Аналіз динаміки зміни середньої затримки пакетів на інтерфейсі маршрутизатора телекомунікаційної мережі

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Analysis Dynamics Change of Average Packet Delay on Telecommunication Network Router Interface

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***Анотація*—Представлені результати дослідження та аналіз динаміки зміни середньої затримки пакетів на інтерфейсі маршрутизатора телекомунікаційної мережі. Визначено, що використання стаціонарних оцінок при обчисленні таких параметрів, як середнє значення довжини черги та середньої затримки пакетів допустимо тільки після закінчення перехідного процесу. В іншому випадку, бажано використовувати більш точні диференціальні моделі. В рамках дослідження було вивчено вплив середньої швидкості потоку та пропускної здатності інтерфейсу разом з початковим станом перехідного процесу на середню довжину черги та середню затримку пакета.**

***Abstract*—Research results and analysis dynamics change of average packet delay on telecommunication network router interface presented. Determined that the use of steady state estimations when calculating such parameters as average queue length and average packet delay allowable only after the end of the transient process. Otherwise, it is advisable to use more accurate differential models. Within the research was investigated the influence of the average flow rate and interface throughput together with initial state at the beginning of the transient process to the average queue size and average packet delay.**

Ключові слова—інтерфейс маршрутизатора; інтенсивність потоку; пропускна здатність; завантаженість черги; середня довжина черги; середня затримка пакетів

Keywords—router interface; flow rate; throughput; queue utilization; average queue length; average packet delay

I. Introduction

Technological mechanisms of queue management on interfaces of telecommunication network (TCN) routers should have effective procedures to analyze its state that enable management decisions in comply with the requirements for ensuring the specified level of quality of service (QoS). Moreover, it is essential to have models describing the dynamics of the network router interface state changes in time in order to obtain more accurate estimates of the queue length and associated QoS parameters (average packet delay and others). Tools of queuing theory allow to obtain an adequate estimation of the required parameters just for steady-state interface operation, i.e., at the end of transient processes associated with a change in state. The processes of estimating the interface state and queue management are real time in the range of tens milliseconds. Thus, in current research presented actual analysis dynamics change of average packet delay on TCN router interface, because estimations of limit values may differ from the values corresponding to dynamics of transient process.

II. Queue Utilization Dynamics Model

There are currently known a lot of types of mathematical models, based on different approximations of dynamics changes in state of TCN router interface [1]. The most efficient in relation to adequacy and clarity, in our opinion, is a model based on use the nonlinear differential equation system of network state obtained by the Pointwise Stationary Fluid Flow

Approximation (PSFFA), where under the network state was understood the average queue length on the router interface [2]. There are known the following model parameters: λ is the average flow rate (packets per second, 1/s) entering the analyzed queue; μ is the interface throughput (packets per second, 1/s) allocated to this queue; $\rho = \lambda/\mu$ is the queue utilization. Several special cases of model PSFFA M/G/1 can be determined [1, 3]. Using M/M/1 queuing system in approximation the following differential equation of average queue length as function of time can be obtained:

$$\dot{q}_{ave}(t) = -\mu\left(\frac{q_{ave}(t)}{q_{ave}(t)+1}\right)+\lambda\,. \tag{1}$$

In turn, according to (1) and using Little`s law can be derived the equation for average packet delay on the network router interface. Then we have

$$\dot{\tau}(t) = 1-\mu\left(\frac{\tau(t)}{\lambda\tau(t)+1}\right)\,. \tag{2}$$

The novelty of presented equations is that average queue length and average packet delay are functions of time that can be used in dynamic modeling of telecommunication system behavior.

III. Convergence Analysis of Average Packet Delay to the Limit Value

Within the research was investigated the influence of the average flow rate and interface throughput together with initial state at the beginning of the transient process to the average queue size and average packet delay. There are shown convergence (see Fig. 1 and Fig. 2) of average packet delay to its limit value in steady state ($d\tau/dt = 0$), i.e. $\tau = 1/(\mu - \lambda)$. In this example the following two cases of router interface state considered. For the first case queue is empty and consequent initial delay is $\tau_0 = 0$ s. For second case transient process begins with the initial value $\tau_0 = 0.4$ s. Values of the flow rate and interface throughput are indicated on figures.

Results of modeling revealed that with high utilization of queue on network router interface (in the range of 0.96…0.97) average packet delay doesn't reach its limit value within observation time interval. That's why it is impossible to use steady state estimations in network management process when correct decisions can't be performed because values of queue lengths and packet delays can't be estimated adequately. In the case of zero initial delay using steady state values an overestimation of these parameters observed (Fig. 1). While when the queue on the interface is not empty ($\tau_0 \neq 0$), parameters are underestimated, which is much more critical.

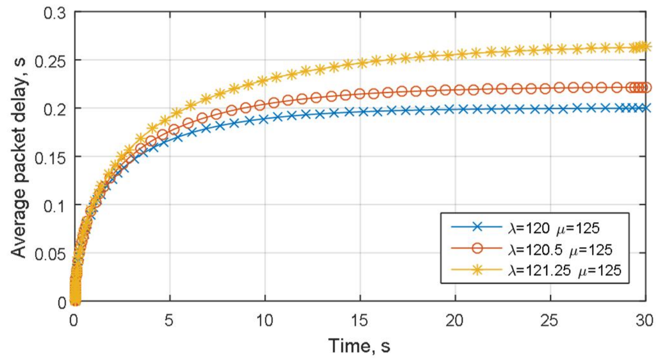

Рис. 1. Convergence of average packet delay to limit value (τ_0=0 s).

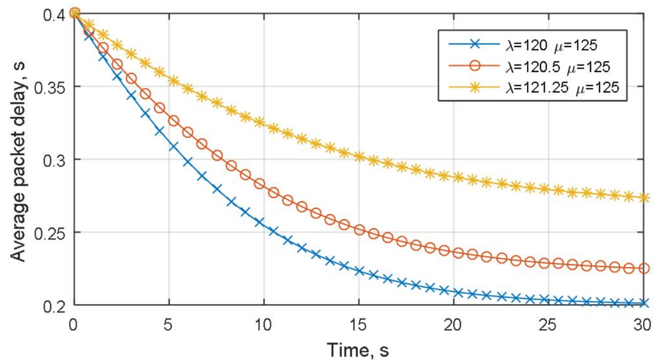

Рис. 2. Convergence of average packet delay to limit value (τ_0=0.4 s).

Conclusion

Presented model (1), (2) can be used in queue management and in solving the problems of congestion management, congestion avoidance and packet routing. Based on obtained results, it is determined that the use of steady state estimations when calculating such parameters as average queue length and average packet delay allowable only after the end of the transient process. Otherwise, it is advisable to use more accurate differential models.

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