Research of Influence Flow Characteristics to Network Routers Queues Utilization

Lebedenko Tetiana
Telecommunication Systems Department
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
e-mail: tatyana_n_lebedenko@mail.ru

Ievdokymenko Marina
Telecommunication Systems Department
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
e-mail: gogolevam@gmail.com

Ali Salem Ali
Network engineering department
Al Iraqi University
Adamiya, Baghdad, Iraq
e-mail: alialbander2004@yahoo.com

***Abstract* — Research results of the influence flow characteristics to network routers queues utilization were presented. It is determined that the use of the steady state estimations when calculating the average queue length is possible only after the end of transient process. Otherwise, it is advisable to use a more accurate differential model. Results of analysis showed that the duration of transient process is influenced by such factors as flow rate, capacity of the router interface, service discipline, etc. Within this research it was shown that the use of non-linear differential model can improve the accuracy of calculation of the average queue length, depending on the state of interface and selected service discipline.**

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

I. INTRODUCTION

In scientific researches on the challenges for the organization and control queues overloading on the network routers, usually finds its application the queuing theory [1-3], with which it is possible to estimate analytically the influence of interface state (throughput, utility, and maximum size of buffer) on average queue length, and through it to numerical value of average delay, jitter and packet loss probability. However, the tools of queuing theory allow to obtain an adequate estimation of the required parameters for steady-state interface operation, i.e., at the end of transient processes associated with a change in the state of interface. Given the fact that the processes of estimating the state of interface and subsequent queue management are real time processes of tens milliseconds range, obtained estimations of the interface state using the limit values of probabilities may differ from the values corresponding to the dynamics of transient process in progress generally. Therefore, it is essential in the queue management to have models describing the dynamics of interface state changes in time in order to obtain more accurate estimates of the queue length and associated quality of service (QoS) parameters.

II. QUEUE UTILIZATION DYNAMICS MODEL

There are currently known a lot of types of mathematical models, based on different approximations of the dynamics of changes in state of telecommunication network (TCN) router interface. The most efficient in relation to adequacy and clarity, in our opinion, is a model based on the use of system of nonlinear differential equations of the network state $\dot{x}(t) = dx(t)/dt$ obtained by the Pointwise Stationary Fluid Flow Approximation (PSFFA), where under the network state was understood the average queue length on the router interface [4].

Within the chosen model there are known the following parameters: λ is the ensemble 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. The next special cases of model PSFFA M/G/1 can be determined: M/M/1, M/D/1, and M/E_k/1 [4]. Thus using in approximation queuing systems will take form:

$$\dot{x}(t) = -\mu\left(\frac{x}{x+1}\right) + \lambda \text{, (M/M/1)}, \quad (1)$$

$$\dot{x}(t) = -\mu\left[(x+1) - \sqrt{x^2+1}\right] + \lambda \text{, (M/D/1)}, \quad (2)$$

$$\dot{x}(t) = -\mu\left[\frac{k(x+1)}{k-1} - \frac{\sqrt{k^2x^2+2kx+k^2}}{k-1}\right] + \lambda \text{, (M/Ek/1)}, \quad (3)$$

where parameter k denotes the number of service stages.

III. RESEARCH OF INFLUENCE FLOW CHARACTERISTICS TO QUEUES UTILIZATION

With the selected model (1)-(3) was performed the analysis of transient processes corresponded to queues utilization on TCN router in terms of influence flow characteristics on the duration of these processes and accuracy of estimates of the average queue length. Taking into account these factors were carried out the following queuing systems: M/M/1, M/D/1 and M/E_k/1 [5].

For illustration represented the next example. Suppose that the VoIP call streams need to be transmitted. Let us consider for comparison that it is used the ITU-T G.711 and G.726.32 codecs for audio companding (Table I). Results of investigation performed are shown in Table II, where queuing systems M/M/1, M/D/1 and M/E_k/1 analyzed for different packet sizes and consequent IP bandwidth. Queuing utilization dynamics was studied according to different number of flows. Parameter characterized the dynamics is the time of convergence of the average queue length to its limit value.

TABLE I. G.711 AND G.726.32 VOIP CODECS CHARACTERISTICS

ITU-T Codec	Codec Type	Bitrate (bps)	IP Packet Size (bytes)	IP Bandwidth (bps)
G.711	PCM[a]	64000	120	96000
G.711	PCM	64000	200	80000
G.711	PCM	64000	280	74659
G.726.32	ADPCM[b]	32000	80	64000
G.726.32	ADPCM	32000	120	48000
G.726.32	ADPCM	32000	160	42662

a. Pulse Code Modulation, PCM.

b. Adaptive Differential Pulse Code Modulation, ADPCM.

Within the analysis by the average flow rate λ understood the bitrate of the VoIP stream, and μ is an IP bandwidth consumed by this flow both transformed into units of 1/s. Then it was calculated the queue utilization as $\rho = \lambda / \mu$, which varies for different sizes of packets in VoIP flow and equal to 0.67, 0.8, and 0.86 for 120 B, 200 B, and 280 B packet size for using G.711 codec, and 0.5, 0.67, and 0.75 for 80 B, 120 B, and 160 B packet size for using G.726.32 codec, respectively.

TABLE II. VOIP FLOWS QUEUE UTILIZATION DYNAMICS

ITU-T G.711 Codec				
Queuing System		**M/M/1**	**M/D/1**	**M/E$_k$/1**
Packet Size 120 B				
Queue Utilization	***Number of Flows***	***Convergence Time, s***		
ρ=64/96	1	0.4	0.28	0.42
ρ=128/192	2	0.2	0.13	0.17
ρ=192/288	3	0.16	0.09	0.13
Packet Size 200 B				
Queue Utilization	***Number of Flows***	***Convergence Time, s***		
ρ=64/80	1	2.1	1.3	1.76
ρ=128/160	2	1.3	0.65	0.87
ρ=192/240	3	0.9	0.47	0.58
Packet Size 280 B				
Queue Utilization	***Number of Flows***	***Convergence Time, s***		
ρ=64/75	1	6.3	3.4	4.8
ρ=128/149	2	3.5	1.9	2.67
ρ=192/224	3	2.8	1.2	1.83
ITU-T G.726.32 Codec				
Queuing System		**M/M/1**	**M/D/1**	**M/E$_k$/1**
Packet Size 80 B				
Queue Utilization	***Number of Flows***	***Convergence Time, s***		
ρ=32/64	1	0.3	0.17	0.23
ρ=64/128	2	0.13	0.08	0.11
ρ=96/192	3	0.1	0.058	0.8
Packet Size 120 B				
Queue Utilization	***Number of Flows***	***Convergence Time, s***		
ρ=32/48	1	0.81	0.38	0.74
ρ=64/96	2	0.5	0.27	0.44
ρ=96/144	3	0.36	0.19	0.3
Packet Size 160 B				
Queue Utilization	***Number of Flows***	***Convergence Time, s***		
ρ=32/43	1	2.3	1.24	1.57
ρ=64/85	2	1.1	0.58	0.77
ITU-T G.711 Codec				
Queuing System		**M/M/1**	**M/D/1**	**M/E$_k$/1**
ρ=96/128	3	0.76	0.47	0.57

IV. CONCLUSION

Due to the high dynamics of changes the interface state in the estimation of average queue length and related QoS key indicators it is required the use of dynamic model, obtained by applying PSFFA and representation of state by the nonlinear differential equation, where the state understood as the average queue length. The higher accuracy of calculation the average queue length, the more informed decisions on the volume of discarded packets from it, and the more accurately, in turn, can be predicted the value of average delay and packet loss probability at the router interface.

Based on the obtained results, it is determined that the use of steady state estimations when calculating the average queue length is possible only after the end of the transient process. Otherwise, it is advisable to use a more accurate differential model. As the results of the analysis, the duration of the transient process is influenced by such factors as the flow rate, capacity of the router interface, service discipline, etc. And it was found that the higher the interface throughput, the duration of transient period is lower. From the set of considered service disciplines it was found that in the case of using the model M/D/1 average queue length convergence to the limit value in the steady state is faster than for other models.

Besides, the main factors of influence flow characteristics to network routers queues utilization were concluded. It was shown that the smaller packet size flows demonstrate the faster transient process. Moreover, with the same initial data appropriate choice of queuing model can reduce the time of convergence. Within the research it was shown that the aggregation of data flows and choosing appropriate VoIP codec allow reducing the duration of the transient process with the same value of queue utilization on TCN router interface.

REFERENCES

[1] O. Lemeshko, and M. Semenyaka, “Research of Queue Management Model That Includes Congestion Avoidance Mechanism,” First International IEEE Conference Problems of Infocommunications. Science and Technology, pp. 42-44, October 2014 [Proceedings of PICS&T-2014, Ukraine, p. 203, 2014].

[2] O. Lemeshko, M. Semenyaka, and O. Simonenko, “Researching and designing of the Dynamic adaptive queue balancing method on telecommunication network routers,” XIIth International Conference The experience of designing and application of CAD systems in microelectronics, pp. 204-207, February 2013 [Proceedings of XIIth CADSM`2013, Ukraine, p. 480, 2013].

[3] O. Lemeshko, A.S. Ali, and M. Semenyaka, “Results of the Dynamic Flow-Based Queue Balancing Model Research,” Modern Problems of Radio Engineering, Telecommunications and Computer Science, pp. 318-319, February 2012 [Proceedings of the international Conference TCSET’2012, Ukraine, p. 552, 2012].

[4] W.-P. Wang, D. Tipper, and S. Banerjee, “A Simple Approximation for modeling Nonstationary Queues,” Proceedings of the Fifteenth Annual Joint Conference of the IEEE Computer Societies (INFOCOM '96), vol. 1, pp. 255–262, 1996.

[5] O.S. Yeremenko, T.M. Lebedenko, T.V. Vavenko, and M.V. Semenyaka, “Investigation of Queue Utilization on Network Routers by the Use of Dynamic Models,” Second International IEEE Conference Problems of Infocommunications. Science and Technology, pp. 46-49, October 2015 [Proceedings of PICS&T-2015, Ukraine, p. 272, 2015].