Mathematical Description of TCP-sessions Using AQM-algorithms for Nonlinear Packet Drop Model

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Abstract - **In this paper a mathematical description of TCP-sessions using AQM-algorithms for nonlinear packet drop model is proposed. The novelty of the model is that it makes it possible to describe the dynamics of multiflow data exchange based on AQM/TCP-algorithms.**

Keywords - **TCP-sessions, AQM, NGN.**

I. Introduction

Modern and future multi-service telecommunication networks (TCS) develops in the direction of introducing the concept of Next Generation Networks (NGN) [1,2]. The effectiveness of TCS depends on the effectiveness of formulating and solving problems related to management of network resources, particularly transport protocol TCP and AQM-alorithms (Active Queue Management).

II. A Mathematical Description of TCP-sessions Using AQM-algorithms

To the mathematical description a TCP-sessions subject to the classes of service in accordance to the version TCP Tahoe [2, 3], the dynamics of multiflow data exchange using AQM-algorithms (Active Queue Management) is displayed in a system of equations:

$$\frac{d\lambda_i^k(t)}{dt}=\begin{cases}\text{slow start mode:}\\ \left(1-P^k(t)\right)\cdot\dfrac{MSS}{RTT^k}\cdot\lambda_i^k(t)-P^k(t)\cdot\left(\lambda_i^k(t)\right)^2+P^k(t)\cdot MSS\cdot\lambda_i^k(t);\\ \text{congestion avoidance mode:}\\ \left(1-P^k(t)\right)\left(\dfrac{MSS}{8\cdot RTT^k}\cdot\lambda_i^k(t)+\dfrac{MSS\cdot MSS}{\left(RTT^k\right)^2}\right)\\ P^k(t)\cdot\left(\lambda_i^k(t)\right)^2+P^k(t)\cdot MSS\cdot\lambda_i^k(t),\end{cases} \quad (1)$$

where λ_i^k - traffic intensity of TCP-session i in flow with service class k ($i=\overline{1,M^k}$), M^k - number of TCP-sessions in flow k ($k=\overline{1,K}$), K – number of service classes, RTT^k - round trip time for flow k, P^k - packet drop probability for packets with service class k.

Packet drop probability can be formalized in accordance with AQM-algorithms that realize preventive queue restriction before its actual overflow. For present the most wide-spread is a mechanism RED (Random Earlier Detection). However RED has a number of disadvantages (difficulty of the choice and need of the administrative parameter adjustment depending on conditions of the network, ungrounded packet drop).

Presence of that has caused a lot of the developments in this area and improvements of given algorithm. Amongst them it should be noted the following variants of the mathematical models of the packet drop probability, which describe the procedure of the congestion avoidance [1]:

1. Linear dependency of packet drop probability from average length queue that corresponds to packet drop probability model used within traditional algorithm RED.

2. For Random Exponential Marking algorithm (REM) [2] expression for probability P has a following view:

$$P=1-\phi^{-\sum_l p_l(t)}, \quad (2)$$

where $\phi>1$ - constant, $p_l(t)$ - congestion measure (queue length) – price for queue l.

3. Square-law dependency to probability of the casting-out package from average length queue, expression for which is of the form of

$$P^k(t)=\varphi\cdot N^k(t), \quad (3)$$

where $\varphi=\dfrac{1}{\left(N_{max}^k\right)^2}$ - normalization coefficient.

4. Nonlinear dependency of packet drop probability from average length queue presented in expression:

$$P^k(t)=\frac{1}{1+\exp\left(-d\cdot N^k(t)+\kappa\right)}, \quad (4)$$

where d and k - some parameters, dynamically changeable or adjusted by administrator.

III. Conclusion

The analysis of the state and perspectives of the modern TCS development have shown that key moment at building of the NGN networks is their ability to service heterogeneous traffic, guaranteeing correspondence to given quality of service level. So important are problems which solved within the protocol TCP. However most traffic management means, among which TCP/AQM-algorithms [1, 2], do not meet the demands on QoS providing and quite often become the reason of the TCS stability loss.

In the paper advanced mathematical TCP-session model is proposed. Within the united model (1)-(4) both processes data communication in accordance with protocol TCP, and congestion avoidance processes (AQM) are formalized. These allow the end devices to operative respond to probable overloading in network and, accordingly, avoid the ungrounded packet losses. The advantage of the proposed TCP-session description is a possibility of the choice of the type AQM-algorithm to taking into account the use the different packet drop models.

References

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