memory (hardware or software) is inefficient. With the expected increase in the share of data traffic in the total, the degree of self-similarity will increase, and the dependence will be more sharp. There is a tendency to constantly increase the performance of switching nodes inspires more optimism, but we must not forget that any network resources are suddenly quickly depleted with the continuous emergence of new services and applications. Good opportunities to reduce the utilization factor arise when increasing the number of independent parallel channels of the software switch with the organization of the common queue to several input ports. This simplifies the algorithms for processing priority data traffic flows by software methods.

Analysis of network management protocols with self-similar traffic

Currently, instead of the classical division of communication networks into primary and secondary networks, modern computer network architecture includes four levels:

- the level of user access to network resources;
- level of transport for data exchange;
- management level based on TMN, Softswitch and IMS technologies (IP Multimedia Subsystem);
- the level of services at which user information circulates.

When using IMS, it is possible for traditional telephone operators, mobile operators and service providers to provide services to users of all types of access networks and all types of terminals through a single backbone network based on the IP-MPLS protocol. This provides the required quality of telecommunications class services, rather than the quality of "as it turns out" (Best Effort), as in a traditional Internet service. However, IMS can only work effectively in "pure" IP networks. Therefore, IMS must be considered as an evolutionary development of Softswitch equipment.

In fact, modern networks, and the Internet in particular, are based on a rather limited list of ideas:

- packet principle of data transmission and control;
- adaptation of packet length to transmission conditions (fragmentation / defragmentation);
- encapsulation of packets into each other;
- dynamic routing.

Due to the use in computer networks of methods of dynamic routing, encapsulation / decapsulation of packets at different levels of the network architecture model, fragmentation / defragmentation of packets during their delivery, the task of estimating the parameters and state of the network is complicated. Network management tasks are also complicated. The main network management protocols today are SNMP and CMIP. The implementation of the centralized paradigm is SNMP.v2, and distributed – CMIP. Comparing the SNMP and CMIP protocols, a number of shortcomings can be identified, which in some cases can become critical.

Working with network-level protocols can lead to possible loss of messages from agents to managers. This will lead to a lack of response to events from the management system, and, consequently, to poor management. Correcting the situation by switching to the transport protocol with the establishment of connections can lead to loss of communication with the huge number of built-in SNMP agents available in the equipment installed in the networks. In addition, it will introduce additional delays.

In turn, the CMIP protocol is characterized by the following disadvantages. When describing a managed object, the conditions for including the description are informal, and therefore it may not be possible to automatically compile the definition

of the object, in contrast to SNMP. The architecture of this protocol is centralized or poorly distributed. As the number of devices increases, there are problems with the frequency of device polls.

Given these considerations, it is advisable to choose a simple SNMP management protocol as the basis of the network management system, which will provide opportunities for both prompt access to information about the state of the network and the transmission of control commands. The transition from centralized management to management of autonomous segments will increase the reliability of management systems (MS) and reduce the amount of office traffic. The main part of the management functions should be placed at the level of autonomous segments. In each of the segments, the application layer control protocol commands can be packed into channel layer frames, bypassing 4 intermediate layers. This will significantly reduce the feedback time with network elements and improve the quality of segment management.

In the table 1 shows a comparative characteristic of SNMP-message delay

Table 1.
A comparative characteristic of SNMP-message delay

Type of management	Additional service information for the SNMP message	Delay of one SNMP message at different baud rates, μ s				
		512 Kbit / s	1024 Kbit / s	2 Mbit / s	10 Mbit / s	100 Mbit / s
Centralized management: SNMP-TCP-IP-CN	46 byte	718	359	184	36,8	3,68
Autonomous network segment management: SNMP-CN	18 byte	281	141	72	14,4	1,44

In fig. 1 shows graphs of the dependence of the delay of the SNMP-message on the baud rate under different control methods [10].

Thus, based on a comparative analysis of different methods of managing a large corporate computer network, we can conclude that the use of management strategy at the level of autonomous segments will reduce the delay of signal and control information by at least 2.5 times, which will significantly improve management.

Conclusions

The question of estimation and choice of a way of management of a telecommunication network in the conditions of considerable loading for various

structures of traffic is considered. The necessity of separate processing of traffic not only with different statistical characteristics, but also with fundamental differences in the structure of traffic is shown. Asymptotic comparative estimates for the classical Poisson and self-similar flows of a single-channel queuing system with expectation are performed.

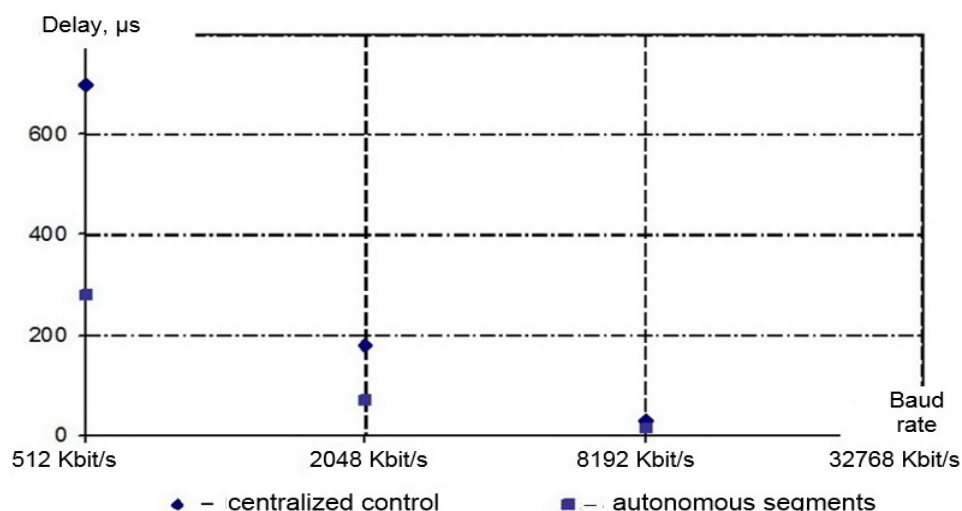


Fig. 1. Delay of SNMP-message in centralized management and management at the level of autonomous segments

The analytical expressions for recurrent calculation of distributions of duration of service waiting for any request (package) are received. The requirements to the characteristics of the software switch for the simplest and self-similar input streams are analyzed and formulated. It is shown that the growth rate of the required amount of memory increases with increasing Hirst parameter, which is due to the degree of grouping of homogeneous packets and bursts of load on the network.

The expediency of increasing the number of independent parallel channels of the software switch with the organization of the general queue to several input ports is caused. The comparison of the main network management protocols (SNMP and CMIP) is performed, their advantages and disadvantages are considered.

The concept of the network management system is proposed, which consists in the use of a two-level model of the autonomous segment with a four-level model of the network as a whole. It is shown that the transition from centralized management to management of autonomous segments allows to increase the reliability of management systems and reduce the amount of service traffic. The main part of the management functions should be placed at the level of autonomous segments.

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