Monitoring and analysis measured and modeled traffic of TCP/IP Networks

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Abstract.

1 Introduction

According to the Cisco forecasts, Internet traffic volume until 2020 will increase to 2 zettabytes [1]. With this increasing of load on the network equipment it is an important task to ensure the effectiveness of its use. One of the methods of solving this problem is to simulate the behavior of traffic flow in computer network that will allows to predict certain trends and enables the creation of tools for efficient management of network equipment. In the literature is known computer network modeling methods based on Markov processes [2], as well as modeling of internet traffic based on properties of self-similarity and Markov Modulated Poisson Proces (self-similarity of Internet Traffic and Markov Modulated Poisson Process) [3]. Also it is known an approach to modeling traffic based on Diffusion and Fluid-Flow Approximations [4]. In this article the authors develop proposed before approach for modeling traffic based on differential equations of oscillating movement [5]. In order to achieve this goal based on the equations proposed by the authors, a software package that monitors the network and simultaneously calculates modeled traffic with proposed equations was developed. The software also allows comparing real and modeled traffic.

2 Mathematical Model Predicting Traffic Flow

Ateb-functions mathematical apparatus made it possible to solve analytical system of differential equations that are describing essentially nonlinear processes in systems with one degree of freeness [6]. To predict the traffic flow in a segment of computer network, differential equation that describes oscillating movement with a small perturbation was used in the form

$$\ddot{x} + a^2 x^n = \varepsilon f(x, \dot{x}, t) \tag{1}$$

where $x(t)$ – the number of packets in the network at time t; α – constant, which determines the amount of traffic fluctuations period, $f(x, \dot{x}, t)$ – arbitrary analytic function that is used to simulate small traffic deviations from the main component of fluctuations, n – a number that determines the degree of non-linearity of the equation, which exudes on the period of a main component of oscillation.

While executing of the following conditions on α and n $\alpha \neq 0$, $n = \frac{2k_1+1}{2k_2+1}$, $k_1, k_2 = 0, 1, 2, \ldots$ was proved that the analytical solution (ξ, ζ) of equation 1 is shown in the form of Ateb-functions

$$\begin{cases} \xi = aCa(n, 1, \phi) - \varepsilon\widetilde{f} \\ \zeta = a^{\frac{1+n}{2}} hSa(1, n, \phi) - \varepsilon\widetilde{f} \end{cases} \tag{2}$$

where $\alpha = \max_t |\zeta| \vee \min_t |\xi|$ - oscillation amplitude, $Ca(n, 1, \phi)$, $Sa(1, n, \phi)$, Ateb-cosine and Ateb-sine accordingly, $h^2 = \frac{2a^2}{1+n}$. Variable ϕ is related with time t by special ratio

$$\phi = \frac{a^{\frac{n-1}{2}}}{L} t + \phi_0 \tag{3}$$

where $L = \frac{2B(\frac{1}{2}, \frac{1}{1+n})}{\Pi(1+n)h}$, B – Beta function, ϕ_0 – initial phase of fluctuations.

Function f represented as:

$$f(t) = \sum_{i=1}^{N} \alpha_i \delta_i(t_i) \tag{4}$$

where α_i – perturbation amplitude, $-A \leq \alpha_i \leq A$, A – maximum perturbation amplitude (based on observation data), δ_i – Dirac function t_i – time, in which there is the i-th disturbance which is generated randomly.

3 Description of the Working Algorithm

In this section is described the software package that is designed for traffic simulation based on mathematical model, which is represented by equations 2 – 4. The software interface is shown on Figure 1.

As shown in Figure 1 the menu provides the following options:Show to show traffic data across time marks To and From; Log - logarithmic scale of Scale Y; Autoupdate to show data for the last 10 minutes with automatic updates; Minutes to show data on the scale of minutes; Hours to show data on the scale of hours; Difference to show the difference between a given Ateb-function and traffic; Match to show graphs of traffic and Ateb-function simultaneously; Graph to open an interface to work with graphs; Capture to open an interface to capture traffic; Settings - see sidebar; Ateb settings - s Ateb function ettings, its type, range and step for computing in Difference mode. In addition, developed software makes it possible to predict the traffic flow parameters for more efficient use of nodal equipment in the segment computer network. Now describe the algorithm of work of the software. Initially the observation time T for the flow of traffic and time t_0-tick-interval are set. Observation time T is limited by the capabilities of

Fig. 1. The interface of developed software system

the hardware and can be chosen arbitrarily. Time t_0-tick-interval is set within the range specified in the data capture and may be in the range of 0,001s to 10 minutes. The developed software allows analyze and store data traffic. There is a search for the minimum and maximum values of traffic in corresponding moment of time during a given tick-interval. The next step is to find the average value (on the axis OY, along the axis OX preset interval is displayed on the interval $[-\Pi(n,1), \Pi(n,1)]$, where $\Pi(n,1)$ Ateb-function period) between the minimum and the maximum, to make a comparison with a selected in program Ateb-function. The average value should be zero, and the maximum and minimum respectively 1 and -1, as a limit of Ateb-functions value. All intermediate values are normalized by dividing by half of the difference between the maximum and minimum values of traffic. Lets introduce into consideration arrays $P = \{P_i | i = 1, \ldots, 100\}$ and $Q = \{Q_i | i = 1, \ldots, 100\}$ that are containing values of traffic flow and calculated values of selected Ateb-function during tick-interval t_0. The next step is calculating the difference $|P_i - Q_i|$ between the stored values P_i and the calculated values of the selected Ateb-function Q_i at the selected interval with step $t_0/100$, i.e. the number of points of calculation J = 100. Then it searches the mean deviation in the array created differences. The mean deviation is calculated as following:

$$\mu = \frac{\sum_{i=1}^{J} |P_i - Q_i|}{J} \tag{5}$$

Then by the equation:

$$M = \frac{2 - \mu}{2} \tag{6}$$

is recalculated of ordinate value of point for plotting the graph of similarity of Ateb-function to real traffic flow values during the observation time T. Block diagram of the algorithm of work of developed software system is shown in Figure 2.

4 The Application and Experiments

The method of analysis and forecasting of traffic flow in the segment of computer network is based on differential equations of oscillating motion. To achieve the this goal, which was in creating a software package for analysis and forecasting of traffic flow in the segment of computer network, which through new actions could reduce packet loss in the hub equipment.

Table 1. Description of customizable features to perform forecasting of traffic flow in the segment of computer network

#	Function	Interval (min)	Step of prediction (min)	Observation time
1	Sa(1/3, 1)	60	1	300
2	Sa(1/5, 1)	60	1	300
3	Sa(1/7, 3)	60	1	300
4	Sin	60	1	300

5 Network Topology

On the next figure the topology of computer network of ACS Department in Lviv Polytechnic National University is presented. Switches that are used in network of ACS department are the following:

1. D-Link DES 1024 R
2. 3Com Swich 3300 xM
3. 3Com Swich 4226 T
4. Allied Telesyn AT8026T

6 The Research Results

To calculate the results of the experiment, the following equations which are describing the maximum correlation and coefficient that shows the ratio of standard

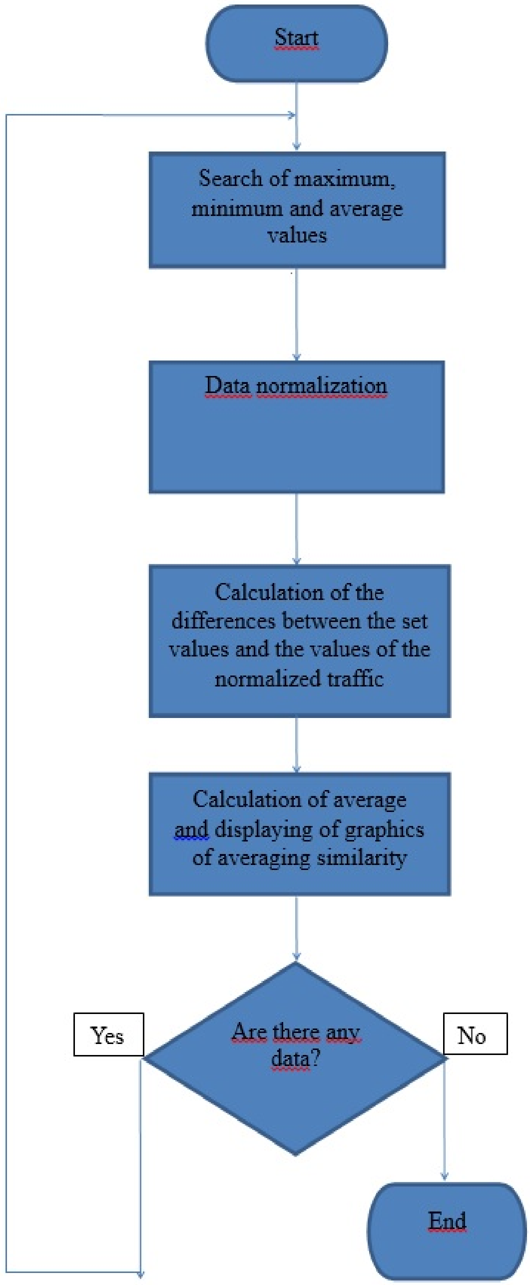

Fig. 2. Flow chart of developed program working mechanism, responsible for forecasting of traffic flow in the segment of computer network.

deviation to the maximum were chosen. Equations that were used for computing:
The maximum correlation :

$$r_{xy} = \frac{\sum_{i=1}^{m}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{(x_i - \overline{x})^2 \sum_{i=1}^{m}(y_i - \overline{y})^2}} = \frac{cov(x,y)}{\sqrt{s_x^2 s_y^2}} \tag{7}$$

where $\rho = \max_x r_{xy}$, $r_{xy} \in A$
Coefficient of ratio of standard deviation to maximum:

$$K = \frac{s_{max}}{s} \tag{8}$$

where

$$s = \sqrt{\frac{n}{n-1}\sigma^2} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{9}$$

Comparison of simulation experiments E1, E2, E3 conducted by the criterion of maximum correlation , and also was calculated coefficient k of ratio of standard deviation to the maximum. The calculated results of the comparison are presented in Table 2.

Table 2. Comparison of traffic simulation results with real data network traffic of ACS department in Lviv Polytechnic for 1 day

Variable	E1	E2	E3
K	10.81	12.56	12.75
ρ	0.79	0.75	0.74

The maximum amplitude of perturbation function was changed - experiment E2 and the number of disturbances - experiment E3. Apparently, the best results were obtained for model experiment data in experiment E1. (Is that sentence needed?)

7 Conclusion

This article describes developed by authors the software system for the simulation of traffic flow for TCP / IP networks based on mathematical model, which is based on differential equations of oscillating motion with one degree of freeness. Interface of the software system, and the algorithm of its work were presented and described. Testing of software system was implemented in the computer network of NULP ACS department. Topology of TCP / IP network in this department was presented. The results of the program while working were graphically illustrated. The relationship between real and simulated traffic was shown. Parameters of correlation between the real and calculated by formulas traffic were calculated.

8 References

References

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8.1 Program Code

Program listings or program commands in the text are normally set in typewriter font, e.g., CMTT10 or Courier.

Example of a Computer Program

```
program Inflation (Output)
  {Assuming annual inflation rates of 7%, 8%, and 10%,...
   years};
   const
     MaxYears = 10;
   var
     Year: 0..MaxYears;
     Factor1, Factor2, Factor3: Real;
   begin
     Year := 0;
     Factor1 := 1.0; Factor2 := 1.0; Factor3 := 1.0;
     WriteLn('Year  7% 8% 10%'); WriteLn;
     repeat
       Year := Year + 1;
       Factor1 := Factor1 * 1.07;
       Factor2 := Factor2 * 1.08;
       Factor3 := Factor3 * 1.10;
       WriteLn(Year:5,Factor1:7:3,Factor2:7:3,Factor3:7:3)
     until Year = MaxYears
end.
```

(Example from Jensen K., Wirth N. (1991) Pascal user manual and report. Springer, New York)

8.2 Citations

For citations in the text please use square brackets and consecutive numbers: [?], [?], [?] – provided automatically by LaTeX's `\cite` ... `\bibitem` mechanism.