Evaluation of traffic self-similarity influence on QoS in local Ethernet network

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Abstract - **In the paper is investigated the influence of self-similar traffic on the Quality of Service (QoS) in local Ethernet network in regard to the parameters: percentage of the information packet loss, average delay and jitter of the packets. The obtained results could be used in research of high reliability networks for remote control in online engineering with higher QoS requirements.**

Keywords – **Hurst parameter, Quality of Service, self-similar network traffic, wavelet-based statistical estimator.**

I. INTRODUCTION

Many studies for real network traffic show that it exhibits self-similar property over a wide range of time scales [4]. The properties of self-similar network traffic are very different from traditional models based on Poisson and related processes [1]. The using of traditional models in the networks characterized by self-similar processes can lead to incorrect conclusions about the QoS of analyzed networks [9]. The main properties of self-similar processes include: slowly decaying variance, long-range dependence, 1/f-noise and Hurst effect. These processes are attractive models mainly because they can be characterized by a single parameter, the *Hurst parameter H*, which can be estimated by using the wavelet-based statistical method [2].

The local network design and operation is often required to ensure a certain QoS for the user or to define the network input parameter range, within the limits of which the required QoS level will be sustained in the network parameter metrics.

The paper goals are as follow:

- To present and analyze an algorithm for simulating a self-similar Ethernet traffic;
- To estimate the influence of self-similar traffic over the QoS of local Ethernet network.

II. AN ALGORITHM FOR SIMULATING A SELF-SIMILAR ETHERNET TRAFFIC

Ethernet protocol requires the length of all packets to be between 64 and 1518 bytes. For generating simulated network traffic, an average value, variance, Hurst parameter and the packets' length has to be assigned.

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The main steps of the mathematical algorithm are:

Step 1 – The input parameters are: traffic length, average length of the packet, minimal and maximal sizes of the packet, Hurst parameter, and relative average error of the Hurst parameter, number of simulated self-similar traffic streams, and the maximal number of tests, based on the wavelet statistical method for determining the degree of self-similarity of the simulated network traffic.

Step 2 - Generating of pseudo-random self-similar sequence with an average value equals zero, variance equals one and a value of the Hurst parameter in the range of 0.5 and 1.

Step 3 - The simulated self-similar sequence is normalized in order to generate only positive numbers. This is accomplished through the transformation formula $Y_i=2^{X_i}$, where X_i is a positive or negative number of the generated self-similar sequence, and Y_i is the normalized positive number, relative to the size of the informational packet of the simulated network traffic.

Step 4 - The simulated self-similar sequence from step three is normalized one more time using the assigned average value and variance.

Step 5 - Using a wavelet-based statistical method, the value of the Hurst parameter of the generated self-similar Ethernet traffic is determined.

Step 6 - The value of the Hurst parameter determined by step five is compared with the input value of the Hurst parameter. If the new value of the Hurst parameter is in the relative average error range, then save the simulated network traffic in a file, otherwise go back to step two.

Step 7 – Check whether the number of the generated network traffics is equal to the maximum number of the simulated self-similar traffic streams. If it is not go to step two, otherwise the process is over.

III. COMPARISON ANALYSIS OF SIMULATED AND REAL ETHERNET TRAFFIC

The validity of the suggested algorithm for simulating self-similar Ethernet traffic is determined by comparing the results of the above algorithm with those published online [10] by Bellcore laboratory's researchers. The results are for Ethernet traffic with self-similarity degree H=0.8.

Fig. 1 shows graphically the simulated Ethernet traffic, using low (H=0.6) and high (H=0.9) degree of self-similarity. It is obvious that the higher degree of self-similarity, the higher level of correlation exists.

Table I demonstrates the average value and the standard deviation of the packet size of the simulated Ethernet traffic, using different values of the Hurst parameter. The average value of the packet size of the simulated Ethernet traffic is lower than the average value between minimal (64 bytes) and maximal (1518 bytes) packet sizes.

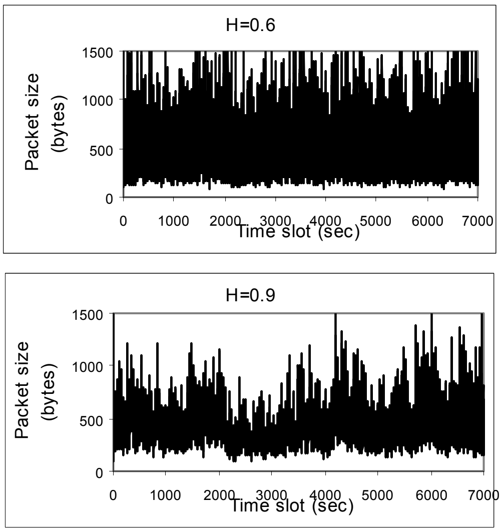

Fig. 1. Sample of synthetic Ethernet traffic

TABLE I
PACKET SIZE MEAN AND STANDART DEVIATION OF SIMULATED ETHERNET TRAFFIC

HURST PARAMETER	MEAN VALUE	STANDART DEVIATION
0.6	486.990	279.530
0.7	479.554	275.554
0.8	463.780	262.309
0.9	445.746	225.977

Fig. 2 displays the autocorrelation functions of the simulated Ethernet network traffic. Three different values of the Hurst parameter are used along with the autocorrelation function of the real Ethernet traffic, when the H=0.8 (BC_pAug89_TL). It can be concluded that the difference between autocorrelation functions of the simulated and the real network traffic it is really minor when the H=0.8.

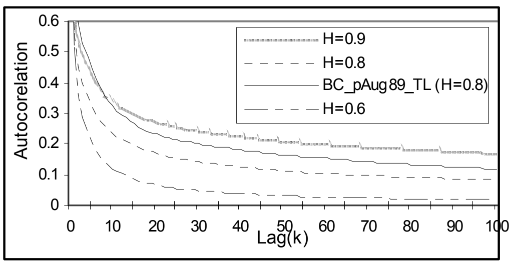

Fig. 2. Autocorrelation function plot of Ethernet traffic

On Fig. 3 are shown the graphical results of the wavelet-based method for determining the Hurst parameter of the simulated and real Ethernet traffic when the H=0.8.

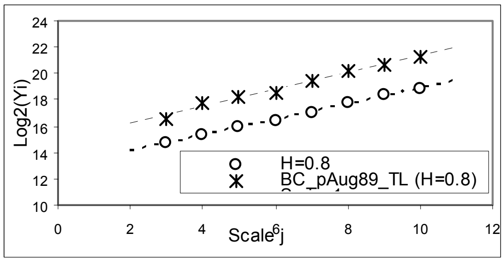

Fig. 3 Wavelet-based plots for Ethernet traffic

Table II demonstrates the determined value of the Hurst parameter and the relative error of the simulated Ethernet traffic. In this case the Hurst parameter is calculated using the wavelet-based statistical method.

TABLE II
PACKET SIZE MEAN AND STANDART DEVIATION OF SIMULATED ETHERNET TRAFFIC

INPUT HURST PARAMETER	SIMULATED ETHERNET DATA		REAL ETHERNET DATA	
	MEAN HURST	RELATIVE ERROR (%)	MEAN HURST	RELATIVE ERROR (%)
0.6	0.600779	0.129806	-	-
0.7	0.703220	0.459953	-	-
0.8	0.800333	0.041686	0.82	2.5%
0.9	0.897661	-0.25988	-	-

The results show that the simulated Ethernet traffic generated by the described above algorithm is very similar to the real Ethernet traffic. A wavelet-based statistical method is used to determine the relative error of the Hurst parameter when the input value H=0.8. The result shows that the error is approximately 2.5%, which is acceptable.

IV. RESEARCH THE INFLUENCE OF THE SELF-SIMILARITY ON QUALITY OF SERVICE IN LOCAL ETHERNET NETWORK

The influence of the self-similarity on the QoS in local Ethernet network is determined in regard to the following parameters: the percentage of the information packet loss, the average delay of the packets in the switch's queue, and the jitter of the packets of multiplexed network traffic (which is a result of the fusion of self-similar traffic streams at the switch's input ports).

The simplified model of a network node (Fig. 4) is consisted of an Ethernet switch. Consider that, two self-similar Ethernet streams are at the switch's input ports and each of them has a maximal speed of 1 Gbps. Moreover, at the ports there are three more traffic streams with total maximum input speed of 1 Gbps. Thess five input traffic streams form all together one self-similar traffic stream with total maximal speed 3 Gbps.

The speed of servicing the packets is 2 Gbps. The simulation time is 32 768 (2^{15}) seconds. The following sizes of the switch's buffer are analyzed: 1 MB, 25 MB, 50 MB, 75 MB, 100 MB and 125 MB. The bottleneck of the analyzed network node is the connection of the Ethernet switch with the feed network, which is with 2 Gbps capacity.

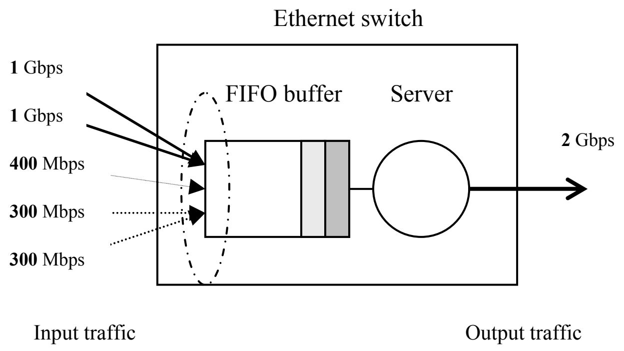

Fig. 4. Network node

Information packets loss

Information packet loss is the ratio of unserviced information packet to the total number of the input packets.

On Figure 5 are shown the graphical results of the information packets loss in respect of the network channel capacity. The traffic streams passing through this channel are with different self-similarity degree. It can be concluded that the highest loss of packets is when H=0.9 and the lowest loss is when H=0.6, 0.7, 0.8 and it is approximately 4 times lower when the channel capacity is 2 Gbps. When the channel capacity is 3 Gbps the packets loss incline to zero. The packet loss of the Poison traffic is 14 times lower than the self-similar traffic stream when H=0.9, and from 2 to 3 times lower when H=0.7 and 0.8 with a channel capacity 2 Gbps.

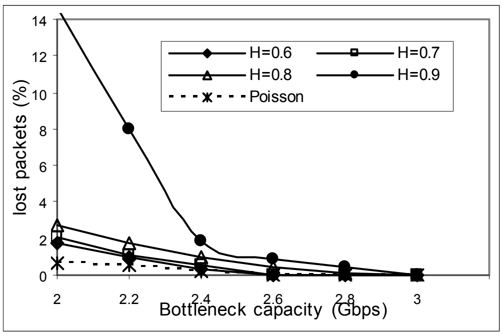

Fig. 5. Estimate of multiplexed self-similar traffic effect on the percentage of lost packets

Network traffic intensity

Traffic intensity is the ratio of the mean rate of packet arrival to the mean rate of service.

The network traffic intensity shows the extent to which the switch capacity is used. If the intensity is closed to one, the switch is overloaded and there is a queue of packets waiting to be served and it is highly possible part of them to be discarded. Contrariwise, if the traffic intensity is closed to zero, then the switched capacity is not entirely used.

On Fig. 6 is shown graphically the relation between traffic streams intensity, Hurst parameter, and network channel capacity. The intensity of the self-similar multiplexed network traffic when H=0.9 and the capacity is between 2.0 and 2.6 Gbps, decreases to 1.0 erl. Then the traffic intensity decreases to 0.9 erl. The traffic intensity of the self-similar multiplexed traffic streams when H=0.6, 0.7 and 0.8 linearly decreases with the network capacity increase. These self-similar traffic streams are with e relatively high traffic intensity. Poison traffic intensity linearly decreases when the channel capacity increases, but it stays less than 0.6 erl for the whole traffic capacity range. The Poison traffic intensity is 0.4 erl lower than the self-similar multiplexed traffic stream intensity when H=0.9, and 0.2 erl lower when H=0.6, 0.7, 0.8.

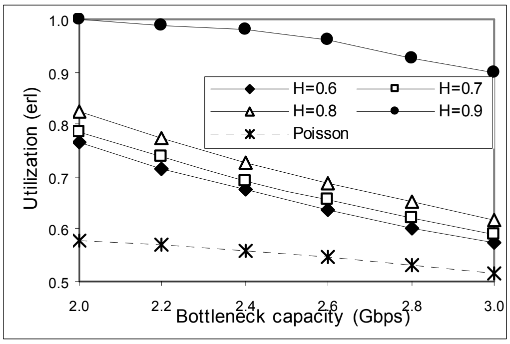

Fig. 6. Estimate of multiplexed self-similar traffic effect on the system utilization factor

Delay

The delay of the information packets in the switch buffer is the ratio of the total time the packets stay in the switch buffer to the number of input packets for a specific period of time.

On Fig. 7 is shown the relation between traffic stream delays, Hurst parameter and channel capacity. The packets delays are highest when H=0.9, and the linearly decrease with capacity channel increase. When the capacity is 2.2 and 2.4 Gbps the self-similar traffic streams delays decrease and they remind unchanged beyond these values. The Poison traffic stream delays are the lowest ones, as they remain almost unchanged with capacity channel increases.

Jitter

Jitter is the variation of delayed packets. It can be determined by the average absolute deviation and is equal to the mathematical expectancy of the absolute value of the subtraction of the packet delay by the average packets delay.

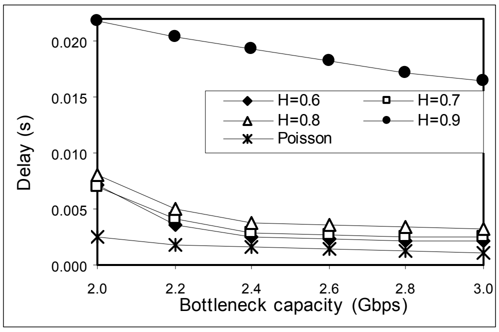

Fig. 7. Estimate of multiplexed self-similar traffic effect on the average delay

On Fig. 8 is shown the relationship between jitter, Hurst parameter, and network traffic capacity. Increasing the capacity values, Jitter decreases for all Hurst parameter values. Poison traffic jitter is from 1.5 to 2 times lower than the self-similar traffic stream jitter within the capacity range 2.2 and 2.4 Gbps.

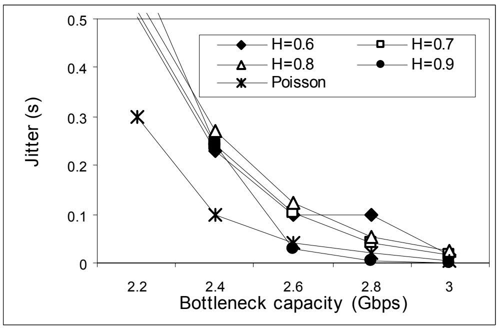

Fig. 8 Estimate of multiplexed self-similar traffic effect on the jitter

V. Conclusion

The obtained results in this paper show that self-similar traffic has potentially serious implications on local Ethernet networks. The lost packets, delay and jitter may by significantly higher than predicted by classical models. Poisson traffic models, as opposed to self-similar traffic models, may underestimate Ethernet packet loss by 2 or 14 orders of magnitude. Self-similar traffic models are thus a valuable tool as a real stress test to local Ethernet networks. The results could be used in research of high reliability networks for remote control in telerobotics, teleservice and online engineering with higher QoS requirements.

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